INVESTIGATIONS ON STIGMA RECEPTIVITY, POLLEN STORAGE, BUD SIZE AND POLLINATION FREQUENCY FOR HYBRID SEED PRODUCTION IN BHENDI (*Abelmoschus esculentus* (L.) Moench)

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the
Degree of

Master of Science (Agriculture)

in

SEED SCIENCE AND TECHNOLOGY

By

AVNEESH KUMAR SINGH

DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD – 580 005

JUNE, 2009

ADVISORY COMMITTEE

DHARWAD

JUNE, 2009

(B. S. VYAKARANAHAL)
CHAIRMAN

Approved by :

Chairman : _____

(B. S. VYAKARANAHAL)

Members : 1. _____

(N. BASAVARAJ)

2. _____

(M. S. PATIL)

3. _____

(V. K. DESHPANDE)

CONTENTS

LIST OF TABLES

10	Effect of pollen storage under different conditions for varying durations on seed yield per plant, seed yield per hectare and seed recovery percentage in bhendi hybrid seed production
11	Effect of pollen storage under different conditions for varying durations on germination percentage and field emergence percentage in bhendi hybrid seed production

Contd...

12	Effect of pollen storage under different conditions for varying durations on shoot length, root length and seedling vigour index in bhendi hybrid seed production
13	Effect of pollen storage under different conditions for varying durations on seedling dry weight and electrical conductivity of seed leachate in bhendi hybrid seed production
14	Effect of flower bud size and number of pollinations on number of flowers crossed, number of crossed fruits retained and fruit set percentage in seed parent in bhendi hybrid seed production
15	Effect of flower bud size and number of pollinations on fruit length, fruit girth, fruit weight per plant, seed weight per fruit and number of seeds per fruit in bhendi hybrid seed production
16	Effect of flower bud size and number of pollinations on 100 seed weight, seed yield per plant, seed yield per hectare and seed recovery percentage in bhendi hybrid seed production
17	Effect of flower bud size and number of pollinations on seed germination percentage, field emergence percentage, shoot length and root length in bhendi hybrid seed production
18	Effect of flower bud size and number of pollinations on seedling vigour index, ten seedling dry weight and electrical conductivity of seed leachate in bhendi hybrid seed production

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Monech), also popularly known as Lady's finger or bhendi is a common vegetable crop grown under tropical and subtropical conditions. Although okra is primarily a rainfed crop, it also comes up well under irrigated conditions during *kharif* and summer seasons. Okra is especially valued for its tender delicious fruits and is a good source of Iodine and Calcium. The green tender fruits of okra are highly nutritious vegetable containing 1107 mg of calcium and 8.9 mg of Iron for every 1000 g edible portion and fair amount of vitamins *viz.,* A, B and C. (Murugesan and Vanangamudi, 2006). These tender fruits can be dehydrated and marketed for vegetable purpose. Apart from its nutritive value, matured fruits and stems contain crude fibre which are used in paper industry. Mucilaginous extracts of the green stem are commonly employed in India for clarifying the sugar cane juice. Dry seeds of okra contain 18 to 20 per cent oil and 20 to 30 per cent crude protein (Berry *et al*., 1988). Seeds contain mainly monounsaturated fatty acids (oleic) and palmitic acid (Martin and Rhodes, 1983) and their high lysine level (Al-Wandawi, 1983). Sometimes the seeds are roasted and used as a substitute for coffee (Martin, 1982). Okra is an important member of the family Malvaceae with 2n=8x=72 or 144 chromosomes and is polyploid in nature. The genus *Abelmoschus* comprises nine species. Among them, cultivated species are *Abelmoschus esculentus* (L.) Moench, *A. caillei* (A. Chev) Stev. And *A.moschatus* sub sp. moschatus var. moschatus. the only species known to be cultivated. However, *A. manihot* sp.cv manihot is also cultivated in limited scale in African continent (Murugesan and Vanangamudi, 2006). Being self pollinated, out crossing to an extent of 20 percent by insects is reported which render considerable genetic diversity.

In India, the area under okra is 3,58,300 hectare, with an annual production of 35,24,900 tonnes of green fruits and with a productivity of 9838 kilogram per hectare. While, in Karnataka it is grown in an area of 85,000 ha, with an annual production of 73,000 tonnes and productivity of 8624 kilogram per hectare of green fruits (Anon., 2007). It is a potential export earner accounting for 60 per cent of exported fresh vegetable (Sharma and Arora, 1993). The per cent share of the bhendi hybrid in total area under bhendi cultivation in India was nearly 5.8% in 1997-98 (Reddy *et al*., 2002)

In okra, ease of emasculation and large number of seeds per fruit provides better opportunity for commercial exploitation of hybrid vigour. Yellow vein mosaic virus (YVMV), powdery mildew and fruit borer pest are known to cause substantial loss in okra yield. A popular Indian YVMV resistant cultivar Pusa Sawani turned out to be susceptible (Singh *et al*., 1962). Recently interspecific derivative resistant cultivars like Punjab Padmini (Sharma, 1982), Arka Abhay and Arka Anamika (Dutta, 1984) and Parbhani Kranti (Jambhale and Nerkar, 1986) have been developed. These were found to be medium susceptible during summer (Rajmony *et al*., 1995). Other hybrids like Shital Uphar and Shital Jyoti developed at Indian Institute of Vegetable Research, Varanasi have also shown high resistance to yellow vein mosaic virus (Rai and Rai, 2006-a).

Manifestation of heterosis for various economic traits has been reported in okra as early as in 1946 by Vijayaraghavan and Warrier, Venkataramani (1952), Joshi *et al*. (1958) and Singh *et al.* (1975). Majority of reports indicated negative and high heterosis for days to first flowering, days to 50 per cent flowering and node to first flowering. Equal magnitude of both positive as well as negative heterosis was reported by many authors for fruit length, fruit diameter, number of fruits per plant and yield per plant. Number of branches and plant height are having high and positive heterosis as reported by majority of authors, (Dhankar *et al*., 1998, Ahmed *et al*., 1999, Prakash *et al*., 2001 and Chauhan *et al*., 2002). Hence, there is a need to initiate research on exploitation of heterosis for hybrid seed production in bhendi.

In bhendi, flowers are solitary, axillary with about 2 cm long peduncle. Epicalyx is up to 10, narrow hairy bracteoles which fall before the fruit reaches maturity. The calyx split longitudinally as flower opens. Flower contains five petals of yellow colour with crimson spot on claw and 5-7 cm length. Staminal column is united to the base of petals with numerous stamens. Ovary is superior, stigma 5-7 mm with deep red colour. The time of anthesis varies with the cultivar, temperature and humidity and it ranges from 8.00 am to 10.00 am (Purewal

and Randhawa, 1947). The dehiscence of anther commences 15 to 20 minutes after anthesis and is complete in 10-15 minutes. The flowers remain open for a short time and they wither late in the afternoon. The stigma is receptive at the time of opening of flowers.

In bhendi, F_1 hybrid seed set and yield are influenced by several factors like flower characteristics, stigma receptivity, pollen viability, flower bud size to be used for emasculation and number of pollinations besides use of improved seed production techniques.

The most productive and desirable hybrid seed can be obtained from the female parent when there is a perfect coincidence of stigma receptiveness and pollen viability. The time of pollination and stigma receptivity plays a crucial role in hybrid seed production of bhendi. Since bhendi is a mainly often cross pollinated crop, pollination is done usually on the day of flower opening itself and can be continued till noon hours, though peak anthesis is seen at 8.30 am to 10.30 am. But success rate of pollination varies from 30 to 50 percent in bhendi hybrid seed production since transfer of male pollens to the female flowers during crossing period is the most sensitive aspect in large scale production. The viable pollens deposited early on stigma may lead to poor seed setting due to non receptive stigma and similar is the case if pollens are deposited very late on stigma due to drying of stigma and loss of pollen viability. In addition to this, the amount of F_1 hybrid seed is also decided by the quantity of the male pollens depositing on the receptive stigma of the female parent. In case, if more pollens are deposited on the stigma there may be more chances of poor seed setting due to competition between germinating pollens. Similar is case with deposition of inadequate viable pollens. The quantity of pollens depositing on stigma can be manipulated by adjusting the crossing ratio of female to male flower (Basavaraj, 2006). Therefore, stigma receptivity and day of emasculation and subsequent pollinations to be optimized to get increased seed set and yield in female parent of bhendi. However, research work pertaining to stigma receptivity and day of emasculation and subsequent pollination is very meagre and inconclusive.

Pollens are most essential and precious genetic material which transmits the male gametic material in sexual reproduction of all higher plants. Unlike varietal seed production, hybrid seed production involves an effective crossing of female parent with a selected male parent. So, only desired and viable pollens play a vital role in deciding the success of hybrid seed set on its parent. Further in hybrid seed production non synchronous flowering in parent plant leads to poor seed set. Hence, proper information is required about the pollen viability, its storage under different conditions for varying durations and its further application in hybrid seed production to obtain higher seed yield.

The success of any hybrid seed production programme which involves hand emasculation and pollination depends upon the selection of proper flower bud size. In case of bhendi, the flower bud appears in axils of each leaf above 6^{th} to 8^{th} leaf depending upon the cultivar. The crown of the stem at this time bears three to four under developed flowers but later on during the period of profuse flowering, there may be as many as ten under developed flowers on a single crown. As the stem elongates, lower most flower buds open into flower. There may be a period of two to three or more days between the times of development of each flower but never does more than one flower appear on a single stem. The buds measuring 2.82 cm x 1.55 cm open into flower (Purewal and Randhawa, 1947). Usually the buds likely to open next day are selected. The maximum pollen fertility is in the period between one hour before and one hour after opening of the flower and stigma is most receptive at the time of flower opening, hence, pollination at bud stage is not successful (Basavaraj, 2006). However, systematic work on flower bud size and number of pollinations is lacking in bhendi hybrid seed production. Hence, there is a need to find out the ideal flower bud size for emasculation and number of pollinations required in bhendi hybrid seed production and study their effect on seed set, seed yield and quality.

Seed is considered as one of the important basic agricultural inputs for obtaining higher yield. Good quality seed acts as a catalyst for realizing the potential of all other inputs in agriculture without good seed, the investment on fertilizer, water, pesticides and other inputs will not play the desired dividends. Its importance has been realized with the passage of time and greater realization that efficiency is the key factor to be competitive in all the agricultural ventures. Therefore, availability of quality seed to the farmer at an affordable price

and in time is considered crucial for enhancing and sustaining the agricultural productivity. Therefore, production of quality seed and maintenance of high seed germination is of utmost importance in a seed programme. Seeds are practically worthless if upon planting they fail to germinate and give adequate plant stand in the field in addition to healthy and vigorous plants.

Keeping in view all above facts, the present investigation was under taken with the following objectives, *viz.*,

i. To study the stigma receptivity of seed parent in hybrid seed production of bhendi.

ii. To know the pollen viability of pollen parent in bhendi hybrid seed production.

iii. To assess the pollen viability under different storage conditions.

iv. To determine the optimum size of flower bud for emasculation, and

v. To know the number of pollinations required for optimum seed set in an emasculated flower bud.

2. REVIEW OF LITERATURE

2.1 Exploitation of heterosis in bhendi

The term heterosis refers to a phenomenon in which F_1 shows increased or decreased vigour over the parents. Shull (1908) referred to this phenomenon as the stimulus of heterozygosity. Generally, the term hybrid vigour is used to denote heterosis in the desirable selection. The heterosis over mid parent, better parent and standard check are designated as average heterosis, heterobeltiosis and standard heterosis respectively.

Manifestation of heterosis for various economic traits has been reported in okra since long back by Vijayraghavan and Warrier (1946) and others. Venkataramani (1952) recorded an increase in yield of 5.4 to 14.5% over the better parent. Joshi *et al*. (1958) reported that hybrid Pusa Makhmali × Long White Durbhanga showed vigorous growth and abundant fruiting, giving 60% increase in yield over the standard variety Pusa Makhmali. Majority of reports indicated negative and high heterosis for days to first flowering, days to 50 per cent flowering and node to first flowering. Equal magnitude of both positive as well as negative heterosis was reported by many authors for fruit length, fruit diameter, number of fruits per plant and yield per plant. Number of branches and plant height are having high and positive heterosis as reported by, Dhankar *et al*. (1998), Ahmed *et al*. (1999), Prakash *et al*. (2001) and Chauhan *et al*. (2002) in okra.

Dhankar *et al*. (1998) estimated extent of heterosis in five inbred lines *viz*. MR 10-1, MR 55, MR 9-2, MR 12-1 and MR 52 in all combinations including reciprocal. The significant and positive heterosis was noticed in the cross combination MR 55 × MR 12-1for number of fruits and yield per plant over standard check.

Ahmed *et al*. (1999) estimated extent of heterosis in eight diverse genotypes. Perkin Long Green, SB-5, SB-3, Parbhani Kranti (PK), Pusa Makhamali, Pusa Sawani, P-7 and SB-8 were crossed in diallel excluding reciprocals. The 28 F_1 crosses and 8 parents were evaluated. Analysis of variance indicated highly significant differences among the genotypes, parents, hybrids and parents vs. hybrids. The F_1 crosses revealed wide range of heterosis over better parent for all the characters. Number of pods per plant recorded maximum heterosis followed by other characters. Among the crosses, hybrids especially SB-3 × P-7, SB-5 × Pusa Sawani, Perkin Long Green × Pusa Sawani and Perkin Long Green × Parbhani Kranti could be considered as potential hybrids for commercial exploitation.

Singh *et al*. (1999) studied the heterosis in okra in a set of 8 × 8 diallel crosses excluding reciprocals. Heterosis over better parent, standard check and inbreeding depression was recorded in many crosses for different characters. Four crosses (P-7 × Arka Abhay, P-7 × Arka Anamika, P-7 × Parbhani Kranti and Parbhani Kranti × Arka Abhay) showed maximum heterosis for fruit yield over standard check (Pusa Sawani).

Prakash *et al*. (2001) conducted an experiment on okra genotypes *viz*., Parbhani Kranti (PK) and Arka Abhay (AA), their F1 hybrids and F2 populations were evaluated to assess the genetic architecture of certain quantitative traits. Arka Abhay was best for high seed yield per plant, whereas Parbhani Kranti registered as a superior parent for number of capsules per plant and days to first flower. Among the F_1 hybrids, Parbhani Kranti (PK) × Arka Abhay (AA) cross gave higher seed yield per plant. Significant heterosis in both generations was observed.

Chauhan *et al*. (2002) carried out a study on heterosis for yield and yield contributing characters in okra. The study revealed that heterosis over the better parent, standard check-1 (Parbhani Kranti) and standard check-2 (Pusa Sawani) was observed for all the traits. DC-97 × P-7 cross combination showed the highest heterosis for seed yield over better parent, standard checks and among other combinations. Whereas, Padmini × Varsha Uphar exhibited higher heterosis over the better parent and standard check-1 (Parbhani Kranti), while Arka Anamika × Arka Abhay also exhibited heterosis over standard check-2 (Pusa Sawani).

Dhankar and Dhankar (2002) studied the heterosis in okra. Estimates of heterosis showed that best cross combination for days to 50 % flowering, number of fruits and yield was MR-10-1 × Varsha Uphar, followed by MR-12 × Raj-12.

Rewale *et al.* (2003) studied the eight yield and yield contributing characters in okra and concluded that heterosis over better parent was exhibited by all the traits. Characters like days to initiation of flowering, days to initiation of fruiting and maturity of fruits showed significant heterosis in SOH-02 × Parbhani Kranti, and SOH-02 × Gold Finger. The cross DVR-3 × Green Gold has recorded significant heterobeltiosis for yield per plant and fruits per plant. The crosses JNDO-5 × Parbhani Kranti and NOL-101 × Green Gold also showed higher heterosis over better parent.

2.2 Effect of crossing ratio

2.2.1 Effect of crossing ratio of on seed yield and its attributes.

Khadi *et al.* (1995) observed that use of one male flower to pollinate three emasculated flower buds (1:3) in cotton was found ideal by recording higher F_1 hybrid seed set and yield compared to 1:5 and 1:6 crossing ratios.

Waghmode *et al.* (2000) reported that one male flower should be used to pollinate three emasculated flowers of female parent in order to get good seed setting percentage and higher seed index and seed yield in NHH-44 hybrid seed production.

Doddagoudar (2005) recorded higher boll weight (4.33 g), seed weight per boll (2.70 g), number of seeds per boll (23.33), seed index (10.6 g) and seed yield (1221 kg/ha), when one male flower used to cross two female flowers in DHH-543 cotton hybrid seed production. Similarly he recorded higher boll weight (3.73 g), seed weight per boll (2.50 g), seed index (10.4 g) and seed yield (1450 kg/ha) when one male flower is used to cross two female flowers in DHB-290 cotton hybrid seed production.

Basavaraj (2006) recorded significantly maximum crossed fruits per plant (5.55), maximum fruit set percentage (34.32),number of seeds per fruit(52.69),seed weight per fruit(2.90 g), hundred seed weight(6.23 g), seed yield per plant (17.65 g), and seed yield per ha (980.27 kg) when four female flowers crossed with one male flower compared to ten female flowers crossed with one male flower (3.93,25.3%,47.74,2.44 g,5.89 g, 10.56 g and 586.51 kg), respectively in bhendi hybrid seed production.

Patil *et al.* (2008) recorded higher fruit set percentage (39.86), fruit weight (329.65g/plant), number of seeds (985.4), seed weight per fruit (4.48g), seed yield per plant (54.32) when four female flowers were crossed with one male flower compared to ten female flower crossed with one male flower (34.80, 298.95g, 857, 3.27g, 30.39g, respectively) in brinjal.

2.2.2 Effect of crossing ratio on seed quality parameters

Doddagoudar (2005) recorded higher germination percentage (86.25) and seedling vigour index (2830) when one male flower was used to cross two emasculated female flowers in DHH-543 cotton hybrid seed production. Similarly he recorded higher germination percentage (81.25) and seedling vigour index (2517) when two female flowers crossed with one male flower in DHB-290 cotton hybrid seed production.

Basavaraj (2006) reported higher germination percentage (86.11), root length (11.49 cm), shoot length (21.10 cm), seedling vigour index (2830) and seedling dry weight (60.78 mg), when four female flowers were crossed with one male flower, compared to ten female flowers to one male flower (76.53%, 10.18cm, 21.10cm, 2436, 56.06 mg, respectively) in bhendi hybrid seed production.

Patil *et al.* (2008) reported increase in germination percentage (78.23), root length (8.51 cm), shoot length (8.12 cm), seedling vigour index (1321) and seedling dry weight (15.10 mg) when four female flowers were pollinated with one male flower compared to ten

emasculated flowers pollinated with one male flower (75.28, 7.99, 7.69, 1203, 13.44 mg, respectively) in brinjal hybrid seed production.

2.3 Effect of stigma receptivity

2.3.1 Effect of stigma receptivity on seed yield and its attributes

Sidhu *et al.* (1980) observed maximum stigma receptivity on second day after emasculation of flower as exhibited by higher values of fruit set, seed recovery, seed to fruit ratio, number of seeds per fruit and seed weight per fruit in tomato.

Kalloo (1991) reported that in tomato stigma becomes receptive 16 to 18 hours before anthesis and retains the receptivity upto six days after anthesis.

Kempegowda (1992) reported that stigma of the sunflower seed parent CMS-234A was completely receptive for two days but a slight reduction was observed after two days as reflected by per cent seed set during *kharif* season at Bangalore. Pollination on stigma after third day of emergence gave 61 per cent seed set, while after fourth day it declined drastically.

Valdes (1995) reported that pollination after two and three days of emasculation increased the fruit set by 19 and 28 per cent, respectively.

Jankulovski *et al.* (1997) reported that the number and total weight of seeds per fruit increased by 100 and 400 per cent, respectively in tomato when pollination was done two and three days after emasculation compared to one day after emasculation. Delayed pollination of 24 and 30 hours after emasculation resulted in 8.6 and 10.2 per cent higher seed yield for Balca and Prisca, respectively compared to the pollination immediately after emasculation

Mandal *et al.* (1997) concluded that for production of hybrid seed in brinjal, pollination should be done in the month of October and November preferably in the forenoon between 9.00 am-12.00 noon.

Dev (1998) noticed that in tomato pollination immediately just after emasculation led to considerable lower fruit set and to lesser number of seeds per fruit, this means at the time of emasculation, the stigma is capable of receiving pollen but all the ovules are not ripe and as a result less seeds are produced.

Yogeesha *et al.* (1999) reported the maximum stigma receptivity on second day after emasculation of flower as exhibited by higher values of fruit set, seed set, seed to fruit ratio, number of seeds per fruit and seed weight per fruit in tomato.

Hazra *et al*. (2003) reported that emasculated flowers of the six parental line of brinjal were hand pollinated with mixed pollens from 8:30 am to 12:30 pm at four stages *viz*., one day before anthesis, during anthesis, one and two day after anthesis. Stigma receptiveness was peak during anthesis by registering highest percentage of fruit set.

Jolli *et al*. (2007) found that pollination after three days of emasculation recorded significantly higher number of crossed fruits (42.91), fruit set (55.89%), seed yield (11.72 g) per plant over other treatments.

Kivadasannavar *et al*. (2009) reported that higher number of crossed fruits retained per plant, fruit set percentage, fruit weight, number of seeds per fruit seed weight per fruit and seed yield per plant (34.81, 49.37%, 56.54 g, 52.75, 6.28 g and 3.80 g, respectively) were observed when pollination was done one day after emasculation

2.3.2 Effect of stigma receptivity on seed quality parameters

Jolli *et al.* (2007) observed higher seed germination (94.93%), field emergence (90.13%), root length (9.46 cm), shoot length (8.77 cm) and seedling vigour index (1709) when pollination was done after three days of emasculation.

Kivadasannavar *et al*. (2009) reported that seed produced from pollination one day after emasculation recorded significantly higher seed germination (88.06%), field emergence (84.90%), seedling root length (8.49 cm), shoot length (8.58 cm) seedling dry weight (0.32 g) and seedling vigour index (1513) over pollination on same day and two days after emasculation.

2.4 Effect of pollen storage condition and duration

2.4.1 Effect on pollen viability

Pollen forms the transportable hereditary unit and its preservation has been considered as one of the methods for long term storage of plant germplasm. Storage of pollen and its use in artificial pollination have been practiced. Pollen can be stored for six months at 5^0C in desiccators.

Rai and Rai (2006b) reported that tomato pollens can be stored for certain duration at low temperature. At room temperature and 70 percent RH, pollen could be stored for five to six days and in flowers for two days.

Kalloo (1991) observed that tomato flowers collected in the afternoon can be stored for a certain period, which depends upon temperature and humidity under ordinary conditions. Pollen can be stored for three to four days. A flower stored for one day at normal temperature exhibited better results than the fresh flower.

Kempegowda (1992) studied the pollen viability in the male parent (6D-1) of sunflower and revealed that the stored pollen either under ambient or controlled condition (refrigerated at 4^0C and 50 per cent RH) upto 24 hours did not make much difference as reflected by the per cent seed set (89.17 to 90.26%). The pollen viability under ambient storage decreased drastically from 32 hours (79.4% seed set) to 56 hours (31.30% seed set), while pollens stored under controlled condition, showed better viability from 32 hours (85.31% seed set) to 56 hours (64.38% seed set) as reflected from their respective seed set percent.

Yogeesha *et al.*(1999) observed that the pollen of tomato varieties viz., Pusa Gaurav and Chikoo stored under room conditions (mean maximum temperature of 26^0C and RH 50%) retained high viability even after five days of storage whereas, under refrigerated condition (constant temperature of 9-10^0C), they showed no significant drop in the viability even after seven days of storage. The number of seeds and seed weight per fruit obtained from the pollination of these pollens did not differ significantly. Tomato pollen of flower just pinched do not have high fertilization ability, and thus show less fruit set and number of seeds per fruit than those obtained by applying pollen from the flowers stored for one day.

Kantharaju (2003) studied pollen viability in sunflower by acetocarmine staining method which indicated that pollens were very susceptible to open storage than that of refrigerated or earthen pot storage. Besides, pollens stored for two days in refrigerator were equally viable to that of pollens stored for one day either in open storage or earthen pot storage.

Stanley and Linskens (1974) opined that temperature and RH plays an important role in maintenance of pollen viability. In most systems, low temperature and low humidity prolong pollen viability.

Herrero and Johnson (1980) ascertained that prolonged storage at temperatures higher than 32^0C resulted in a significant decrease of pollen grain germination in many maize genotypes. All genotypes had a lower germination at 38^0C than at 32 or 27^0C and several genotypes exhibited no germination after 48 hours at 38^0C.

Sahar and Roy (1980) observed that the storage life of clemantine mandarin pollen grains was effectively extended in an oxygen free atmosphere, upto 7 weeks at 4^0C and germination of 20 per cent was maintained in nitrogen atmosphere after 20 weeks.

Sharma and Malik (1980) reported that the storage of *Amryllis vittata* pollen at room temperature (25+2^{0}C) under dark and light conditions adversely affected percentage pollen germination and per cent tube growth. Pollen storage at -4^{0}C in a refrigerator did not affect germination and pollen tube growth. The stored pollen could germinate upto 4 months and produced the tubes comparable to the fresh pollen grains.

Islam and Khan (1998) collected bulk pollen samples between 6:30 and 7:00 am and were stored under four temperature conditions viz., room temperature (27-30^{o}C), 10^{o}C, O^{O}C, and –5^{O}C for 0 to 55 days. Based on acetocarmine test, pollen viability decreased with increasing duration of storage. Reduction in viability was more marked for the pollens stored at higher temperatures (room temperature and 10^{0}C) particularly after 25 days of storage. Best results were obtained with pollens stored at 0^{0}C (48% at 45 days) but pollens showed little tolerance (9.9% at 45 days) under long term freezing conditions (-5^{0}C).

Kivadasannavar *et al*. (2008) stated that *in vitro* studies on pollen viability indicated that pollens were very susceptible to storage under ambient conditions when compared to pollen stored in refrigerator or moist earthen pot. Pollens stored in refrigerator even upto two days were equally germinable with better pollen tube growth compared to that of pollen stored for one day in earthen pot. Fresh pollen recorded significantly higher pollen germination (87.60%) and pollen tube length (1034.2 µm) followed by pollen storage in refrigerator for one day (86.4% and 963.1µm).

2.4.2 Effect on fruit set, seed yield and quality

Mc Guire (1952) opined that the quantity of viable pollen formed is the most important criteria in pollen production. The most reliable method of assessing pollen viability is to place the pollen on stigmas of emasculated flowers grown in the optimum environment and count seed numbers in the fruit. Further, he reported that pollination with flower stored for one day at normal temperature exhibited better results than the use of fresh flower.

Xanthopoulas (1991) studied the percentage seed set and pollen tube growth in style of 6 sunflower cultivars. Seed set was measured in one group after maturity and other group was examined for pollen tube penetration 48 h after pollination. Results showed a strong correlation between seed set and percentage of penetrated styles.

Kempegowda (1992) found that in sunflower male sterile line CMS 234A, the stigma receptivity was upto 3-4 days and pollen viability in 6D-1 was upto 72 hours when stored under laboratory conditions while it was more than 80 hours when stored under refrigerated conditions as reflected by percent seed setting during KBSH-1 hybrid seed production.

Borikar *et al.* (1993) observed stigma receptivity for three days in 338A and 207B in *rabi* season and seed setting was more than 70 percent when pollinated within 3 days of starvation period and also found that pollen was viable for 22 hours. Hence, fertile pollen was available throughout the day for pollination in sunflower hybrids LDMRSH-1 and LDMRSH-3 seed production.

Gayathri *et al.* (1993) observed a gradual decrease in seed number per panicle with an increase in starvation period from 0 to 11 days in sorghum, number of seeds per earhead varied significantly in seed parent with the advancement of starvation period of pollen from 0 hour (9.00a.m.) to 4 hours (12 noon) in both CSH-13R and CSH-14 hybrids. The higher seed set was found to be at 10.00 am over 8.00 am and 9.00 am.

Yogeesha *et al.* (1999) stated that the pollens of tomato Pusa Gaurav and Chikoo varieties stored under room conditions (mean maximum temperature of 26^{0}C and RH of 47%) retained higher viability even after five days of storage where as, under refrigerated condition (constant temperature of 9-10^{0}C). drop in pollen viability was not significant even after seven days of storage. Similarly, number of seeds and seed weight per fruit obtained from the pollination of these pollens did not differ significantly.

Shete *et al.* (1994) revealed that significant variation in seed setting, seed setting index and 100 seed weight in sunflower. The MSL-338A was superior for seed setting and

100-seed weight while seed setting index was higher in 207A. Increase in pollen storage period depressed 100-seed weight.

Sudhir (1994) found that pollen viability in 6D-1 was up to 54 hours when stored under laboratory, as reflected by percent seed setting in sunflower.

Jawale *et al.* (1998) observed that stigma receptivity lasts for 3 days in 338A and 207A of sunflower more than 60 percent seed set was obtained when pollinated within 3 days of florets opening. Pollen viability retained for 22 hours.

Nascimento *et al*. (2000) stated that in brinjal, manual pollination could be done in the morning by using pollens of freshly opened flowers on the same day. Pollens were collected from male line flowers by using a vibrator and further stored in microtubes kept in aliminium container with silica gel under 5° C temperature in refrigeration for 0 to 60 days period. The fertilization was less in the flowers pollinated with pollens stored for 30 or more days. Pollens stored for 50 and 60 days led to fruits with lower seed quality. Pollens stored up to 20 days recorded higher fertilization, optimum seed set and better seed quality.

Rajshekhar (2000) reported on the basis of *in vivo* studies on pollen viability of sunflower that, there was no significant differences in seed set percent with fresh pollen (62.08%), refrigerated storage (61.38%) and earthen pot storage (61.10%) for a period of 24 hours. It was observed that pollination with stored pollen either in refrigerator or earthen pot up to one day did not show much difference in the percent seed set in sunflower.

Kanthraju (2003) reported maximum seed setting percentage in cent percent fresh pollen (61.98%), 100 seed weight (5.27g), seed yield (16.08g/ plant), germination (96.66%), shoot length (13.38cm), root length (14.05cm), seedling vigour index (2651) and field emergence (91.00%) followed by pollen stored in refrigerator for one day in sunflower.

Chen (2003) revealed that brinjal pollen retained its viability for 8-10 days at 20-22^{0}C temperature and 50-55 percent relative humidity. Best results were attained when the stored pollen was used within four days.

Patil (2005) reported that use of stored pollen in refrigerated condition recorded significantly higher fruit set (45.25%), seed yield (57.49g/plant), seed germination (83.99%) and vigour index (1301) compared to farmers method of pollen storage. Whereas, fresh pollens recorded significantly higher results for these traits as compared to two day and three day old pollens.

Jolli (2008) reported that the pollen stored in refrigerator recorded higher fruit set percentage (53.28) over the ambient storage conditions (50.78). Two days old pollens recorded significantly higher per cent of fruit set (55.69) compared to one (48.80) and three days (51.69) old pollens. Crossed fruit yield per plant showed that the pollen stored in refrigerator recorded significantly higher fruit yield of 1844.42 g per plant than the ambient one (1466.40 g). Two days old pollen when used for pollination recorded significantly higher fruit yield of 1846.40 g per plant compared to three days (1644.65 g) and one day old pollen (1439.99 g) used for pollination. Refrigerated stored pollens recorded significantly higher seed yield of 10.37 g per plant over ambient method (9.79 g/plant). Two days old pollen gave significantly higher seed yield of 11.46 g per plant over use of three days (10.39 g) and one day old pollens (8.35 g) for pollination.

Kivadasannavar *et al*. (2008) reported that the use of fresh pollen recorded significantly higher fruit set (33.06%), seed yield per plant (6.95 g), seed germination (87.41%) and seedling vigour index (1451) followed by pollen stored in refrigerator for one day (33.02%, 6.94 g, 86.17% and 1426 respectively).

2.5 Effect of flower bud size and number of pollinations

Purewal and Randhawa (1947) stated that in bhendi, the flower bud appears in axil of each leaf above 6th to 8th leaf depending upon the cultivar. The crown of the stem at this time bears three to four under developed flowers but later on during the period of profuse

flowering, there may be as many as ten under developed flowers on a single crown. As the stem elongates, lower most flower buds open into flowers. There may be a period of two to three or more days between the times of development of each flower but never does more than one flower appear on a single stem. The buds measuring 2.82 cm x 1.55 cm open into flowers.

Mc Guire (1952) reported that two time pollination of same bud in a day at 8:30 am and then at about 4:30 pm did not show any difference in fruit and seed setting.

Rick and Dempsey (1969) in tomato found out that pollination was adversely affected by abnormalities in flower structure. The normal position of stigma should be just within the cone of stamens. If it was exerted beyond the cone, fruit set was reduced since exertion encouraged pollen escape before reaching the stigma and led it to desiccation of stigmatic surface.

Van Ravestijn (1970) opined that fertilization of tomato flower was seen only whe pollens were adhered to the stigmatic surface.

Kalloo (1986) described three forms of flowers in tomato. In first type of flower style and stigma are hidden in the anther cone, in second type stigmatic position is at the level of anther cone and in the third type style is elongated. The later two forms are suitable for production of hybrid.

Kalloo (1988) recognized five phases of flower on the basis of size of anthers and pistil. The start of the third phase (from the opening of the flower bud to the expansion of the sepals at an angle of 45° from the axis of the flower) is the best phase for emasculation. For emasculation, the flowers are selected at the opening stage of 45° (one day before opening) and with the help of needles or forceps, anthers and petals are removed.

Dev (1988) opined that selection of the flower buds for emasculation is the primary step and proper size of bud selected decides to a greater extent the success of hybridization. Usually the buds about to open or due to open the following day are selected. The flower buds where the tips of the corolla have not been separated can be selected for emasculation in tomato.

Kaul (1991) observed that in tomato the flowers of the fertile female plants are emasculated in different phases of their development. The flowers of the fertile plants are emasculated in the phase “fully developed bud beginning or opening”. The emasculation in an earlier phase of the flower is associated with lower seed yield and in a later phase with the danger of self pollination.

Yogeesha *et al*. (1999) stated that tomato flower buds with slightly yellow anthers which wee expected to open two days later were selected among the first three flower buds of clusters.

Basavaraj (2006) opined that usually the buds likely to open next day are selected. The maximum pollen fertility is in the period between one hour before and one hour after opening of the flower and stigma is most receptive at the time of flower opening, hence, pollination at bud stage is not successful.

Rai and Rai (2006b) observed that sometimes emasculation and pollination are completed on the same day. But in this process there is a chance of getting selfed seeds. Repeated pollinations have been found better for fruit setting in tomato. They also stated that there are four types of flowers in brinjal, long styled, medium styled, short styled and pseudo short styled. Fruit setting occurs only in long and medium styled flowers.

Eevera and Vanangamudi (2007) stated that in tomato flower buds from the second cluster which will open in 2-3 days are chosen for emasculation. The petals should be slightly out of the flower bud not opened. Flowers from the first cluster are removed. Pollination is usually done three times a week.

Malarkodi *et al*. (2007) opined that for hybrid seed production in brinjal only the flower buds having long and medium style should be selected.

Jolli *et al*. (2008b) reported that in tomato more than 50 percent open bud stage (fully matured) resulted in significantly higher fruit set (52.92%), number of seeds per fruit (103.44), seed recovery (4.49%), seed yield per plant (7.75 g), germination (96%), field emergence (90.35%) and seedling vigour index (1675) compared to the other treatments. Three times pollination gave better results than single pollination.

2.5 Effect of pollination time

2.5.1 Effect of pollination time on seed yield and its attributes.

Padda *et al.* (1971) noticed that maximum flower opening occurred between 7.00 and 8.00 am while maximum anther dehiscence occurred between 9.00 and 11.00 am in five varieties of chillies.

Prasad and Batham (1975) studied pollen viability in 20 varieties of tomato at Kanpur and reported that maximum pollen viability ranged from 93.35 to 98.60 per cent in the strain 5193 and variety Pusa Ruby in the month of December when temperature was 15 ± 2^0C and relative humidity of 82.5± 0.5 per cent. Pollen viability in the range of 88.10 to 95.00 per cent was recorded in the month of November in strain 5442, Variety Kalyanpur and Angurlata, when temperature was 19.5 ± 2^0 C and relative humidity of 82.5± 0.5 per cent.

Dev (1988) observed when pollination done immediately after emasculation led to considerable lower fruit set and lesser number of seeds per fruit in tomato.

Kaul (1991) reported that in tomato pollination is usually done one day after the flower anthesis and can be carried out on throughout the day. The successful cross pollination varies from 50 to 70 per cent. Generally, temperature in the range of 22 to 28^0 C is optimum for good seed set.

Mandal *et al.* (1997) concluded that for production of hybrid seed in brinjal, emasculation and pollination can be carried out in month of October and November, preferably in the forenoon between 9.00 am to 12 noon.

Deshpande *et al.* (1999) reported significant increase in per cent boll set (31.11), seed number per boll (20.17) and seed weight per boll (1.30g) in cotton when pollination was carried out at 10.00 am compared to the pollination at 2.00 pm (22.77,17.00,1.17, respectively).

Yogeesha *et al.* (1999) observed maximum stigma receptivity on second day after emasculation of flower as exhibited by higher values of fruit set , seed recovery, seed to fruit ratio, number of seeds per fruit and seed weight per fruit in tomato.

Jolli (2004) reported that significantly higher fruit weight (80.95 g), seed weight per fruit (0.826 g), number of seeds (85.97), seed yield per plant (11.86 g) and seed recovery percentage (4.75) when pollination was carried out at 11.00 am compared to the pollination done at 2.00 pm (59.33, 0.475, 51.66, 6.64, 3.77, respectively) in tomato.

Basavaraj (2006) reported significantly maximum fruits per plant (6.27), fruit set percentage (38.75), number of seeds per fruit (57.91), seed weight per fruit (3.20 g),seed yield per plant (20.23 g) and seed yield per ha(1123.93 kg) when pollination done at 9.00 am compared to 4.00 pm(2.23,14.43%, 37.24,1.88 g,5.55 g,5.22 g and 289.95 kg), respectively in bhendi seed production.

Patil *et al.* (2008) recorded significantly maximum number of seeds per fruit (921.4), seed weight per fruit (4.47g) and seed yield per plant (56.43g) when pollination was done at 9.00 am compared to 1.00 pm (790.5, 3.69, 23.57 respectively) pollination in brinjal hybrid seed production.

Kivadasannavar *et al*. (2009) reported that highest number of crossed fruits retained per plant (28.37), fruit set (40.25%), fruit weight per plant (52.54 g), number of seeds per fruit (51.11) seed weight/fruit (0.27 g) and seed yield per plant (6.64 g) were observed in the pollination between 9 am to 12 noon in chilli.

2.5.2 Effect of pollination time on seed quality parameters

Jolli (2004) while working in tomato, recorded significantly higher percentage of seed germination (94.65), field emergence (82.20), root length (9.21 cm), shoot length (8.70 cm) and seedling vigour index (1701) with 11.00 am pollination compared to pollination at 2.00 pm (69.02, 63.81, 7.21, 6.70, 1254, respectively).

Patil (2005) observed significantly maximum seed germination percentage (83.23), root length (8.56 cm), shoot length (8.34 cm), seedling vigour index (1406) and seedling dry weight (15.19 mg) with 11.00 am pollination compared to pollination at 1.00 pm (70.21, 7.73, 7.31, 1091, 12.72, respectively) in brinjal.

Basavaraj (2006) reported significantly maximum germination percentage (88.55), root length (12.20cm), shoot length (21.99 cm), seedling vigour index (3035) and seedling dry weight (63.35 mg) when pollination was done at 9.00 am compared to the pollination at 4.00 pm (70.42 %,9.30 cm, 17.42 cm, 1896 and 51.03 mg, respectively) in bhendi hybrid seed production.

Kivadasannavar *et al*. (2009) found seed quality parameters like 100 seed weight (0.55 g), seed germination (85.86%), root length (8.49 cm), shoot length (8.43 cm), seedling vigour index (1432) and field emergence (82.41%) to be significantly higher in pollination of chilli between 9 am to 12 noon as compared to other treatments.

3. MATERIAL AND METHODS

A field investigation was carried out on standardization of hybrid seed production techniques in bhendi at Main Agricultural Research Station, College of Agriculture, University of Agricultural Sciences, Dharwad during *kharif* 2008.

An investigation was initiated with three different field experiments simultaneously by taking the combination of different objectives and factors. The details of the experiment and techniques adopted during the course of investigation are furnished in this chapter.

3.1 General Description

3.1.1 Location of the experimental site

Experiments were conducted in black soil of the seed production block at Main Agricultural Research Station, College of Agriculture, University of Agricultural Sciences, Dharwad. Geographically it is situated at 15° 27' N latitude, 75° E longitude and at an altitude of 678 m above mean sea level. The location lies in northern transitional zone.

3.1.2 Climate

Dharwad, has the benefit of southwest and northwest monsoons. The rainfall is confined to the monsoon period from May to November with occasional showers in pre-monsoon months of April and May. During the period of experimentation, the total rainfall received was 629.2 mm (July to December 2008-09) with highest rainfall during August (213.2 mm). The mean maximum temperature during the period of experimentation ranged between 30.3^{0}C in October to 26.9^{0}C in August. The mean minimum temperature during the period of experimentation ranged between 20.7^{0}C in July to 13.8^{0}C in December. The mean relative humidity ranged between 75.4% in December to 91.5 per cent in August (Appendix-I).

3.1.3 Soil condition

The experiments were conducted in black soil, which was porous and well drained in nature. The physical and chemical composition of the field experimental soil is presented in Appendix-II

3.1.4 Previous crop on the experimental site

Previous crop on the experimental site was tomato in 2007 and it was left fallow in rabi/summer.

3.1.5 Parent materials

The seed materials of female parent: Arka Anamika and male parent: Arka Abhay was obtained from the Indian Institute of Horticultural Research, Bangalore.

3.1.6 Morphogenetic traits of parents

3.1.6.1 Arka Anamika

The okra cv. Arka Anamika is a selection from interspecific cross between *Abelmoschus esculentus* and a wild species *Abelmoschus manihot* spp. *tetraphyllus.* It was released during 1984 by Institute of Horticultural Research, Bangalore. Plants are medium tall and grow to a height of 100 cm with short internodal length, less branched, splashes of purple pigmentation present on stem, petiole and lower surface of leaf. Leaves are green, small and deeply lobed. Stem, petiole and leaves are hairy. It is resistant to yellow vein mosaic disease. It takes about 50 days for flower initiation and early maturing. The first picking of green

30 DAS

60 DAS

Plate 1. General view of the experimental plots

fruits can be made within 58-60 days. Fruits are medium, green, rough, five ridged and start after 5-6th node. It is high yielding and gives about 115q per ha of green fruits. During 1990, it has been identified for general cultivation under the All India Coordinated Vegetable Improvement Project (Sharma and Arora, 1993).

3.1.6.2 Arka Abhay

A sister line of Arka Anamika, developed and released by Institute of Horticultural Research, Bangalore in 1991. It is also developed by interspecific hybridization using *Abelmoschus tetraphyllus* var. *tetraphyllus* with *Abelmoschus esculentus* cv. 'Pusa Sawani'. Plants are tall (170 cm), erect and well branched. Short branches commence mainly during the second flush. Fruit is medium long (18 cm length and 8 cm girth), 5-6 lobed, spineless, lush green, tender and borne in two flushes. Fruit stalk is long and easy to snap. It has good cooking and keeping quality. The variety is resistant to yellow vein mosaic disease. It yields 170-200 q per ha of green fruits in 120-130 days which is 30 per cent higher than okra cv. Pusa Sawani.

3.1.7 Isolation

Okra is predominantly a self pollinated crop however, it exhibits out- crossing up to an extent of twenty per cent, mainly due to entomophily. Hence, it requires more isolation as compared to other self pollinated crops. Therefore, an isolation distance of 400 m as recommended by the seed certification agency was maintained between experimental crop and other contaminating okra varieties in field.

3.1.8 Days to initiation and completion of emasculation and crossing

The emasculation and crossing work was initiated on 49th day after sowing and it was completed on 93rd day after sowing. Hence, the emasculation and crossing programme was carried out for a total period of 45 days.

3.1.9 Number of flower buds emasculated

In all the experiments, eleven flower buds were emasculated per plant.

3.2 Experimental Details

The details of the experiment with design, treatments, plot size are given below. The research consisted of three field experiments.

3.2.1 Experiment – I: Effect of stigma receptivity of seed parent on seed yield and quality of bhendi hybrid

3.2.1.1 Hand emasculation and Hand pollination

3.2.1.2 Materials required for emasculation and pollination work

For emasculation of flower bud, forceps, scalpel, needles are required while plastic containers, scissors and brush are needed for pollen extraction from anthers and for pollination work.

3.2.1.3 Hand emasculation

The removal of androecium (stamens) from bisexual flower is called as emasculation. The matured buds which were expected to open next day were selected in female parent and emasculation was carried out by removing the androecium along with the corolla. In the treatments of pollination one day before anthesis, the buds which were distinguishably smaller in size than the normal matured ones were selected. While for the treatment of two days before anthesis, the buds which were nearly half of the fully matured buds were chosen for emasculation. These emasculated buds were covered with butter paper packets to avoid cross pollination and also for easy identification of emasculated flower for pollination.

Plate 2. Steps involved in the emasculation

The emasculation was carried out daily from 2.00 to 5.00 pm. Care was taken to remove the unemasculated flowers as per treatment and during emasculation to avoid genetic contamination in the crossed ones (Plate 2).

3.2.1.4 Pollination

The transfer of pollen from male parent to female parent is called as pollination. The just opened flowers were picked from the male parent in a separate brown paper packets and used for crossing of emasculated buds. After crossing different colour threads were tied to the pedicel of the crossed buds for easy identification. Pollination was carried daily between 8.00 to 10.00 am. The crossing was carried out for a period of 45 days from the initiation of flowering. The buds and flowers that appeared subsequently after the completion of crossing programme were manually removed to facilitate better development of the crossed fruits and to avoid the selfed seeds in the hybrid.

3.2.1.5 Treatment details

The pollination of the emasculated flower bud was carried out as follows to study the stigma receptivity of seed parent:-

S_{-2}	:	Pollination two days before anthesis
S_{-1}	:	Pollination one day before anthesis
S_0	:	Pollination on the day of emasculation
S_1	:	Pollination one day after emasculation
S_2	:	Pollination two days after emasculation
S_3	:	Pollination three days after emasculation

Number of Treatments	:	Six
Replications	:	Four
Design	:	Randomized Block Design
Spacing	:	60 cm × 30 cm
Sowing season	:	*Kharif* (June-July) -2008
Parents	:	Female Parent- Arka Anamika
		Male Parent- Arka Abhay
Soil	:	Black clay
Fertilizer dose	:	125:75:62.5 kg NPK/ha
Gross Plot Size	:	3.0 m × 4.5 m
Net Plot Size	:	1.8 m × 3.9 m

3.2.2 Experiment – II: Effect of pollen storage under condition and duration conditions on pollen viability of male parent and on seed yield and quality in bhendi hybrid

3.2.2.1Treatment details:

Factor –I : Storage of pollens (C)

C_1	:	Storage of pollens under ambient conditions

C_2 : Storage of pollens under refrigerated conditions

C_3 : Storage of pollens in earthen pots

Factor –II : Pollination with stored pollens (P)

P_0 : Pollination with fresh pollens

P_1 : Pollination with one day stored pollens

P_2 : Pollination with two days stored pollens

P_3 : Pollination with three days stored pollens

P_4 : Pollination with four days stored pollens

Treatment combinations : 3 × 5 = 15

C_1P_0	C_1P_1	C_1P_2	C_1P_3	C_1P_4
C_2P_0	C_2P_1	C_2P_2	C_2P_3	C_2P_4
C_3P_0	C_3P_1	C_3P_2	C_3P_3	C_3P_4

Replications : Three

Design : RBD (in factorial concept)

Spacing : 60 cm × 30 cm

Sowing season : *Kharif* (June-July) -2008

Parents : Female Parent- Arka Anamika

Male Parent- Arka Abhay

Soil : Black clay

Fertilizer dose : 125:75:62.5 kg NPK/ha

Gross Plot Size : 3.0 m × 4.5 m

Net Plot Size : 1.8 m × 3.9 m

3.2.2.2 Pollen collection

Just opened flowers were pinched off from male parent plants and collected in a polythene bag during early hours of the day. Anthers were separated from sepals and petals and spread on a thin cloth and exposed to sun for two hours. Dry anthers were kept in a steel cup and the pollens were separated from the anthers leaving behind the dead tissues of the anthers. Separated pollens from the anthers in this way were transferred to plastic containers with the help of a camel brush. The plastic cups were kept in a cool place over night under ambient condition or stored in a refrigerator or in earthen pots covered with moist sand for required period. Such stored pollens were used for pollinating the emasculated flowers.

3.2.2.3 Pollination

The stored pollens in the plastic containers were taken out and gently applied to the emasculated female flower stigma with the help of camel brush. The buds with optimum size were selected and emasculated (Plate 3).

Pollination with stored pollens

Pollination with stored pollens

Pollination with fresh pollens

Pollinated bud

Pollinated bud covered with butter paper bag

Plate 3. Steps involved in the pollination

3.2.2.4 Acetocarmine stain preparation for pollen viability study

Acetocarmine stain was prepared by mixing 55 ml of distilled water and 45 ml of acetic acid and 2 grams of carmine powder. This mixture was boiled gently for 5 minutes and shaken well. After cooling it was filtered through Whatman No. 71 filter paper.

Pollen grains were collected early in the morning from male parent Arka Abhay plants to know the pollen viability. The pollens were placed on a cavity slide containing 2-3 drops of acetocarmine stain (2%). These were mixed using a clean needle and left for 2-3 minutes for proper staining. The cover slip was then placed on a cavity slide and examined under microscope for staining pattern. The pollens were classified based on the intensity of staining into two categories viz., stained and unstained. The pollen grains which took stain of acetocarmine were considered as viable and unstained as non-viable. Pollen grains were observed randomly from average of four microscopic fields and numbers of viable and non-viable pollens were recorded. The pollen viability study was also conducted for different storage conditions and periods viz., pollen stored at room temperature (Ambient condition: 25 ± 2℃), at refrigerator (5℃ and 50% RH) and stored in earthen pot (earthen pot was placed in a tray and bottom of the pot was covered with moist sand and pollen grains were kept inside the pot in plastic containers).

3.2.3 Experiment – III: Effect of flower bud size and number of pollinations on seed yield and quality in bhendi hybrid

3.2.3.1 Treatment details:

Factor –I : Size of flower bud (B)

B_1 : Emasculation of less than 50% opened bud

B_2 : Emasculation of more than 50% opened bud

Factor –II : Number of pollinations on emasculated bud (N)

N_1 : One time pollination (8.00 a.m.-10.00 a.m.)

N_2 : Two time pollination of same bud (8.00 a.m.- 10.00 a.m. + 3.00 p.m.-5.00 p.m.)

N_3 : Three time pollination of same bud (8.00 a.m.- 10.00 a.m. + 3.00 p.m.-5.00 p.m. + next day 8.00 a.m.-10.00 a.m.)

Treatment combinations	:	2 × 3 = 6	
	B_1N_1	B_1N_2	B_1N_3
	B_2N_1	B_2N_2	B_2N_3
Replications	:	Four	
Design	:	RBD (in factorial concept)	
Spacing	:	60 cm × 30 cm	
Sowing season	:	*Kharif* (June-July) -2008	
Parents	:	Female Parent- Arka Anamika	
		Male Parent- Arka Abhay	

Soil	:	Black clay
Fertilizer dose	:	125:75:62.5 kg NPK/ha
Gross Plot Size	:	3.0 m × 4.5 m
Net Plot Size	:	1.8 m × 3.9 m

3.2.3.2 Selection of Buds

The flower buds in which more than half of the bud had protruded out of the calyx cup were considered as more than 50 percent opened while the other smaller sized buds were considered as less than 50 percent opened. The required sized buds as per the treatments were selected, emasculated in the evening hours and covered with butter paper packets.

3.2.3.3 Pollination

The previous day emasculated buds were pollinated with fresh male parent flowers according to the treatments. One time pollination was done in the morning hours only between 8.00 a.m. to 10.00 a.m. Repeated pollinations of the same buds were done on the same day in evening hours between 3.00 pm to 5.00 pm in case of two times pollination treatments. In three times pollination treatment the third supplementary pollination was done on the next day morning between 8.00 am to 10.00 am. In the repeated pollination treatments, the buds were re-covered with the butter paper packets after each pollination treatment.

3.2.4 Cultural practices

3.2.4.1 Preparation of experimental plot

The land was brought to a fine tilth by ploughing with mould board plough and repeated blade harrowing. The plots were laid out by fixing wooden pegs at all corners of the plots.

3.2.4.2 Manures and fertilizers

Farm yard manure @ 25 t per ha was incorporated one month prior to sowing, while the recommended 50 per cent nitrogen and entire dose of phosphorus and potassium was applied @ 62.5:75:62.5 kg NPK per ha at the time of sowing as basal dose. The remaining 50 per cent nitrogen was top dressed at 30 days after sowing. The nitrogen was applied in the form of urea, phosphorus in the form of DAP and potash in the form of muriate of potash.

3.2.4.3 Sowing

The seeds of parental lines were treated with captan at the rate of 2 g per kg of seeds and used for sowing during *kharif* 2008-09 as per the treatments. The sowing was carried out by hand dibbling of two to three seeds per hill at 5 cm depth. In all the experiments, Arka Abhay was used as male parent while Arka Anamika was utilized as female parent. The planting ratio of 3:1 female to male was kept constant that is after every three female lines one male line was sown. The border of experimental plot was marked by the two male lines on all the sides (Plate 1).

3.2.4.4 Thinning

The thinning operation was carried out by removing weak and diseased plants and maintaining only one healthy and vigorous seedling per hill.

3.2.4.5 Weeding and Intercultivation

Four hand weeding (at 30, 45, 60 and 75 DAS) were carried out during the crop growth period. Intercultivations with entire blade hoes were carried out at an interval of 15 days starting from 20 to 30 days after sowing.

3.2.4.6 Plant protection measures

Necessary plant protection measures were taken to control pests and diseases as and when required.

3.2.4.7 Irrigation

The protective irrigations of 5-6 were given during the experimental period depending upon the weather condition.

3.2.4.8 Harvesting and drying

The development of hair line cracks, splitting at tip of fruit was considered as the stage of maturity. The fruits were harvested as and when matured in each treatment from all the plants in the net plot area excluding five plants tagged earlier for recording the growth and yield parameters. The fruits were harvested and seeds were separated manually. The seeds were dried in shade for four to five days until it records about 8 to 9 per cent moisture content.

3.3 Collection of Experimental Data

Sampling Procedure

Five plants in each treatment and replication were randomly selected and tagged for recording the observations on growth characters at 30, 60, 90 days after sowing (DAS) and also at harvest. The seed yield and quality parameters were recorded at and after harvest of crop in all the three experiments.

3.3.1 Growth and flowering characters

3.3.1.1 Plant height (cm)

The plant height was measured from the ground level to the tip of the main stem at 30, 60, 90 DAS and at harvest. The average height was computed and expressed in centimeters.

3.3.1.2 Number of internodes per plant

The number of internodes per plant was manually counted at 30, 60, and 90, days after sowing and at harvest on tagged plants. The average of five plants were computed and expressed in average number of internodes per plant.

3.3.1.3 Days to initiation of flowering

The days to first flowering in each treatment was recorded and expressed as days to initiation of flowering.

3.3.1.4 Days to 50 per cent flowering

The days taken for 50 per cent of plants to produce first flower in each plot were recorded from the date of sowing and expressed in number as days to 50 per cent flowering.

3.3.1.5 Number of flowers crossed per plant

Emasculated flowers in five tagged plants in each treatment were pollinated and were counted, recorded and worked out as the mean number of flowers crossed per plant.

3.3.1.6 Number of crossed fruits per plant

Total number of crossed fruits borne on each of five tagged plants in each treatment was counted after ten days at the end of last crossing date. A fruit having a minimum 3-4 cm

length was counted as crossed fruit and the mean value was worked out and recorded as the number of crossed fruits per plant.

3.3.1.7 Fruit set percentage

After 45 days of crossing work, the fruit set was computed based on the number of fruits retained out of number of flowers crossed per plant and expressed in percentage.

$$\text{Fruit set (\%)} = \frac{\text{Number of crossed fruits retained on a plant}}{\text{Number of emasculated flowers crossed per plant}} \times 100$$

3.3.2 Yield and yield components

3.3.2.1 Fruit length (cm)

After the harvest from five plants, ten fruits were selected at random for recording the length of the fruit. The length was measured from the tip to the point of attachment to the pedicel. The mean of ten fruits was computed and expressed in centimeters.

3.3.2.2 Fruit girth (cm)

The ten fruits used for measuring the fruit length were used for measuring fruit girth. The girth was measured at the centre of the fruit with the help of vernier caliperse. The mean fruit girth was computed and expressed in centimeters.

3.3.2.3 Fruit weight per plant (g)

The matured fruits harvested at each picking from five tagged plants were recorded, later added to get total fruit yield. Mean fruit weight was worked out and expressed in grams per plant

3.3.2.4 Number of crossed seeds per fruit

The ten fruits used for measuring length and girth were used for recording the number of crossed seeds per fruit. The seeds from each fruit were separated manually by hand and counted. The average number of seeds was calculated and expressed in number.

3.3.2.5 Seed weight per fruit (g)

The ten fruits used for measuring length and girth were used for recording the seed weight per fruit. The seeds from each fruit were separated manually by hand and weighed. The average of seed weight was calculated and expressed in gram per fruit.

3.3.2.6 Seed weight per plant (g)

The seeds were extracted from the fruits of five earlier randomly tagged plants. The weight of seeds from each plot was recorded carefully with the help of electronic balance. The average seed yield was computed and expressed in gram per plant.

3.3.2.7 Seed yield per hectare (kg)

The seed yield of five tagged plants for recording the observation was added to the seed yield of net plot area to calculate the unprocessed seed yield per hectare. The yield was expressed in kilogram per hectare.

3.3.2.8 Seed recovery percentage

The unprocessed seeds from the net plot area including those from the five tagged plants were subjected to double screen arrangement with top screen of 6.0 mm (r) and bottom screen of 4.0 mm (r) size. The undersized or smaller seeds passed through the bottom screen while oversized were collected over the top screen. The seed recovery was calculated based on weight of the seeds retained on the bottom screen to the total weight of the unprocessed seeds. Seed recovery was expressed in percentage.

$$\text{Seed recovery (\%)} = \frac{\text{Seed weight retained on bottom screen (g)}}{\text{Unprocessed seed weight (g)}} \times 100$$

3.3.2.9 Hundred seed weight (g)

The hundred seed weight in grams was recorded from each treatment combination as per the procedure given by ISTA (Anon, 1999)

3.3.3 Seed quality parameters

The seeds obtained from each treatment combination were evaluated for the following characteristics in the Post Graduate laboratory of Department of Seed Science and Technology at College of Agriculture, Dharwad.

3.3.3.1 Germination percentage

The laboratory test was conducted as per the ISTA rules (Anon, 1999) by adopting rolled towel method. Hundred seeds in four replications were taken at random from each treatment and uniformly placed on germination paper. The rolled towel kept in the seed germinator and maintained at constant temperature of 25^0 C and 95 per cent relative humidity. The first and final germination counts were taken on 4^{th} and 21^{st} day, respectively. The number of normal seedlings were counted and expressed as germination percentage.

3.3.3.2 Field emergence percentage

A sample of two hundred seeds was drawn at random from each of the treatment and sown in four replications on well prepared, raised seedbed and water was added at regular interval to maintain adequate moisture in the bed. The number of seedlings emerged in each replication on 21^{st} day were recorded and expressed as field emergence per cent.

3.3.3.3 Root length (cm)

Ten normal seedlings in each treatment were randomly selected from the germination test for measuring root length on 21^{st} day of germination. The root length was measured from the collar region to the tip of the root. Average root length of ten seedlings was computed and expressed in centimeters.

3.3.3.4 Shoot length (cm)

The ten seedlings used for the root length measurement were used for measuring the shoot length also. The shoot length was measured from the collar region to the point of attachment of cotyledons. The average of ten seedlings was computed and expressed in centimetres.

3.3.3.5 Seedling dry weight (mg)

The ten seedlings used for recording the seedling length were kept in a butter paper bag and placed in an oven maintained at 80^0C for 24 hours. After drying, the seedlings were kept in a desiccator for cooling. Then the weight was recorded and expressed in mg per seedling.

3.3.3.6 Seedling vigour index

The vigour index of seedling was calculated by adapting the method suggested by Abdul-Baki and Anderson (1973) and expressed in whole number by using following formula.

Seedling vigour index = Germination (%) x seedling length (cm).

3.3.3.7 Electrical Conductivity of seed leachate (dS/m)

Electrical conductivity of seed leachate test was conducted thirty days after harvest. Five grams of seeds were weighed and surface sterilized with 0.1 per cent mercuric chloride solution for five minutes and washed four times with distilled water. Then the seeds were soaked in 25 ml of distilled water for 12 hours at room temperature. The leachate was decanted into a beaker for measuring the electrical conductivity with the help of conductivity meter and expressed in dSm^{-1}(Presley, 1958).

3.4 Statistical Analysis

The mean data was statistically analysed by adapting the appropriate methods outlined by Panse and Sukhatme (1978) and Sundararajan *et al.* (1972). The critical differences were calculated at 5 per cent (for field observations) and 1 per cent (for laboratory observations) level of probability whenever the 'F' test was significant. The percentage data was transformed into arc sine transformation, wherever it was applicable, then statistical analysis was made.

4. EXPERIMENTAL RESULTS

An investigation which involved three field experiments on standardization of hybrid seed production technique in bhendi was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *kharif* 2008-09. The results of these experiments are presented in this chapter.

4.1 Experiment-I: Effect of stigma receptivity of seed parent on seed yield and quality of bhendi hybrid

The results of experiment conducted on influence of stigma receptivity of seed parent on seed yield and quality of bhendi hybrid are presented hereunder.

4.1.1 Growth and flowering parameters

4.1.1.1 Plant height (cm)

The data on plant height are presented in Appendix III.

The results showed non significant difference for plant height. However, numerically maximum plant height was recorded in $S_{(-2)}$ at 30 days after sowing (18.79), at 60 days after sowing (59.01), at 90 days after sowing (91.44) and at harvest (94.06). S_0 recorded lower plant height at 90 days after sowing (86.85) and at harvest (90.10). The mean plant height recorded at 90 days after sowing was 89.06 cm and 92.18 cm at harvest.

4.1.1.2 Number of internodes per plant

The results on number of internodes per plant are presented in Appendix III.

The results showed non significant difference for number of internodes per plant. However, S_3 recorded numerically maximum number of internodes per plant at 90 days after sowing (15.85) and at harvest (18.75). S_0 recorded lower number of internodes per plant at 90 days after sowing (14.75) and at harvest (17.75). The mean number of internodes per plant recorded at 90 days after sowing was 15.41 and 18.28 at harvest.

4.1.1.3 Days to initiation of flowering

The data on number of days for flowering initiation in both male and female parents are presented in Appendix IV.

The results showed non significant difference for number of days for flowering initiation in both parents. However, male parent recorded early flowering as compared to female parent by one day in S_0 and S_1 and by half or more than half a day in S_3 and $S_{(-1)}$. The mean number of days for flowering initiation as recorded in male was 43.33 while it was 43.92 in female.

4.1.1.4 Days to 50 percent flowering

The data on number of days for 50 percent flowering in both male and female parents are presented in Appendix IV.

The results showed non significant difference for number of days for 50 percent flowering in both parents. However, male parent required less number of days for 50 percent flowering as compared to female parent. The mean number of days for 50 percent flowering recorded in male was 46.21 while in female it was 46.83.

Table 1: Effect of stigma receptivity on number of flowers crossed, number of crossed fruits retained and fruit set percentage in seed parent in bhendi hybrid seed production

Treatment	Number of flowers crossed / plant	Number of crossed fruits retained/ plant	Fruit set (%)
$S_{(-2)}$:Pollination two days before anthesis	10.65	1.05	9.91 (18.31)*
$S_{(-1)}$:Pollination one day before anthesis	10.85	2.30	21.18 (27.40)
$S_{(0)}$:Pollination on the day of emasculation	10.65	3.50	32.91 (35.02)
$S_{(1)}$:Pollination one day after emasculation	10.75	2.55	23.77 (29.19)
$S_{(2)}$:Pollination two days after emasculation	10.65	1.55	14.68 (22.48)
$S_{(3)}$:Pollination three days after emasculation	10.65	0.55	5.18 (13.05)
MEAN	**10.70**	**1.92**	**17.94 (24.24)**
SEm±	0.10	0.10	0.83
CD (5%)	NS	0.31	2.50

NS: Non significant
*Figures in parenthesis indicate arcsine transformed values

Fruit setting in the day of anthesis

Fruit setting in one day after emasculation

Fruit length in pollination treatment on the day of anthesis and two days before anthesis

Germination in the day of anthesis

Field emergence

Plate 4. Effect of stigma receptivity on fruit and seed characters

4.1.1.5 Number of flowers crossed per plant

The results on number of flowers crossed per plant as influenced by stigma receptivity are presented in Table 1.

The results showed non significant difference for number of flowers crossed per plant as influenced by stigma receptivity. However numerically maximum number (10.85) of crossed flowers were recorded in $S_{(-1)}$, followed by S_1 (10.75), while $S_{(-2)}$, S_0, S_2 and S_3 recorded minimum number (10.65) of crossed flowers per plant. The mean number of flowers crossed per plant was 10.70.

4.1.1.6 Number of crossed fruits retained per plant

The results on number of crossed fruits retained per plant as influenced by stigma receptivity are presented in Table 1.

The stigma receptivity influenced significantly the number of crossed fruits retained per plant. Significantly maximum number of crossed fruits retained per plant was noticed in pollination on the day of emasculation S_0 (3.50) compared to S_1 (2.55) which was on par with $S_{(-1)}$ (2.30), followed by S_2 (1.55) and $S_{(-2)}$ (1.05), however minimum number of crossed fruits was noticed in pollination three days after emasculation S_3 (0.55).

Number of crossed fruits retained per plant decreased when pollination was delayed or provided earlier from the day of emasculation and anthesis of flower respectively.

4.1.1.7 Fruit set percentage

The data on fruit set percentage as influenced by stigma receptivity are presented in Table 1 and Fig. 1 (Plate 4).

The stigma receptivity influenced significantly the fruit set percentage. Significantly higher fruit set percentage was noticed in pollination on the day of emasculation S_0 (32.91) compared to S_1 (23.77) and $S_{(-1)}$ (21.18), later two were on par with each other, followed by S_2 (14.68) and $S_{(-2)}$ (9.91). However, minimum fruit set percentage was noticed in pollination three days after emasculation S_3 (5.18).

The decrease in fruit set percentage was noticed due to increased difference between day of pollination and the day of emasculation along with anthesis.

4.1.2 Yield and its components

4.1.2.1 Fruit length (cm)

The results on fruit length as influenced by stigma receptivity are presented in Table 2 (Plate 4).

The stigma receptivity had significant influence on fruit length. Among the treatments, S_0 recorded the maximum fruit length (26.31) which is on par with S_1 (25.84) followed by $S_{(-1)}$ (25.10), S_2 (23.90) and S_3 (20.89). However, minimum fruit length was observed in $S_{(-2)}$ (18.31). The fruit length decreased gradually with increase in delay in pollination of the emasculated flowers. Also pollination before anthesis has shown a decrease in fruit length.

Table 2: Effect of stigma receptivity on fruit length, fruit girth, fruit weight per plant, seed weight per fruit, number of seeds per fruit and 100 seed weight in bhendi hybrid seed production

Treatment	Fruit length (cm)	Fruit girth (cm)	Fruit weight / plant (g)	Seed weight / fruit (g)	Number of seeds / fruit	100 seed weight (g)
$S_{(-2)}$	18.31	5.22	12.74	2.53	36.17	5.51
$S_{(-1)}$	25.10	5.99	24.39	3.64	58.14	6.76
$S_{(0)}$	26.31	6.32	33.17	4.04	59.47	7.27
$S_{(1)}$	25.84	6.17	26.49	3.70	58.38	6.94
$S_{(2)}$	23.90	5.79	23.80	3.15	54.82	6.47
$S_{(3)}$	20.89	5.62	16.32	2.96	50.71	5.53
MEAN	**23.39**	**5.85**	**22.82**	**3.33**	**52.95**	**6.41**
SEm±	0.33	0.11	0.55	0.07	0.47	0.12
CD (5%)	1.00	0.34	1.66	0.22	1.41	0.37

$S_{(-2)}$: Pollination two days before anthesis
$S_{(-1)}$: Pollination one day before anthesis
$S_{(0)}$: Pollination on the day of emasculation
$S_{(1)}$: Pollination one day after emasculation
$S_{(2)}$: Pollination two days after emasculation
$S_{(3)}$: Pollination three days after emasculation

4.1.2.2 Fruit girth (cm)

The results on fruit girth as influenced by stigma receptivity are presented in Table 2.

Stigma receptivity influenced significantly the fruit girth. Significantly maximum fruit girth was recorded in the pollination on the day of emasculation S_0 (6.32) which was on par with S_1 (6.17) and $S_{(-1)}$ (5.99) followed by S_2 (5.79) and S_3 (5.62), however minimum fruit girth was observed in $S_{(-2)}$ (5.22). The fruit girth decreased gradually with increased delay in pollination of the emasculated flowers. Also pollination before anthesis has shown a decrease in fruit girth.

4.1.2.3 Fruit weight per plant (g)

The data on fruit weight per plant as influenced by stigma receptivity are presented in Table 2.

The significant variation on fruit weight per plant as influenced by day of pollination was observed. Pollination on the day of emasculation S_0 recorded significantly maximum (33.17) fruit weight per plant followed by S_1 (26.49), $S_{(-1)}$ (24.39), S_2 (23.80) and S_3 (16.32). Significantly minimum fruit weight per plant was noticed in pollination two days before anthesis $S_{(-2)}$ (12.74).

The decrease in fruit weight per plant was noticed due to increasing difference between day of pollination and the day of emasculation along with anthesis.

4.1.2.4 Seed weight per fruit (g)

The data on influence of stigma receptivity on seed weight per fruit are presented in Table 2.

Seed weight per fruit was influenced significantly due to stigma receptivity. Significantly higher seed weight per fruit was noticed in pollination on the day of emasculation S_0 (4.04) compared to S_1 (3.70) and $S_{(-1)}$ (3.64), later two were on par with each other, followed by S_2 (3.15) and S_3 (2.96), however minimum fruit set percentage was noticed in pollination two days before anthesis $S_{(-2)}$ (2.53).

The decrease in seed weight per fruit was noticed due to increased difference between day of pollination and the day of emasculation along with anthesis.

4.1.2.5 Number of seeds per fruit

The results on number of seeds per fruit as influenced by stigma receptivity are presented in Table 2.

Stigma receptivity had significant influence on number of seeds per fruit. Significantly maximum number of seeds per fruit was recorded in the pollination on the day of emasculation S_0 (59.47) which was on par with S_1 (58.38) and $S_{(-1)}$ (58.14) followed by S_2 (54.82) and S_3 (50.17), however minimum number of seeds per fruit was observed in $S_{(-2)}$ (36.17). The number of seeds per fruit decreased with increased delay in pollination of the emasculated flowers. Also pollination before anthesis has shown a decrease in number of seeds per fruit.

4.1.2.6 Hundred seed weight (g)

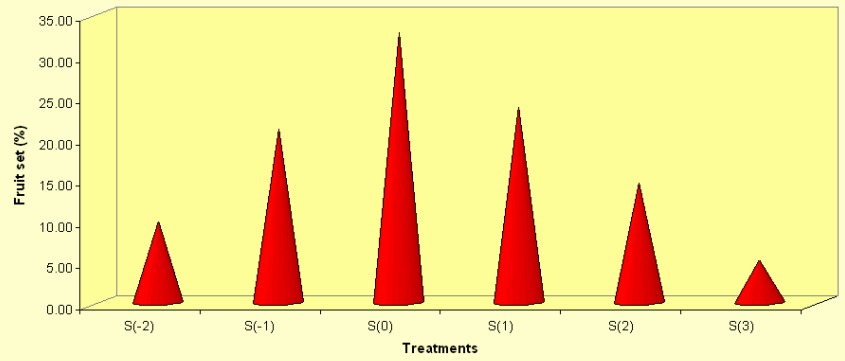
The data on hundred seed weight as influenced by stigma receptivity are presented in Table 2.

Hundred seed weight varied significantly due to stigma receptivity. Maximum hundred seed weight was recorded in the pollination on the day of emasculation S_0 (7.27) which was on par with S_1 (6.94) followed by $S_{(-1)}$ (6.76) which was on par with S_2 (6.47), while S_3 (5.53)

Table 3: Effect of stigma receptivity on seed yield per plant, seed yield per hectare and seed recovery percentage in bhendi hybrid seed production

Treatment	Seed yield / plant (g)	Seed yield / hectare (kg)	Seed recovery (%)
$S_{(-2)}$:Pollination two days before anthesis	6.89	420.81	84.27 (66.68)*
$S_{(-1)}$:Pollination one day before anthesis	19.76	1207.52	91.38 (72.99)
$S_{(0)}$:Pollination on the day of emasculation	28.65	1750.80	93.05 (74.79)
$S_{(1)}$:Pollination one day after emasculation	21.49	1313.08	92.10 (73.77)
$S_{(2)}$:Pollination two days after emasculation	13.15	803.38	89.65 (71.28)
$S_{(3)}$:Pollination three days after emasculation	5.06	309.44	87.64 (69.49)
MEAN	**15.83**	**967.51**	**89.68 (71.50)**
SEm±	0.84	51.51	0.55
CD (5%)	2.54	155.27	1.65

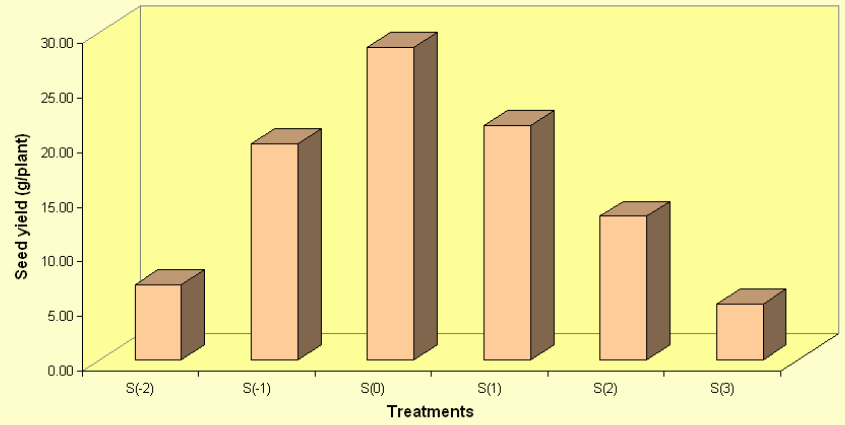
*Figures in parenthesis indicate arcsine transformed values



S (-2) : Pollination two days before anthesis S (0) : Pollination on the day of emasculation S (2) : Pollination two days after emasculation
S (-1) : Pollination one day before anthesis S (1) : Pollination one day after emasculation S (3) : Pollination three days after emasculation

Fig.1. Effect of stigma receptivity on fruit set percentage

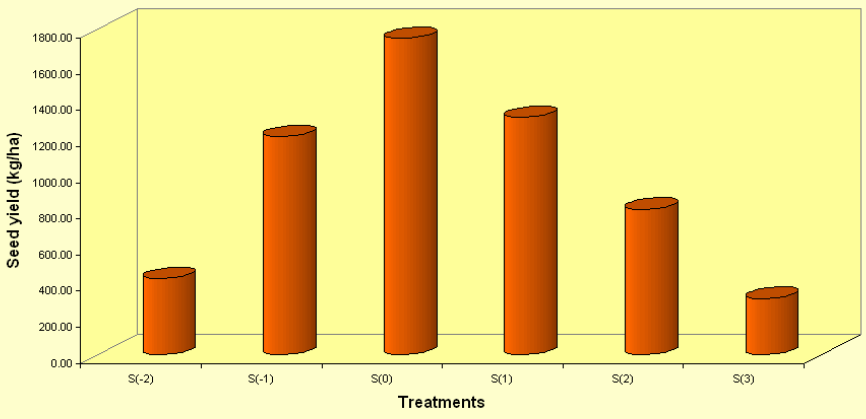
Fig.1. Effect of stigma receptivity on fruit set percentage



S (-2) : Pollination two days before anthesis S (0) : Pollination on the day of emasculation S (2) : Pollination two days after emasculation
S (-1) : Pollination one day before anthesis S (1) : Pollination one day after emasculation S (3) : Pollination three days after emasculation

Fig.2. Effect of stigma receptivity on seed yield (g/plant)

Fig.2. Effect of stigma receptivity on seed yield (g/plant)



S (-2) : Pollination two days before anthesis S (0) : Pollination on the day of emasculation S (2) : Pollination two days after emasculation
S (-1) : Pollination one day before anthesis S (1) : Pollination one day after emasculation S (3) : Pollination three days after emasculation

Fig.3. Effect of stigma receptivity on seed yield (kg/ha)

Fig.3. Effect of stigma receptivity on seed yield (kg/ha)

recorded lower hundred seed weight which was on par with $S_{(-2)}$ (5.51) which had minimum hundred seed weight.

The decrease in hundred seed weight was noticed due to increased difference between day of pollination and the day of emasculation along with anthesis.

4.1.2.7 Hybrid seed yield per plant (g)

The data on seed yield per plant as influenced by stigma receptivity are presented in Table 3 and Fig. 2.

Stigma receptivity had significant influence on seed yield per plant. Significantly highest seed yield per plant was noticed in pollination on the day of emasculation S_0 (28.65) compared to S_1 (21.49) and which was on par with $S_{(-1)}$ (19.76), followed by S_2 (13.15), lower seed yield per plant was recorded in $S_{(-2)}$ (6.89) which was on par with minimum seed yield per plant as recorded in S_3 (5.06).

The decrease in seed yield per plant was noticed due to increase in difference between day of pollination and the day of emasculation along with anthesis.

4.1.2.8 Hybrid seed yield per hectare (kg)

The results on seed yield per hectare as influenced by stigma receptivity are presented in Table 3 and Fig. 3.

Stigma receptivity significantly influenced the seed yield per hectare. Significantly higher seed yield per hectare was noticed in pollination on the day of emasculation S_0 (1750.80) compared to S_1 (1313.08) and $S_{(-1)}$ (1207.52) which were on par with each other, followed by S_2 (803.38). However, lower seed yield per plant was recorded in $S_{(-2)}$ (420.81) which was on par with S_3 (309.44), later has shown minimum seed yield per hectare.

4.1.2.9 Seed recovery percentage

The results on seed recovery percentage as influenced by stigma receptivity are presented in Table 3 and Fig. 4.

The significant variations on seed recovery percentage as influenced by day of pollination were observed. Pollination on the day of emasculation S_0 recorded significantly maximum (93.05) seed recovery percentage which was on par with S_1 (92.10), followed by $S_{(-1)}$ (91.38), S_2 (89.65) and S_3 (87.64), while significantly minimum seed recovery percentage was recorded in pollination two days before anthesis $S_{(-2)}$ (84.27).

4.1.3 Seed quality parameters

4.1.3.1 Seed germination percentage

The data on seed germination percentage as influenced by stigma receptivity are presented in Table 4 and Fig. 5 (Plate 4).

The significant variations on seed germination percentage as influenced by day of pollination were observed. Significantly higher seed germination percentage was noticed in pollination on the day of emasculation S_0 (93.25), which was on par with S_1 (91.25), followed by $S_{(-1)}$ (89.50), S_2 (84.75) and S_3 (76.25), while it was significantly lower in pollination two days before anthesis $S_{(-2)}$ (72.00).

The decrease in seed germination percentage was noticed due to increased difference between day of pollination and the day of emasculation along with anthesis.

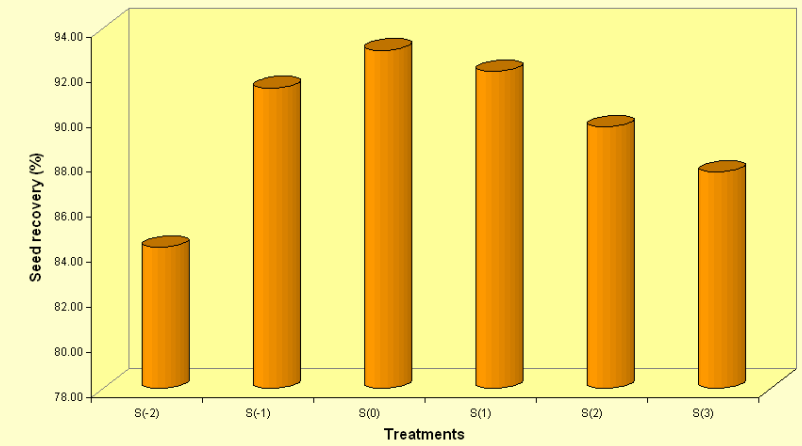
4.1.3.2 Field emergence percentage

The data on field emergence percentage as influenced by stigma receptivity are presented in Table 4 and Fig. 6 (Plate 4).

Table 4: Effect of stigma receptivity on seed germination percentage, field emergence percentage, shoot length and root length in bhendi hybrid seed production

Treatment	Germination (%)	Field emergence (%)	Shoot length (cm)	Root length (cm)
$S_{(-2)}$:Pollination two days before anthesis	72.00 (58.09)*	62.75 (52.44)*	16.70	8.86
$S_{(-1)}$:Pollination one day before anthesis	89.50 (71.15)	80.75 (64.02)	21.31	11.08
$S_{(0)}$:Pollination on the day of emasculation	93.25 (75.01)	83.75 (66.32)	23.20	12.33
$S_{(1)}$:Pollination one day after emasculation	91.25 (72.85)	79.50 (63.12)	21.80	11.86
$S_{(2)}$:Pollination two days after emasculation	84.75 (67.07)	76.75 (61.23)	20.45	10.81
$S_{(3)}$:Pollination three days after emasculation	76.25 (60.88)	64.75 (53.65)	17.25	9.06
MEAN	**84.50 (67.51)**	**74.71 (60.13)**	**20.12**	**10.66**
SEm±	0.57	1.15	0.20	0.14
CD (1%)	2.37	#3.47	0.85	0.58

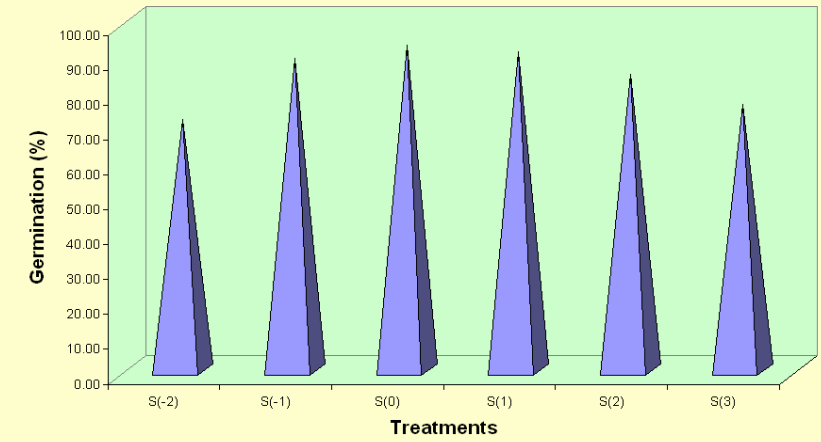
*Figures in parenthesis indicate arcsine transformed values
#CD (5%)



S (-2) : Pollination two days before anthesis S (0) : Pollination on the day of emasculation S (2) : Pollination two days after emasculation
S (-1) : Pollination one day before anthesis S (1) : Pollination one day after emasculation S (3) : Pollination three days after emasculation

Fig.4. Effect of stigma receptivity on seed recovery percentage

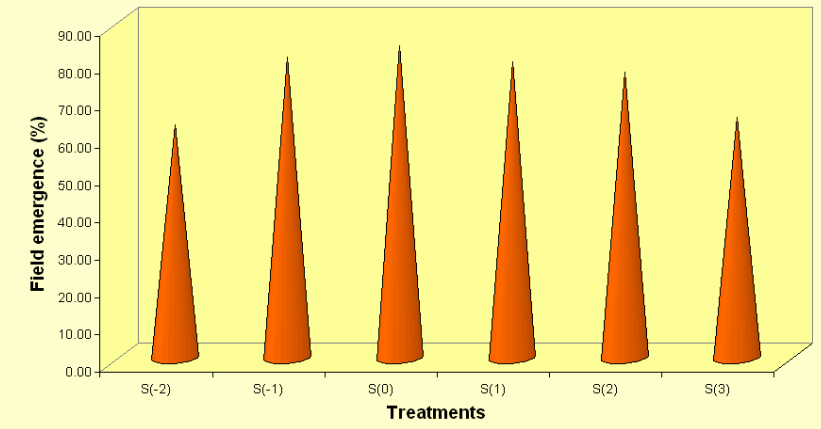
Fig.4. Effect of stigma receptivity on seed recovery percentage



S (-2) : Pollination two days before anthesis S (0) : Pollination on the day of emasculation S (2) : Pollination two days after emasculation
S (-1) : Pollination one day before anthesis S (1) : Pollination one day after emasculation S (3) : Pollination three days after emasculation

Fig.5. Effect of stigma receptivity on germination percentage

Fig.5. Effect of stigma receptivity on germination percentage



S (-2) : Pollination two days before anthesis S (0) : Pollination on the day of emasculation S (2) : Pollination two days after emasculation
S (-1) : Pollination one day before anthesis S (1) : Pollination one day after emasculation S (3) : Pollination three days after emasculation

Fig.6. Effect of stigma receptivity on field emergence percentage

Fig.6. Effect of stigma receptivity on field emergence percentage

The significant variation on field emergence percentage as influenced by day of pollination was observed.. Significantly higher field emergence percentage was recorded in the pollination on the day of emasculation S_0 (83.75) which was on par with $S_{(-1)}$ (80.75) and S_1 (79.50) followed by S_2 (76.75). However, minimum field emergence percentage was observed in $S_{(-2)}$ (62.75) which was on par with S_3 (64.75). The decrease in field emergence percentage was noticed due to increase in difference between day of pollination and the day of emasculation along with anthesis.

4.1.3.3 Shoot length (cm)

The results on shoot length as influenced by stigma receptivity are presented in Table 4 and Fig. 7.

Stigma receptivity has shown significant influence on shoot length. Significantly higher shoot length was noticed in pollination on the day of emasculation S_0 (23.20) compared to S_1 (21.80) which was on par with $S_{(-1)}$ (21.31), followed by S_2 (20.45), lower shoot length was recorded in S_3 (17.25) which was on par with minimum shoot length as recorded in $S_{(-2)}$ (16.70)

4.1.3.4 Root length (cm)

The data on root length as influenced by stigma receptivity are presented in Table 4 and Fig. 8.

Root length was influenced significantly by the stigma receptivity. Significantly higher root length was noticed in pollination on the day of emasculation S_0 (12.33) which was on par with S_1 (11.86) as compared to $S_{(-1)}$ (11.08) which was on par with S_2 (10.81), lower root length was recorded in S_3 (9.06) which was on par with minimum root length as recorded in $S_{(-2)}$ (8.86).

4.1.3.5 Seedling vigour index

The results on seedling vigour index as influenced by stigma receptivity are presented in Table 5 and Fig. 9.

The significant variations on seedling vigour index as influenced by day of pollination were observed. Pollination on the day of emasculation S_0 recorded significantly maximum (3312) seedling vigour index followed by S_1 (3072), $S_{(-1)}$ (2899), S_2 (2649) and S_3 (2004), while it was significantly minimum in pollination two days before anthesis $S_{(-2)}$ (1838).

The decrease in seedling vigour index was noticed due to increase in difference between day of pollination and the day of emasculation along with anthesis.

4.1.3.6 Seedling dry weight (mg)

The data on seedling dry weight as influenced by stigma receptivity are presented in Table 5.

The significant variations on seedling dry weight as influenced by day of pollination were observed. Significantly highest seedling dry weight was noticed in pollination on the day of emasculation S_0 (63.96), which was on par with S_1 (62.44), followed by $S_{(-1)}$ (62.02), S_2 (54.41) and S_3 (52.43), while it was significantly minimum in pollination two days before anthesis $S_{(-2)}$ (49.06).

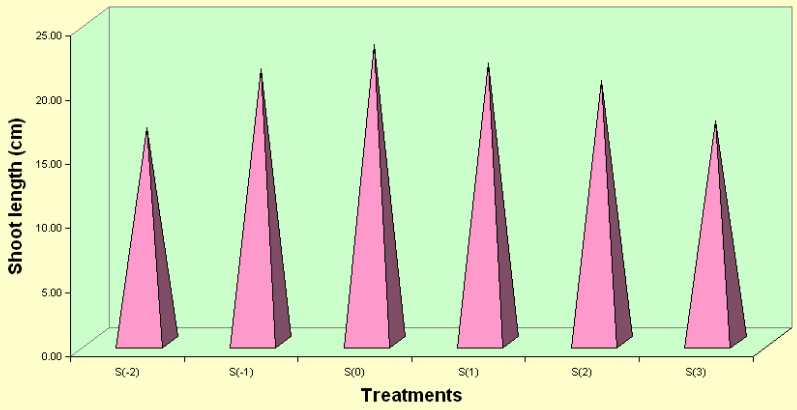
4.1.3.7 Electrical conductivity of seed leachate (dS/m)

The data on electrical conductivity (EC) of seed leachate as influenced by stigma receptivity are presented in Table 5.

The significant variations on electrical conductivity (EC) of seed leachate as influenced by day of pollination were observed. Significantly lower electrical conductivity (EC) of seed leachate was noticed in pollination on the day of emasculation S_0 (0.642), followed

Table 5: Effect of stigma receptivity on seedling vigour index, ten seedling dry weight and electrical conductivity of seed leachate in bhendi hybrid seed production

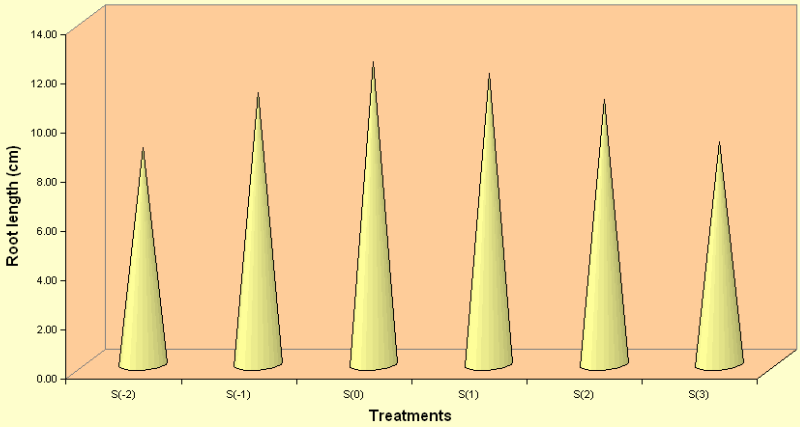
Treatment	Seedling vigour index	Ten seedling dry weight (mg)	Electrical conductivity of seed leachate (dSm^{-1})
$S_{(-2)}$:Pollination two days before anthesis	1838	49.06	0.779
$S_{(-1)}$:Pollination one day before anthesis	2899	62.02	0.708
$S_{(0)}$:Pollination on the day of emasculation	3312	63.96	0.642
$S_{(1)}$:Pollination one day after emasculation	3072	62.44	0.681
$S_{(2)}$:Pollination two days after emasculation	2649	54.41	0.739
$S_{(3)}$:Pollination three days after emasculation	2004	52.43	0.762
MEAN	**2629**	**57.39**	**0.718**
SEm±	33.00	0.44	0.005
CD (1%)	100.00	1.33	0.015



S (-2) : Pollination two days before anthesis S (0) : Pollination on the day of emasculation S (2) : Pollination two days after emasculation
S (-1) : Pollination one day before anthesis S (1) : Pollination one day after emasculation S (3) : Pollination three days after emasculation

Fig.7. Effect of stigma receptivity on shoot length

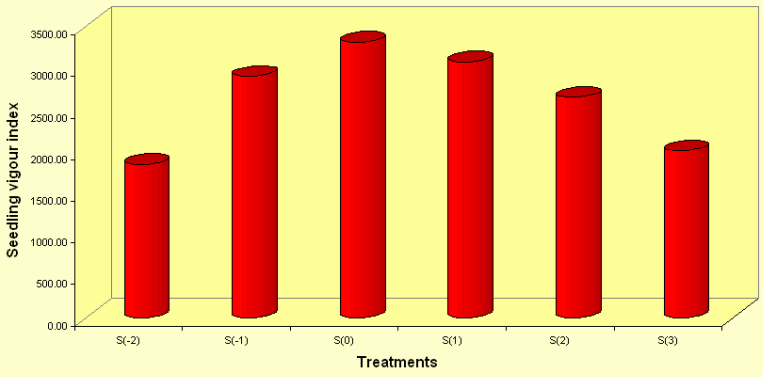
Fig.7. Effect of stigma receptivity on shoot length



S (-2) : Pollination two days before anthesis S (0) : Pollination on the day of emasculation S (2) : Pollination two days after emasculation
S (-1) : Pollination one day before anthesis S (1) : Pollination one day after emasculation S (3) : Pollination three days after emasculation

Fig.8. Effect of stigma receptivity on root length

Fig.8. Effect of stigma receptivity on root length



S (-2) : Pollination two days before anthesis S (0) : Pollination on the day of emasculation S (2) : Pollination two days after emasculation
S (-1) : Pollination one day before anthesis S (1) : Pollination one day after emasculation S (3) : Pollination three days after emasculation

Fig.9. Effect of stigma receptivity on seedling vigour index

Fig.9. Effect of stigma receptivity on seedling vigour index

by S_1 (0.681), $S_{(-1)}$ (0.708), S_2 (0.739) and S_3 (0.762), while it was significantly highest in pollination two days before anthesis $S_{(-2)}$ (0.779).

4.2 Experiment–II: Effect of duration of pollen storage under different storage conditions on seed yield and quality of bhendi hybrid

4.2.1 Growth parameters

4.2.1.1 Plant height (cm)

The data on plant height are presented in Appendix V.

The results showed non significant difference for plant height. However, numerically higher plant height was recorded in C_1 at 90 days after sowing (91.10) and at harvest (94.20) and in P_2 at 90 days after sowing (91.27) and at harvest (94.37). The mean plant height at 90 days after sowing and at harvest was 90.25 and93.35 cm respectively.

4.2.1.2 Number of internodes per plant

The data on number of internodes per plant are presented in Appendix VI.

The results showed non significant difference for number of internodes per plant. However, numerically higher number of internodes per plant was recorded in C_2 at 90 days after sowing (15.61) and at harvest (17.75) and P_4 at 90 days after sowing (15.64) and at harvest (17.76). The mean number of internodes per plant at 90 days after sowing and at harvest was 15.28 and 17.44 cm respectively.

4.2.1.3 Days to initiation of flowering

The results on number of days for flowering initiation in both male and female parents are presented in Appendix VII.

The results showed non significant difference for number of days for flowering initiation in both parents. However, male parent recorded early flowering initiation as compared to female parent. The mean for flowering initiation as recorded in male was 43.67 while in female it was 43.82 days after sowing.

4.2.1.4 Days to 50 percent flowering

The data on number of days for 50 percent flowering in both male and female parents are presented in Appendix VIII.

The results showed non significant difference for number of days for 50 percent flowering in both parents. However, male parent required less number of days for 50 percent flowering as compared to female parent. The mean for 50 percent flowering in male was 46.69 while in female it was 47.07 days after sowing.

4.2.1.5 Pollen viability percentage

The results on pollen viability percentage of male parent as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 6 and Fig. 10.

The pollen viability was significantly influenced by the pollen storage condition, pollen storage duration and their interaction.

The storage condition significantly influenced the pollen viability percentage. The pollens stored under refrigerated conditions (C_2) recorded higher viability (92.93%) as compared to the pollen stored in earthen pot covered with wet sand C_3 (84.68 %) and storage under ambient conditions C_1 (83.74 %), later two were on par with each other.

Table 6: Effect of pollen storage under different conditions for varying durations on pollen viability of pollen parent in bhendi hybrid seed production

Treatment	Number of stained pollens	Number of unstained pollens	Pollen viability (%)
Storage condition (C)			
C_1 : Ambient	147.53	28.47	83.74 (66.75)*
C_2 : Refrigerated	202.73	15.40	92.93 (74.66)
C_3 : Earthen pot	197.73	33.20	84.68 (67.49)
SEm±	12.97	2.08	0.29
CD (1%)	NS	8.13	1.11
Storage duration (P)			
P_0 : Fresh pollens	207.78	15.00	93.48 (75.26)
P_1 : One day	169.89	19.56	89.56 (71.37)
P_2 : Two days	198.11	25.44	88.20 (70.24)
P_3 : Three days	157.44	29.22	83.29 (66.44)
P_4 : Four days	180.11	39.22	81.04 (64.86)
SEm±	20.51	3.29	0.45
CD (1%)	NS	12.85	1.76
Interaction (C x P)			
C_1P_0	155.00	11.00	93.46 (75.22)
C_1P_1	139.67	22.00	86.48 (68.47)
C_1P_2	182.00	29.33	85.29 (67.64)
C_1P_3	119.00	31.67	78.90 (62.69)
C_1P_4	142.00	48.33	74.55 (59.74)
C_2P_0	196.67	14.33	93.51 (75.33)
C_2P_1	170.67	12.33	93.14 (74.90)
C_2P_2	206.33	14.67	93.00 (74.76)
C_2P_3	207.33	16.00	92.72 (74.39)
C_2P_4	232.67	19.67	92.27 (73.94)
C_3P_0	271.67	19.67	93.46 (75.24)
C_3P_1	199.33	24.33	89.06 (70.73)
C_3P_2	206.00	32.33	86.32 (68.33)
C_3P_3	146.00	40.00	78.26 (62.24)
C_3P_4	165.67	49.67	76.30 (60.91)
MEAN	**182.67**	**25.69**	**87.11 (69.64)**
SEm±	29.01	4.65	0.64
CD (1%)	NS	NS	2.49

NS: Non significant

*Figures in parenthesis indicate arcsine transformed values

The pollen viability percentage was significantly influenced by the pollen storage duration. The fresh pollens P_0 recorded significantly higher viability (93.48 %) as compared to one day P_1 (89.56 %) and two days P_2 (88.20 %) stored pollens, later two were on par with each other. The minimum viability was observed in pollens stored for four days P_4 (81.04 %) and it was on par with three day stored pollens P_3 (83.29 %).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for the pollen viability percentage. The interaction C_2P_0 recorded higher pollen viability percentage (93.51) and it was on par with C_3P_0 (93.46), C_1P_0 (93.46), C_2P_1 (93.14), C_2P_2 (93.00), C_2P_3 (92.72) and C_2P_4 (92.27). However, the minimum viability was recorded in the pollens stored for four days under ambient condition C_1P_4 (74.55 %).

4.2.1.6 Number of flowers crossed per plant

The results on number of flowers crossed per plant as influenced by storage condition, duration of pollen storage and their interaction are presented in Table 7.

The results showed non significant difference for number of flowers crossed per plant as influenced by pollen storage condition, pollen storage duration and their interactions. However, numerically maximum number of crossed flowers per plant was recorded in storage condition treatments C_1 (10.87), followed by C_3 (10.85) and C_2 (10.73). While, among the days of storage treatments, higher number of flowers crossed per plant was recorded in P_2 (10.89) followed by P_1 (10.87), P_0 (10.80), P_3 (10.78) and P_4 (10.76).

The interactions of C_1P_2 and C_3P_4 (11.00 each) recorded more number of flowers crossed per plant. However, lower number of flowers crossed per plant was recorded in C_2P_4 (10.60).Irrespective of storage conditions and days of storage the mean number of flowers crossed per plant was 10.82.

4.2.1.7 Number of crossed fruits retained per plant

The data on number of crossed fruits retained per plant as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 7 (Plate 5).

The storage conditions influenced significantly the number of crossed fruits retained per plant. Significantly maximum number of crossed fruits retained per plant was noticed in the treatment of pollen storage under refrigerated conditions C_2 (3.21) followed by pollen storage in the earthen pots covered with moist sand C_3 (2.99). However, lower number of crossed fruits retained per plant was noticed in the treatment of pollen storage under ambient conditions C_1 (2.56).

The number of crossed fruits retained per plant was significantly influenced by the number of days of pollen storage. Significantly higher number of crossed fruits was retained in the pollination by fresh pollens P_0 (4.04). Pollination by one day stored pollens P_1 (3.33) was on par with pollination done with pollens stored for two days P_2 (3.18). However, lower number of crossed fruits retained per plant was observed in the treatment pollination with three day stored pollens P_3 (2.11) and it was on par with pollination with pollens stored for four days P_4 (1.93).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for crossed fruits retained per plant. The fresh pollens under refrigerated conditions C_2P_0 and in earthen pots C_3P_0 recorded higher number of crossed fruits retained per plant (4.07 each), these two were on par with C_1P_0 (4.00). Pollen storage up to one day under refrigerated conditions C_2P_1 (3.80) was found to be on par with C_2P_2 (3.53). The C_1P_3 (1.93) and C_1P_4 (1.47) produced less number of crossed fruits per plant.

4.2.1.8 Fruit set percentage

The data on fruit set percentage as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 7 and Fig. 11.

Table 7: Effect of pollen storage under different conditions for varying durations on number of flowers crossed, number of crossed fruits retained and fruit set percentage in seed parent in bhendi hybrid seed production

Treatment	Number of flowers crossed / plant	Number of crossed fruits retained / plant	Fruit set (%)
Storage condition (C)			
C_1 : Ambient	10.87	2.56	23.56 (28.75)*
C_2 : Refrigerated	10.73	3.21	30.02 (33.08)
C_3 : Earthen pot	10.85	2.99	27.54 (31.44)
SEm±	0.05	0.04	0.30
CD (5%)	NS	0.12	0.86
Storage duration (P)			
P_0 : Fresh pollens	10.80	4.04	37.52 (37.78)
P_1 : One day	10.87	3.33	30.73 (33.63)
P_2 : Two days	10.89	3.18	29.25 (32.71)
P_3 : Three days	10.78	2.11	19.64 (26.29)
P_4 : Four days	10.76	1.93	18.08 (25.05)
SEm±	0.08	0.07	0.47
CD (5%)	NS	0.19	1.36
Interaction (C x P)			
C_1P_0	10.93	4.00	36.61 (37.25)
C_1P_1	10.87	2.73	25.27 (30.19)
C_1P_2	11.00	2.67	24.24 (29.49)
C_1P_3	10.87	1.93	17.88 (25.02)
C_1P_4	10.67	1.47	13.82 (21.82)
C_2P_0	10.67	4.07	38.30 (38.24)
C_2P_1	10.87	3.80	35.03 (36.30)
C_2P_2	10.87	3.53	32.61 (34.83)
C_2P_3	10.67	2.33	21.94 (27.93)
C_2P_4	10.60	2.33	22.24 (28.08)
C_3P_0	10.80	4.07	37.64 (37.86)
C_3P_1	10.87	3.47	31.88 (34.39)
C_3P_2	10.80	3.33	30.91 (33.79)
C_3P_3	10.80	2.07	19.09 (25.91)
C_3P_4	11.00	2.00	18.18 (25.23)
MEAN	**10.82**	**2.92**	**27.04 (31.09)**
SEm±	0.12	0.09	0.66
CD (5%)	NS	0.27	1.92

NS: Non significant

*Figures in parenthesis indicate arcsine transformed values

The storage conditions influenced significantly the fruit set percentage. Significantly maximum fruit set percentage was noticed in the treatment of pollen storage under refrigerated conditions C_2 (30.02) followed by pollen storage in the earthen pots covered with moist sand C_3 (27.54). However, lower fruit set percentage was noticed in the treatment of pollen storage under ambient conditions C_1 (23.56).

The fruit set percentage was significantly influenced by the number of days of pollen storage. Significantly higher fruit set percentage was noticed in the pollination by fresh pollens P_0 (37.52). Pollination by one day stored pollens P_1 (30.73) was on par with pollination by two day stored pollens P_2 (29.25). However, lower fruit set percentage was observed in the treatment pollination with three day stored pollens P_3 (19.64) and it was on par with pollination with pollens stored for four days P_4 (18.08).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for fruit set percentage. The C_2P_0 (38.30), C_3P_0 (37.64) and C_1P_0 (36.61) recorded higher fruit set percentage and these three were on par with each other. Pollen storage up to one day under refrigerated conditions C_2P_1 (35.03) was found to be on par with C_2P_2 (32.61) and C_3P_1 (31.88). However, C_1P_4 (13.82) recorded minimum fruit set percentage.

4.2.2 Yield and its components

4.2.2.1 Fruit length (cm)

The results on fruit length as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 8.

The storage conditions influenced significantly the fruit length. Significantly maximum fruit length was noticed in the treatment of pollen storage under refrigerated conditions C_2 (25.30) followed by pollen storage in the earthen pots covered with moist sand C_3 (24.03). However, lower fruit length was noticed in the treatment of pollen storage under ambient conditions C_1 (23.43).

The fruit length was significantly influenced by the number of days of pollen storage. Significantly the highest fruit length was noticed in the pollination by fresh pollens P_0 (25.62). Pollination by one day stored pollens P_1 (24.77) was on par with pollination by two day stored pollens P_2 (24.32). However, lower fruit length was observed in the treatment pollination with three day stored pollens P_3 (23.37) and it was on par with pollination with pollens stored for four days P_4 (23.17).

The interactions between pollen storage conditions and the number of days of pollen storage (C x P) was found to be non significant for fruit length. However, the C_2P_0 (26.49) recorded maximum fruit length, followed by C_2P_1 (26.33), C_2P_2 (25.69) C_3P_0 (25.25) and C_1P_0 (25.14). The C_1P_3 (22.54) and C_1P_4 (22.39) recorded the minimum fruit length. Irrespective of storage conditions and duration the mean fruit length was recorded to be 24.25 cm.

4.2.2.2 Fruit girth (cm)

The data on fruit girth as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 8.

Significant influence of the storage conditions was noticed on the fruit girth. Significantly maximum fruit girth was noticed in the treatment of pollen storage under refrigerated conditions C_2 (5.94) followed by pollen storage in the earthen pots covered with moist sand C_3 (5.77). However, lower fruit girth was noticed in the treatment of pollen storage under ambient conditions C_1 (5.61).

The fruit girth was significantly influenced by the number of days of pollen storage. Significantly higher fruit girth was noticed in the pollination by fresh pollens P_0 (6.14).

Pollination by one day stored pollens P_1 (5.96) was on par with pollination by two day stored pollens P_2 (5.85). However, lower fruit girth was observed in the treatment pollination with three day stored pollens P_3 (5.52) and it was on par with four day stored pollens P_4 (5.40).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be non significant for fruit girth. However, the C_2P_0 (6.25) recorded higher fruit girth, followed by C_2P_1 (6.21), C_3P_0 (6.09), C_2P_2 (6.08), and C_1P_0 (6.07). The C_1P_3 (5.37) and C_1P_4 (5.23) recorded lower fruit girth. Irrespective of storage conditions and duration the mean fruit girth was recorded to be 5.77 cm.

4.2.2.3 Fruit weight per plant (g)

The results on fruit weight per plant as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 8.

The storage conditions influenced significantly the fruit weight per plant. Significantly maximum fruit weight per plant was noticed in C_2 (31.26) followed by C_3 (29.75). However, lower fruit weight per plant was noticed in the treatment of pollen storage under ambient conditions C_1 (27.74).

The fruit weight per plant was significantly influenced by the number of days of pollen storage. Significantly higher fruit weight per plant was noticed in the pollination by fresh pollens P_0 (38.41), followed by pollination by one day stored pollens P_1 (35.64) and two day stored pollens P_2 (33.84). However, lower fruit weight per plant was observed in the treatment pollination with three day stored pollens P_3 (20.67) and it was on par with pollination with pollens stored for four days P_4 (19.38).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for fruit weight per plant. The C_1P_0 (38.93), C_3P_0 (38.23), C_2P_1 (38.15), C_2P_0 (38.06) and C_2P_2 (37.25) recorded higher fruit weight per plant and all these treatment combinations were on par with each other. The pollen storage in the earthen pots up to one day C_3P_1 (35.84) and two day C_3P_2 (34.25) was recorded to be on par with each other. However, lower fruit weight per plant was recorded in the C_2P_3 (21.46) which was on par with C_2P_4 (21.40), C_3P_3 (20.49), C_1P_3 (20.06) and C_3P_4 (19.96). The minimum fruit weight per plant was observed in C_1P_4 (16.77).

4.2.2.4 Seed weight per fruit (g)

The data on seed weight per fruit as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 9.

The seed weight per fruit was significantly influenced by the storage conditions. Significantly maximum seed weight per fruit was noticed in the treatment of pollen storage under refrigerated conditions C_2 (3.70) followed by pollen storage in the earthen pots covered with moist sand C_3 (3.40). However, lower seed weight per fruit was noticed in the treatment C_1 (3.22).

The seed weight per fruit was significantly influenced by the number of days of pollen storage. Significantly higher seed weight per fruit was noticed in the pollination by fresh pollens P_0 (4.02), followed by pollination by one day stored pollens P_1 (3.67) and two day stored pollens P_2 (3.53), later two were on par with each other. However, lower seed weight per fruit was observed in the treatment pollination with three day stored pollens P_3 (3.04) and it was on par with P_4 (2.97).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for seed weight per fruit. The C_2P_0 (4.13) recorded maximum seed weight per fruit and it was on par with C_3P_0 (4.00), C_1P_0 (3.92) and C_2P_1 (3.88), followed by C_3P_1 (3.80) which was on par with C_2P_2 (3.74) and C_3P_2 (3.66). The minimum seed weight per fruit was observed in C_3P_4 (2.67) which was on par with C_3P_3 (2.85), C_1P_3 (2.84) and C_1P_4 (2.83).

Table 8: Effect of pollen storage under different conditions for varying durations on fruit length, fruit girth and fruit weight per plant in bhendi hybrid seed production

Treatment	Fruit length (cm)	Fruit girth (cm)	Fruit weight / plant (g)
Storage condition (C)			
C_1 : Ambient	23.43	5.61	27.74
C_2 : Refrigerated	25.30	5.94	31.26
C_3 : Earthen pot	24.03	5.77	29.75
SEm±	0.18	0.05	0.31
CD (5%)	0.53	0.14	0.89
Storage duration (P)			
P_0 : Fresh pollens	25.62	6.14	38.41
P_1 : One day	24.77	5.96	35.64
P_2 : Two days	24.32	5.85	33.84
P_3 : Three days	23.37	5.52	20.67
P_4 : Four days	23.17	5.40	19.38
SEm±	0.29	0.08	0.49
CD (5%)	0.83	0.22	1.41
Interaction (C x P)			
C_1P_0	25.14	6.07	38.93
C_1P_1	23.83	5.75	32.91
C_1P_2	23.25	5.62	30.02
C_1P_3	22.54	5.37	20.06
C_1P_4	22.39	5.23	16.77
C_2P_0	26.49	6.25	38.06
C_2P_1	26.33	6.21	38.15
C_2P_2	25.69	6.08	37.25
C_2P_3	24.10	5.65	21.46
C_2P_4	23.90	5.53	21.40
C_3P_0	25.25	6.09	38.23
C_3P_1	24.16	5.93	35.84
C_3P_2	24.03	5.83	34.25
C_3P_3	23.48	5.55	20.49
C_3P_4	23.22	5.44	19.96
MEAN	**24.25**	**5.77**	**29.59**
SEm±	0.41	0.11	0.69
CD (5%)	NS	NS	2.00

NS: Non significant

4.2.2.5 Number of seeds per fruit

The results on number of seeds per fruit as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 9.

Significant influence of storage conditions on the number of seeds per fruit was observed. Significantly maximum number of seeds per fruit was noticed in the treatment C_2 (50.93) followed by pollen storage in the earthen pots covered with moist sand C_3 (49.64). However, lower number of seeds per fruit was noticed in the treatment of pollen storage under ambient conditions C_1 (47.70).

The number of seeds per fruit was significantly influenced by the number of days of pollen storage. Significantly higher number of seeds per fruit was noticed in the pollination by fresh pollens P_0 (59.51). Pollination by one day stored pollens P_1 (56.86) was on par with the two day stored pollens P_2 (56.20). However, lower number of seeds per fruit was observed in the treatment pollination with three day stored pollens P_3 (37.38) and it was on par with P_4 (37.17).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for number of seeds per fruit. The C_2P_0 (59.98) recorded maximum number of seeds per fruit and it was on par with C_1P_0 (59.39), C_3P_0 (59.15) and C_2P_1 (58.88), followed by C_3P_1 (57.42). The minimum number of seeds per fruit was observed in C_1P_3 (35.13) which was on par with C_1P_4 (35.34).

4.2.2.6 Hundred seed weight (g)

The results on hundred seed weight as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 9.

The storage conditions influenced significantly the hundred seed weight. Significantly maximum hundred seed weight was noticed in the treatment of pollen storage under refrigerated conditions C_2 (6.86) followed by pollen storage in the earthen pots covered with moist sand C_3 (6.68). However, lower hundred seed weight was noticed in the treatment of pollen storage under ambient conditions C_1 (6.08).

The hundred seed weight was significantly influenced by the number of days of pollen storage. Significantly higher hundred seed weight was noticed in the pollination by fresh pollens P_0 (7.25). Pollination by one day stored pollens P_1 (6.70) was on par with the two day stored pollens P_2 (6.55). However, lower hundred seed weight was observed in the treatment pollination with three day stored pollens P_3 (6.18) and it was on par with P_4 (6.01).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for hundred seed weight. The maximum hundred seed weight was recorded in C_2P_0 (7.38) and it was on par with C_3P_0 (7.26) and C_1P_0 (7.12), followed by C_2P_1 (6.89) which was on par with C_3P_1 (6.86), C_2P_2 (6.83), C_3P_2 (6.80) and C_2P_3 (6.66). However, lower hundred seed weight was recorded in the C_2P_4 (6.53) which was on par with C_1P_1 (6.36) and C_3P_3 (6.34). The minimum hundred seed weight was observed in C_1P_4 (5.33) which was on par with C_1P_3 (5.55).

4.2.2.7 Hybrid seed yield per plant (g)

The data on seed yield per plant as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 10 and Fig. 12.

The seed yield per plant showed significant results due to influence of storage conditions. Significantly maximum seed yield per plant was noticed in the treatment of pollen storage under refrigerated conditions C_2 (24.63) followed by pollen storage in the earthen pots covered with moist sand C_3 (22.87). However, lower seed yield per plant was noticed in the treatment of pollen storage under ambient conditions C_1 (20.55).

Table 9: Effect of pollen storage under different conditions for varying durations on seed weight per fruit, number of seeds per fruit and 100 seed weight in bhendi hybrid seed production

Treatment	Seed weight /fruit (g)	Number of seeds / fruit	100 seed weight (g)
Storage condition (C)			
C_1 : Ambient	3.22	47.70	6.08
C_2 : Refrigerated	3.72	50.93	6.86
C_3 : Earthen pot	3.40	49.64	6.68
SEm±	0.04	0.21	0.05
CD (5%)	0.11	0.62	0.14
Storage duration (P)			
P_0 : Fresh pollens	4.02	59.51	7.25
P_1 : One day	3.67	56.86	6.70
P_2 : Two days	3.53	56.20	6.55
P_3 : Three days	3.04	37.38	6.18
P_4 : Four days	2.97	37.17	6.01
SEm±	0.06	0.34	0.08
CD (5%)	0.18	0.98	0.22
Interaction (C x P)			
C_1P_0	3.92	59.39	7.12
C_1P_1	3.34	54.28	6.36
C_1P_2	3.20	54.39	6.02
C_1P_3	2.84	35.13	5.55
C_1P_4	2.83	35.34	5.33
C_2P_0	4.13	59.98	7.38
C_2P_1	3.88	58.88	6.89
C_2P_2	3.74	58.33	6.83
C_2P_3	3.43	38.69	6.66
C_2P_4	3.41	38.76	6.53
C_3P_0	4.00	59.15	7.26
C_3P_1	3.80	57.42	6.86
C_3P_2	3.66	55.88	6.80
C_3P_3	2.85	38.33	6.34
C_3P_4	2.67	37.42	6.15
MEAN	**3.45**	**49.42**	**6.54**
SEm±	0.09	0.48	0.11
CD (5%)	0.26	1.39	0.31

The seed yield per plant was significantly influenced by the number of days of pollen storage. Significantly higher seed yield per plant was noticed in the pollination by fresh pollens P_0 (33.19). Pollination by one day stored pollens P_1 (28.28) was on par with the two day stored pollens P_2 (27.24). However, lower seed yield per plant was observed in the treatment pollination with three day stored pollens P_3 (12.76) and it was on par with P_4 (11.96).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for seed yield per plant. The C_1P_0 (33.37) recorded maximum seed yield per plant and it was on par with C_3P_0 (33.11), C_2P_0 (33.08) and C_2P_1 (32.50), followed by C_2P_2 (30.26) which was on par with C_3P_1 (29.03). However, lower seed yield per plant was recorded in the C_3P_3 (12.49) which was on par with C_3P_4 (12.34) and C_1P_3 (12.24). The minimum seed yield per plant was observed in C_1P_4 (9.76).

4.2.2.8 Hybrid seed yield per hectare (kg)

The data on seed yield per hectare as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 10 and Fig. 13.

The storage conditions influenced significantly the seed yield per hectare. Significantly maximum seed yield per hectare was noticed in the treatment of pollen storage under refrigerated conditions C_2 (1505.50) followed by C_3 (1397.64). However, lower seed yield per hectare was noticed in the treatment of pollen storage under ambient conditions C_1 (1255.95).

The seed yield per hectare was significantly influenced by the number of days of pollen storage. Significantly higher seed yield per hectare was noticed in the pollination by fresh pollens P_0 (2028.23). Pollination by one day stored pollens P_1 (1728.35) was on par with the two day stored pollens P_2 (1664.59). However, lower seed yield per hectare was observed in the treatment pollination with three day stored pollens P_3 (779.57) and it was on par with P_4 (731.07).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for seed yield per hectare. The C_1P_0 (2039.45) recorded maximum seed yield per hectare and it was on par with C_3P_0 (2023.76), C_2P_0 (2021.48) and C_2P_1 (1986.05). The C_2P_2 (1849.63) was on par with C_3P_1 (1773.95), followed by C_3P_2 (1673.38). However, lower seed yield per hectare was recorded in the C_3P_3 (763.18) which was on par with C_3P_4 (753.91) and C_1P_3 (747.93). The minimum seed yield per hectare was observed in C_1P_4 (596.56).

4.2.2.9 Seed recovery percentage

The data on seed recovery percentage as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 10 and Fig. 14.

The storage conditions influenced significantly the seed recovery percentage. Significantly maximum seed recovery percentage was noticed in the treatment of pollen storage under refrigerated conditions C_2 (89.99) followed by pollen storage in the earthen pots covered with moist sand C_3 (88.82). However, lower seed recovery percentage was noticed in the treatment of pollen storage under ambient conditions C_1 (85.73).

The seed recovery percentage was significantly influenced by the number of days of pollen storage. Significantly higher seed recovery percentage was noticed in the pollination by fresh pollens P_0 (92.77), followed by P_1 (89.97) and P_2 (88.73) and. However, minimum seed recovery percentage was observed in the treatment of pollen storage for four days P_4 (84.03) and it was on par with P_3 (85.40).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for seed recovery percentage.

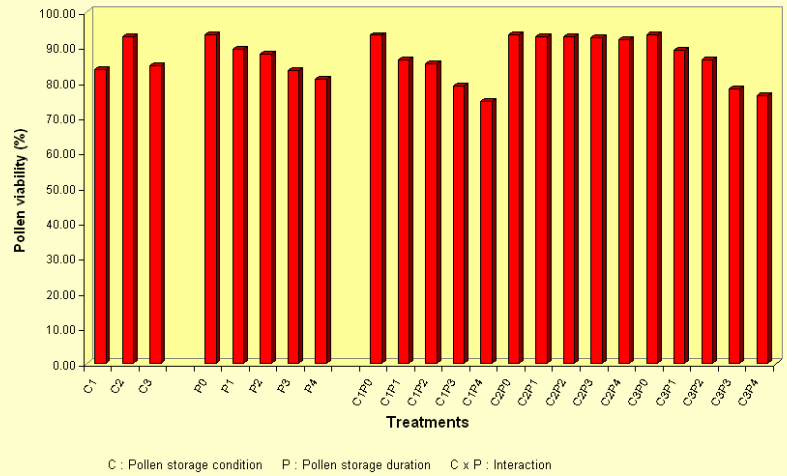


Fig.10. Effect of pollen storage on pollen viability percentage

Fig.10. Effect of pollen storage on pollen viability percentage

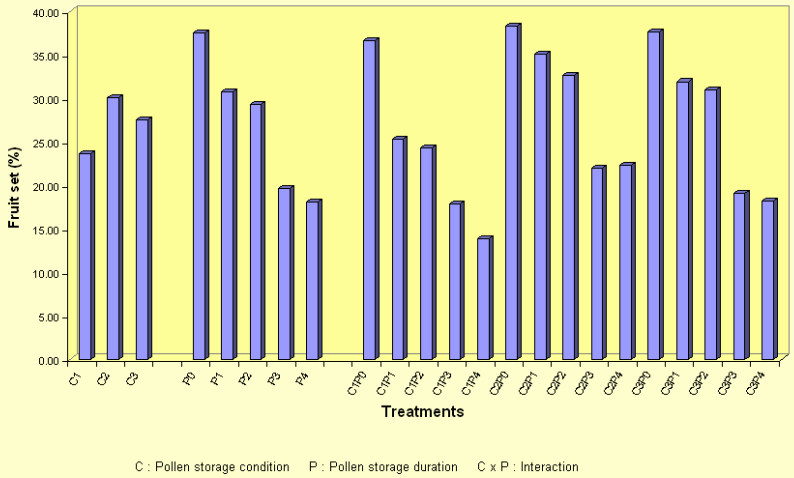


Fig.11. Effect of pollen storage on fruit set percentage

Fig.11. Effect of pollen storage on fruit set percentage

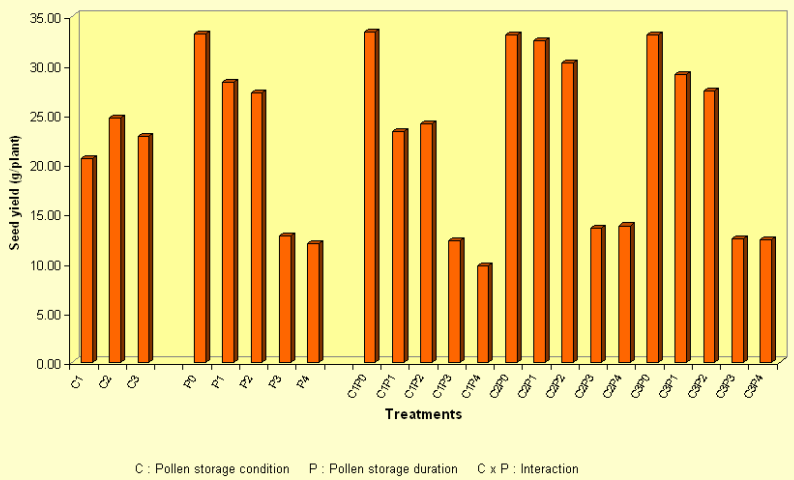


Fig.12. Effect of pollen storage on seed yield (g/plant)

Fig.12. Effect of pollen storage on seed yield (g/plant)

Table 10: Effect of pollen storage under different conditions for varying durations on seed yield per plant, seed yield per hectare and seed recovery percentage in bhendi hybrid seed production

Treatment	Seed yield / plant (g)	Seed yield (kg/ha)	Seed recovery (%)
Storage condition (C)			
C_1 : Ambient	20.55	1255.95	85.73 (68.06)*
C_2 : Refrigerated	24.63	1505.50	89.99 (71.84)
C_3 : Earthen pot	22.87	1397.64	88.82 (70.67)
SEm±	0.31	18.70	0.25
CD (5%)	0.89	54.16	0.73
Storage duration (P)			
P_0 : Fresh pollens	33.19	2028.23	92.77 (74.48)
P_1 : One day	28.28	1728.35	89.97 (71.81)
P_2 : Two days	27.24	1664.59	88.73 (70.52)
P_3 : Three days	12.76	779.57	85.40 (67.60)
P_4 : Four days	11.96	731.07	84.03 (66.53)
SEm±	0.48	29.56	0.40
CD (5%)	1.40	85.64	1.15
Interaction (C x P)			
C_1P_0	33.37	2039.45	92.48 (74.14)
C_1P_1	23.32	1425.06	85.79 (67.91)
C_1P_2	24.06	1470.76	85.53 (67.70)
C_1P_3	12.24	747.93	83.69 (66.22)
C_1P_4	9.76	596.56	81.15 (64.31)
C_2P_0	33.08	2021.48	93.29 (75.10)
C_2P_1	32.50	1986.05	93.27 (75.07)
C_2P_2	30.26	1849.63	90.61 (72.20)
C_2P_3	13.54	827.60	86.75 (68.69)
C_2P_4	13.79	842.74	86.04 (68.11)
C_3P_0	33.11	2023.76	92.53 (74.19)
C_3P_1	29.03	1773.95	90.86 (72.44)
C_3P_2	27.38	1673.38	90.06 (71.67)
C_3P_3	12.49	763.18	85.77 (67.89)
C_3P_4	12.34	753.91	84.90 (67.17)
MEAN	**22.68**	**1386.36**	**88.18 (70.19)**
SEm±	0.68	41.81	0.56
CD (5%)	1.98	121.11	1.63

*Figures in parenthesis indicate arcsine transformed values

The C_2P_0 (93.29) recorded maximum seed recovery percentage and it was on par with C_2P_1 (93.27), C_3P_0 (92.53) and C_1P_0 (92.48). This was followed by C_3P_1 (90.86) which was found to be on par with C_2P_2 (90.61) and C_3P_2 (90.06). However, lower seed recovery percentage was recorded in the C_2P_3 (86.75) which was on par with C_2P_4 (86.04), C_1P_1 (85.79), C_3P_3 (85.77), C_1P_2 (85.53) and C_3P_4 (84.90), followed by C_1P_3 (83.69). The minimum seed recovery percentage was observed in C_1P_4 (81.15).

4.2.3 Seed quality parameters

4.2.3.1 Seed germination percentage

The data on seed germination percentage as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 11 and Fig. 15 (Plate 5).

The storage conditions influenced significantly the seed germination percentage. Significantly maximum seed germination percentage was noticed in the treatment of pollen storage under refrigerated conditions C_2 (88.60) followed by pollen storage in the earthen pots covered with moist sand C_3 (84.87). However, lower seed germination percentage was noticed in the treatment of pollen storage under ambient conditions C_1 (82.07).

The seed germination percentage was significantly influenced by the number of days of pollen storage. Significantly higher seed germination percentage was noticed in the pollination by fresh pollens P_0 (92.67), followed by P_1 (87.78) which was on par with P_2 (86.00). However, minimum seed germination percentage was observed in the treatment P_4 (78.56) which was on par with P_3 (80.89).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for seed germination percentage. The C_2P_0 (93.33) recorded maximum seed germination percentage and it was on par with C_3P_0 (92.33) and C_1P_0 (92.33) followed by C_2P_1 (90.33) which was on par with C_3P_1 (88.67), C_2P_2 (87.33) and C_2P_3 (87.33). However, the minimum seed germination percentage was observed in C_1P_4 (73.67) and it was on par with C_3P_4 (77.33) and C_1P_3 (75.33).

4.2.3.2 Field emergence percentage

The data on field emergence percentage as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 11 and Fig. 16 (Plate 5).

The storage conditions influenced significantly the field emergence percentage. Significantly maximum field emergence percentage was noticed in the treatment of pollen storage under refrigerated conditions C_2 (79.67) followed by pollen storage in the earthen pots covered with moist sand C_3 (75.07). However, lower field emergence percentage was noticed in the treatment of pollen storage under ambient conditions C_1 (72.00).

The field emergence percentage was significantly influenced by the number of days of pollen storage. Significantly higher field emergence percentage was noticed in the pollination by fresh pollens P_0 (83.89), followed by P_1 (79.89) and P_2 (76.78). However, minimum field emergence percentage was observed in the treatment P_4 (67.56) and it was on par with P_3 (69.78).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for field emergence percentage. The C_2P_0 (85.33) recorded maximum field emergence percentage and it was on par with C_1P_0 (83.67) and C_3P_0 (82.67), followed by C_2P_1 (81.67) which was on par with C_3P_1 (80.67) and C_2P_2 (80.33). However, lower field emergence percentage was recorded in the C_3P_3 (69.00) which was on par with C_3P_4 (66.67). The minimum field emergence percentage was observed in C_1P_4 (61.67) and it was on par with C_1P_3 (63.67).

Table 11: Effect of pollen storage under different conditions for varying durations on germination percentage and field emergence percentage in bhendi hybrid seed production

Treatment	Germination (%)	Field emergence (%)
Storage condition (C)		
C_1 : Ambient	82.07 (65.43)*	72.00 (58.35)*
C_2 : Refrigerated	88.60 (70.52)	79.67 (63.34)
C_3 : Earthen pot	84.87 (67.55)	75.07 (60.28)
SEm±	0.34	0.32
CD (1%)	1.32	#0.94
Storage duration (P)		
P_0 : Fresh pollens	92.67 (74.40)	83.89 (66.40)
P_1 : One day	87.78 (69.73)	79.89 (63.45)
P_2 : Two days	86.00 (68.13)	76.78 (61.28)
P_3 : Three days	80.89 (64.31)	69.78 (56.78)
P_4 : Four days	78.56 (62.59)	67.56 (55.39)
SEm±	0.54	0.51
CD (1%)	2.09	#1.49
Interaction (C x P)		
C_1P_0	92.33 (74.02)	83.67 (66.21)
C_1P_1	84.33 (66.73)	77.33 (61.61)
C_1P_2	84.67 (67.00)	73.67 (59.17)
C_1P_3	75.33 (60.26)	63.67 (52.96)
C_1P_4	73.67 (59.17)	61.67 (51.78)
C_2P_0	93.33 (75.14)	85.33 (67.53)
C_2P_1	90.33 (71.98)	81.67 (64.69)
C_2P_2	87.33 (69.26)	80.33 (63.72)
C_2P_3	87.33 (69.21)	76.67 (61.17)
C_2P_4	84.67 (67.00)	74.33 (59.60)
C_3P_0	92.33 (74.05)	82.67 (65.44)
C_3P_1	88.67 (70.48)	80.67 (64.05)
C_3P_2	86.00 (68.12)	76.33 (60.94)
C_3P_3	80.00 (63.47)	69.00 (56.20)
C_3P_4	77.33 (61.61)	66.67 (54.78)
MEAN	**85.18 (67.83)**	**75.58 (60.66)**
SEm±	0.76	0.73
CD (1%)	2.96	#2.10

*Figures in parenthesis indicate arcsine transformed values
#CD (5%)

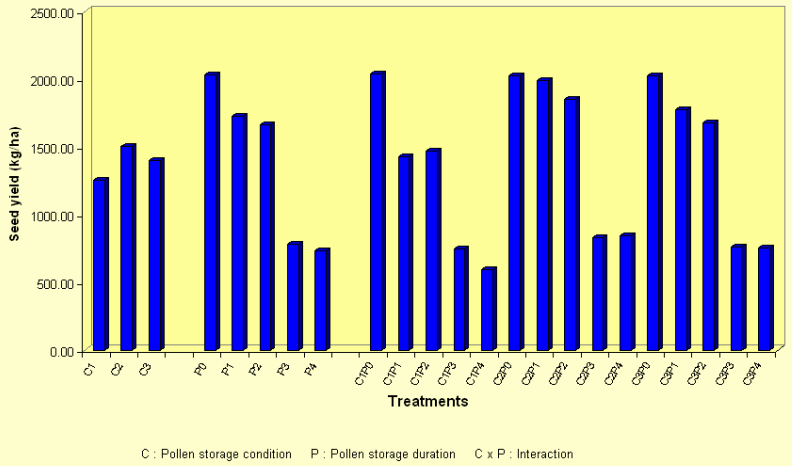


Fig.13. Effect of pollen storage on seed yield (kg/ha)

Fig.13. Effect of pollen storage on seed yield (kg/ha)

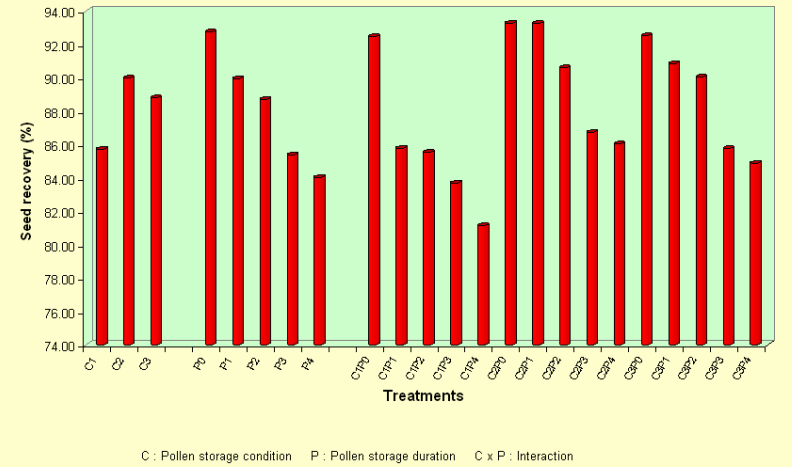


Fig.14. Effect of pollen storage on seed recovery percentage

Fig.14. Effect of pollen storage on seed recovery percentage

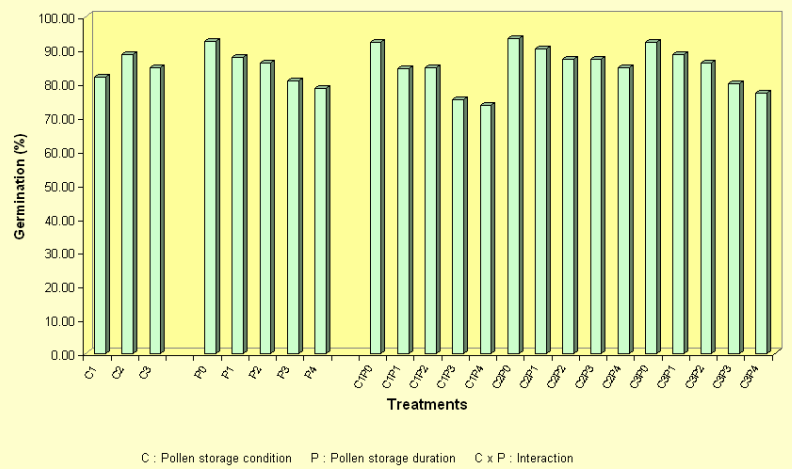


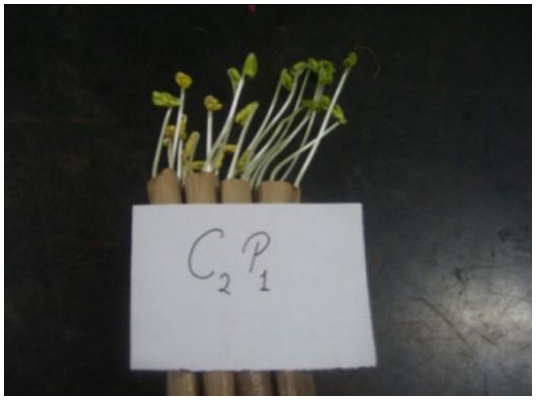
Fig.15. Effect of pollen storage on germination percentage

Fig.15. Effect of pollen storage on germination percentage

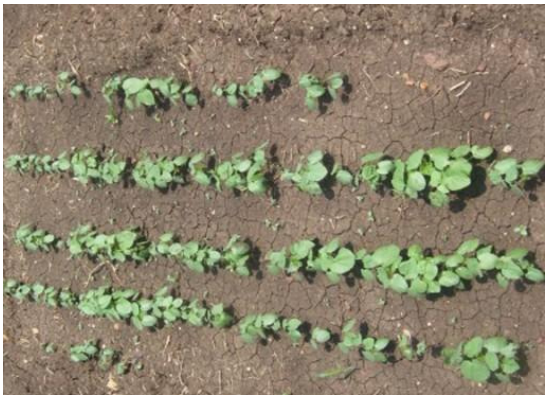
One day storage

Two day storage

Fruit setting in refrigerated pollen storage condition



Germination for one day refrigerated storage



Field emergence for refrigerated pollen storage

Field emergence for ambient storage

Field emergence for earthen pot storage

Fruit setting for >50% open bud in size

Plate 5. Effect of pollen storage and flower bud size on fruit and seed characters

4.2.3.3 Shoot length (cm)

The data on shoot length as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 12 and Fig. 17.

The storage conditions influenced significantly the shoot length. Significantly maximum shoot length was noticed in the treatment of pollen storage under refrigerated conditions C_2 (20.07) followed by pollen storage in the earthen pots covered with moist sand C_3 (19.37). However, lower shoot length was noticed in the treatment of pollen storage under ambient conditions C_1 (17.31).

The shoot length was significantly influenced by the number of days of pollen storage. Significantly higher shoot length was noticed in the pollination by fresh pollens P_0 (23.02), followed by P_1 (19.20) which was on par with P_2 (18.79). However, minimum shoot length was observed in the treatment P_4 (16.58) which was on par with P_3 (16.99).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for shoot length. The C_2P_0 (23.33) recorded maximum shoot length and it was on par with C_3P_0 (23.27) and C_1P_0 (22.47), followed by C_2P_1 (21.30) which was on par with C_2P_2 (20.60). However, lower shoot length was recorded in the C_3P_3 (17.67) which was on par with C_3P_4 (17.57), C_1P_1 (17.03) and C_1P_2 (16.67). The minimum shoot length was observed in C_1P_4 (14.97) and it was on par with C_1P_3 (15.40).

4.2.3.4 Root length (cm)

The data on root length as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 12 and Fig. 17.

The storage conditions influenced significantly the root length. Significantly maximum root length was noticed in the treatment of pollen storage under refrigerated conditions C_2 (9.58) followed by pollen storage in the earthen pots covered with moist sand C_3 (8.77). However, lower root length was noticed in the treatment of pollen storage under ambient conditions C_1 (8.13).

The root length was significantly influenced by the number of days of pollen storage. Significantly higher root length was noticed in the pollination by fresh pollens P_0 (11.18), followed by P_1 (10.11) which was on par with P_2 (9.61). However, minimum root length was observed in the treatment P_4 (6.37) which was on par with P_3 (6.86).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for root length. The C_2P_0 (11.30) recorded maximum root length and it was on par with C_1P_0 (11.17), C_3P_0 (11.07) and C_2P_1 (10.90), followed by C_2P_2 (10.40) which was on par with C_3P_1 (9.77) and C_1P_1 (9.67). However, lower root length was recorded in the C_3P_3 (6.97) which was on par with C_3P_4 (6.40. The minimum root length was observed in C_1P_4 (5.43) and it was on par with C_1P_3 (5.57).

4.2.3.5 Seedling vigour index

The data on seedling vigour index as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 12 and Fig. 18.

The storage conditions influenced significantly the seedling vigour index. Significantly maximum seedling vigour index was noticed in the treatment of pollen storage under refrigerated conditions C_2 (2636) followed by pollen storage in the earthen pots covered with moist sand C_3 (2407). However, lower seedling vigour index was noticed in the treatment of pollen storage under ambient conditions C_1 (2119).

The seedling vigour index was significantly influenced by the number of days of pollen storage. Significantly higher seedling vigour index was noticed in the pollination by fresh pollens P_0 (3169), followed by P_1 (2577), P_2 (2443) and P_3 (1939). However, minimum seedling vigour index was observed in the treatment P_4 (1809).

Table 12: Effect of pollen storage under different conditions for varying durations on shoot length, root length and seedling vigour index in bhendi hybrid seed production

Treatment	Shoot length (cm)	Root length (cm)	Seedling vigour index
Storage condition (C)			
C_1 : Ambient	17.31	8.13	2119
C_2 : Refrigerated	20.07	9.58	2636
C_3 : Earthen pot	19.37	8.77	2407
SEm±	0.13	0.08	19.00
CD (1%)	0.50	0.33	75.00
Storage duration (P)			
P_0 : Fresh pollens	23.02	11.18	3169
P_1 : One day	19.20	10.11	2577
P_2 : Two days	18.79	9.61	2443
P_3 : Three days	16.99	6.86	1939
P_4 : Four days	16.58	6.37	1809
SEm±	0.20	0.13	30.00
CD (1%)	0.80	0.52	118.00
Interaction (C x P)			
C_1P_0	22.47	11.17	3105
C_1P_1	17.03	9.67	2250
C_1P_2	16.67	8.80	2153
C_1P_3	15.40	5.57	1580
C_1P_4	14.97	5.43	1506
C_2P_0	23.33	11.30	3231
C_2P_1	21.30	10.90	2907
C_2P_2	20.60	10.40	2705
C_2P_3	17.90	8.03	2267
C_2P_4	17.20	7.27	2070
C_3P_0	23.27	11.07	3170
C_3P_1	19.27	9.77	2573
C_3P_2	19.10	9.63	2471
C_3P_3	17.67	6.97	1969
C_3P_4	17.57	6.40	1852
MEAN	**18.92**	**8.82**	**2387**
SEm±	0.29	0.19	43.00
CD (1%)	1.13	0.74	167.00

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for seedling vigour index. The C_2P_0 (3231) recorded maximum seedling vigour index and it was on par with C_3P_0 (3170), and C_1P_0 (3105), followed by C_2P_1 (2907), C_2P_2 (2705) and C_3P_1 (2573), later two were on par with each other. However, lower seedling vigour index was recorded in the C_3P_3 (1969) which was on par with C_3P_4 (1852). The minimum seedling vigour index was observed in C_1P_4 (1506) and it was on par with C_1P_3 (1580).

4.2.3.6 Seedling dry weight (mg)

The data on seedling dry weight as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 13.

The storage conditions influenced significantly the seedling dry weight. Significantly maximum seedling dry weight was noticed in the treatment of pollen storage under refrigerated conditions C_2 (60.98) followed by pollen storage in the earthen pots covered with moist sand C_3 (58.62). However, lower seedling dry weight was noticed in the treatment of pollen storage under ambient conditions C_1 (52.74).

The seedling dry weight was significantly influenced by the number of days of pollen storage. Significantly higher seedling dry weight was noticed in the pollination by fresh pollens P_0 (63.57), followed by P_1 (58.43) which was on par with P_2 (57.23). However, minimum seedling dry weight was observed in the treatment P_4 (53.66) which was on par with P_3 (54.33).

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for seedling dry weight. The C_2P_0 (64.37) recorded maximum seedling dry weight and it was on par with C_3P_0 (63.81), C_2P_1 (62.70) and C_1P_0 (62.53), followed by C_2P_2 (61.07) which was on par with C_2P_3 (59.22), C_3P_2 (58.60) and C_3P_1 (58.55). However, lower seedling dry weight was recorded in the C_1P_1 (54.04) which was on par with C_1P_2 (52.02). The minimum seedling dry weight was observed in C_1P_4 (47.43) and it was on par with C_1P_3 (47.68).

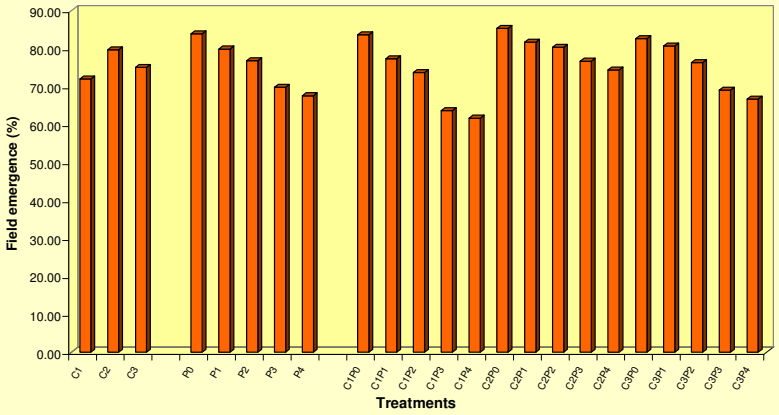
4.2.3.7 Electrical conductivity of seed leachate (dS/m)

The data on electrical conductivity of seed leachate as influenced by storage condition, duration of pollen storage and their interactions are presented in Table 13.

The storage conditions influenced significantly the electrical conductivity of seed leachate. Significantly minimum electrical conductivity of seed leachate was noticed in the treatment of pollen storage under refrigerated conditions C_2 (0.677) which was on par with pollen storage in the earthen pots covered with moist sand C_3 (0.699). However, higher electrical conductivity of seed leachate was noticed in the treatment of pollen storage under ambient conditions C_1 (0.718).

The electrical conductivity of seed leachate was significantly influenced by the number of days of pollen storage. Significantly lower electrical conductivity of seed leachate was noticed in the pollination by fresh pollens P_0 (0.639), followed by P_1 (0.665) which was on par with P_2 (0.679). However, maximum electrical conductivity of seed leachate was observed in the treatment P_4 (0.757) which was on par with P_3 (0.750).

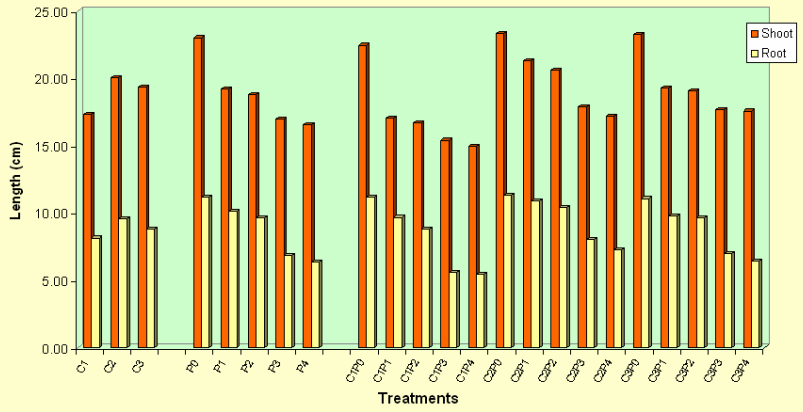
The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for electrical conductivity of seed leachate. The C_2P_0 (0.637) recorded minimum electrical conductivity of seed leachate and it was on par with C_3P_0 (0.640), C_1P_0 (0.640), C_2P_1 (0.655), C_2P_2 (0.656) and C_3P_1 (0.663) followed by C_3P_2 (0.669) which was on par with C_1P_1 (0.671). However, higher electrical conductivity of seed leachate was recorded in the C_2P_3 (0.716) which was on par with C_1P_2 (0.719) and C_2P_4 (0.720). The maximum electrical conductivity of seed leachate was observed in C_1P_4 (0.783) and it was on par with C_1P_3 (0.778), C_3P_4 (0.766) and C_3P_3 (0.755).



C : Pollen storage condition P : Pollen storage duration C x P : Interaction

Fig.16. Effect of pollen storage on field emergence percentage

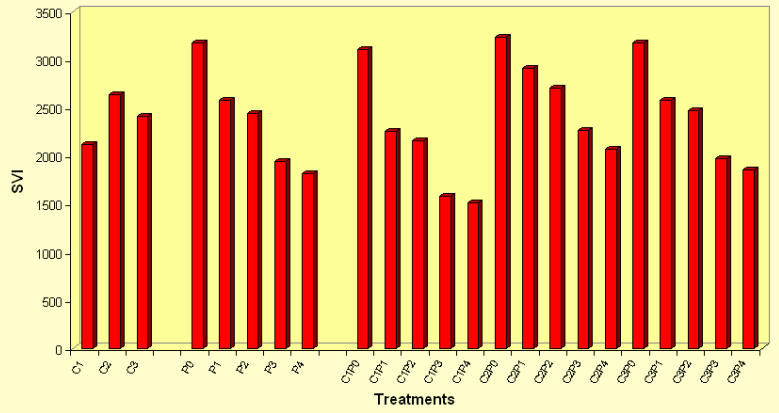
Fig.16. Effect of pollen storage on field emergence percentage



C : Pollen storage condition P : Pollen storage duration C x P : Interaction

Fig.17. Effect of pollen storage on shoot and root length (cm)

Fig.17. Effect of pollen storage on shoot and root length (cm)



C : Pollen storage condition P : Pollen storage duration C x P : Interaction

Fig.18. Effect of pollen storage on seedling vigour index (SVI)

Fig.18. Effect of pollen storage on seedling vigour index (SVI)

Table 13: Effect of pollen storage under different conditions for varying durations on seedling dry weight and electrical conductivity of seed leachate in bhendi hybrid seed production

Treatment	Ten Seedling dry weight (mg)	Electrical conductivity of seed leachate (dSm^{-1})
Storage condition (C)		
C_1 : Ambient	52.74	0.718
C_2 : Refrigerated	60.98	0.677
C_3 : Earthen pot	58.62	0.699
SEm±	0.37	0.003
CD (1%)	1.43	0.013
Storage duration (P)		
P_0 : Fresh pollens	63.57	0.639
P_1 : One day	58.43	0.665
P_2 : Two days	57.23	0.679
P_3 : Three days	54.33	0.750
P_4 : Four days	53.66	0.757
SEm±	0.58	0.005
CD (1%)	2.26	0.020
Interaction (C x P)		
C_1P_0	62.53	0.640
C_1P_1	54.04	0.671
C_1P_2	52.02	0.719
C_1P_3	47.68	0.778
C_1P_4	47.43	0.783
C_2P_0	64.37	0.637
C_2P_1	62.70	0.655
C_2P_2	61.07	0.656
C_2P_3	59.22	0.716
C_2P_4	57.53	0.720
C_3P_0	63.81	0.640
C_3P_1	58.60	0.663
C_3P_2	58.55	0.669
C_3P_3	56.10	0.755
C_3P_4	56.03	0.766
MEAN	**57.44**	**0.698**
SEm±	0.82	0.007
CD (1%)	3.20	0.028

4.3 Experiment-III: Effect of flower bud size and number of pollinations on bhendi hybrid seed production

4.3.1 Growth parameters

4.3.1.1 Plant height (cm)

The data on plant height are presented in Appendix IX.

The results showed non significant difference for plant height. However, numerically higher plant height was recorded in B_1 at 90 days after sowing (90.92) and at harvest (93.99) and in N_2 recorded at 90 days after sowing (90.46) and at harvest (93.51). The mean plant height at 90 days after sowing and at harvest was 89.93 and 92.94 cm respectively.

4.3.1.2 Number of internodes per plant

The data on number of internodes per plant are presented in Appendix IX.

The results showed non significant difference for number of internodes per plant. However, numerically higher number of internodes per plant was recorded in B_2 at 90 days after sowing (16.10) and at harvest (18.02) and N_2 recorded maximum number of internodes per plant at 90 days after sowing (16.10) and at harvest (18.10). The mean number of internodes per plant at 90 days after sowing and at harvest was 15.87 and 17.80 cm respectively.

4.3.1.3 Days to initiation of flowering

The data on number of days for flowering initiation in both male and female parents are presented in Appendix X.

The results showed non significant difference for number of days for flowering initiation in both parents. However, male parent recorded early flowering initiation as compared to female parent. The mean for flowering initiation as recorded in male was 43.58 while in female it was 43.75 days after sowing.

4.3.1.4 Days to 50 percent flowering

The data on number of days for 50 percent flowering in both male and female parents are presented in Appendix X.

The results showed non significant difference for number of days for 50 percent flowering in both parents. However, male parent required less number of days for 50 percent flowering as compared to female parent. The mean for 50 percent flowering in male was 46.58 while in female it was 47.08 days after sowing.

4.3.1.5 Number of flowers crossed per plant

The data on number of flowers crossed per plant as influenced by flower bud size, number of pollinations and their interactions are presented in Table 14.

The results showed non significant difference for number of flowers crossed per plant as influenced by flower bud size, number of pollinations and their interactions. However, numerically more number of crossed flowers per plant was recorded in B_2 (10.82), as compared to B_1 (10.78). While, among the number of pollination treatments, higher number of flowers crossed per plant was recorded in N_1 (10.85) followed by N_2 (10.80), and N_3 (10.75).

In the interaction treatments maximum number of flowers crossed per plant was recorded in B_1N_1 (10.95). However, lower number of flowers crossed per plant was recorded in B_1N_3 (10.65).

Irrespective of flower bud size and number of pollinations the mean number of flowers crossed per plant was 10.80.

4.3.1.6 Number of crossed fruits retained per plant

The data on number of crossed fruits retained per plant as influenced by flower bud size, number of pollinations and their interactions are presented in Table 14 (Plate 5).

The flower bud size influenced significantly the number of crossed fruits retained per plant. Significantly maximum number of crossed fruits retained per plant was noticed in the treatment of flower bud more than 50 percent open in size B_2 (3.78). However, lower number of crossed fruits retained per plant was noticed in the treatment of flower bud less than 50 percent open in size B_1 (1.95).

The number of crossed fruits retained per plant was significantly influenced by the number of pollinations. Significantly higher number of crossed fruits was retained in the single pollination treatment N_1 (3.25). Lower number of crossed fruits retained per plant was noticed in pollination for two times N_2 (2.75) and it was on par with pollination for three times N_3 (2.60).

The interactions between flower bud size and number of pollinations (B x N) was found to be significant for crossed fruits retained per plant. The single pollination on bigger size buds B_2N_1 recorded higher number of crossed fruits retained per plant (4.05), followed by B_2N_3 (3.70) which was on par with B_2N_2 (3.60). However, lower number of crossed fruits retained per plant was observed in B_1N_1 (2.45) and B_1N_2 (1.90). The treatment B_1N_3 (1.50) recorded minimum number of crossed fruits retained per plant.

4.3.1.7 Fruit set percentage

The data on fruit set percentage as influenced by flower bud size, number of pollinations and their interactions are presented in Table 14 and Fig. 19.

The flower bud size influenced significantly the fruit set percentage. Significantly maximum fruit set percentage was noticed in the treatment of flower bud more than 50 percent open in size B_2 (35.06). However, lower fruit set percentage was noticed in the treatment of flower bud less than 50 percent open in size B_1 (18.09).

The fruit set percentage was significantly influenced by the number of pollinations. Significantly higher fruit set percentage was recorded in the single pollination treatment N_1 (30.11). Lower fruit set percentage was noticed in pollination for two times N_2 (25.48) and it was on par with pollination for three times N_3 (24.14).

The interactions between flower bud size and number of pollinations (B x N) was found to be significant for fruit set percentage. The single pollination on bigger size buds B_2N_1 recorded higher fruit set percentage (37.82), followed by B_2N_3 (34.14) which was on par with B_2N_2 (33.23). However, lower fruit set percentage was observed in B_1N_1 (22.41) and B_1N_2 (17.73). The treatment B_1N_3 (14.14) recorded minimum fruit set percentage.

4.3.2 Yield and its components

4.3.2.1 Fruit length (cm)

The data on fruit length as influenced by flower bud size, number of pollinations and their interactions are presented in Table 15.

The flower bud size influenced significantly the fruit length. Significantly higher fruit length was noticed in the treatment of flower bud more than 50 percent open in size

Table 14: Effect of flower bud size and number of pollinations on number of flowers crossed, number of crossed fruits retained and fruit set percentage in seed parent in bhendi hybrid seed production

Treatment	Number of flowers crossed / plant	Number of crossed fruits retained /plant	Fruit set (%)
Flower bud size (B)			
B_1: Less than 50 % open	10.78	1.95	18.09 (25.08)*
B_2: More than 50 % open	10.82	3.78	35.06 (36.31)
SEm±	0.06	0.04	0.34
CD (5%)	NS	0.13	1.03
Number of pollinations (N)			
N_1: One time	10.85	3.25	30.11 (33.10)
N_2: Two times	10.80	2.75	25.48 (30.06)
N_3: Three times	10.75	2.60	24.14 (28.92)
SEm±	0.08	0.05	0.42
CD (5%)	NS	0.16	1.27
Interaction (B x N)			
B_1N_1	10.95	2.45	22.41 (28.24)
B_1N_2	10.75	1.90	17.73 (24.90)
B_1N_3	10.65	1.50	14.14 (22.08)
B_2N_1	10.75	4.05	37.82 (37.96)
B_2N_2	10.85	3.60	33.23 (35.22)
B_2N_3	10.85	3.70	34.14 (35.77)
MEAN	**10.80**	**2.87**	**26.58 (30.70)**
SEm±	0.11	0.08	0.59
CD (5%)	NS	0.23	1.79

NS: Non significant

*Figures in parenthesis indicate arcsine transformed values

N_1: One time pollination (8:00 a.m.-10:00 a.m.)

N_2: Two time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m.)

N_3: Three time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m. + next day 8:00 a.m.-10:00 a.m.)

B_2 (26.21), as compared to the treatment flower bud less than 50 percent open in size B_1 (22.34).

The fruit length was significantly influenced by the number of pollinations. Significantly higher fruit length was recorded in the single pollination treatment N_1 (24.81). Lower fruit length was noticed in pollination for two times N_2 (24.17) and it was on par with pollination for three times N_3 (23.86).

The interactions between flower bud size and number of pollinations (B x N) was found to be non significant for fruit length. However, the single pollination on bigger size buds B_2N_1 recorded higher fruit length (26.45), followed by B_2N_3 (26.13), B_2N_2 (26.05), B_1N_1 (23.16) and B_1N_2 (22.26). The treatment B_1N_3 (21.58) recorded minimum fruit length. Irrespective of flower bud size and number of pollinations the mean fruit length was recorded to be 24.28 cm.

4.3.2.2 Fruit girth (cm)

The data on fruit girth as influenced by flower bud size, number of pollinations and their interactions are presented in Table 15.

The flower bud size influenced significantly the fruit girth. Significantly higher fruit girth was noticed in the treatment of flower bud more than 50 percent open in size B_2 (6.21), as compared to the treatment flower bud less than 50 percent open in size B_1 (5.40).

The fruit girth was significantly influenced by the number of pollinations. Significantly higher fruit girth was recorded in the single pollination treatment N_1 (5.99). Lower fruit girth was noticed in pollination for two times N_2 (5.73) and it was on par with pollination for three times N_3 (5.68).

The interactions between flower bud size and number of pollinations (B x N) was found to be non significant for fruit girth. However, the single pollination on bigger size buds B_2N_1 recorded higher fruit girth (6.38), followed by B_2N_3 (6.13), B_2N_2 (6.11), B_1N_1 (5.61) and B_1N_2 (5.36). The treatment B_1N_3 (5.23) recorded minimum fruit girth. Irrespective of flower bud size and number of pollinations the mean fruit girth was recorded to be 5.80 cm.

4.3.2.3 Fruit weight per plant (g)

The data on fruit weight per plant as influenced by flower bud size, number of pollinations and their interactions are presented in Table 15.

The flower bud size influenced significantly the fruit weight per plant. Significantly maximum fruit weight per plant was noticed in the treatment of flower bud more than 50 percent open in size B_2 (37.72). However, lower fruit weight per plant was noticed in the treatment of flower bud less than 50 percent open in size B_1 (22.58).

The fruit weight per plant was significantly influenced by the number of pollinations. Significantly higher fruit weight per plant was recorded in the single pollination treatment N_1 (34.32). Lower fruit weight per plant was noticed in pollination for two times N_2 (28.87), while, the minimum fruit weight per plant was recorded in pollination for three times N_3 (27.27).

The interactions between flower bud size and number of pollinations (B x N) was found to be significant for fruit weight per plant. The B_2N_1 recorded higher fruit weight per plant (38.21) which was on par with B_2N_3 (37.65) and B_2N_2 (37.30). However, lower fruit weight per plant was observed in B_1N_1 (30.43) and B_1N_2 (20.44). The treatment B_1N_3 (16.89) recorded minimum fruit weight per plant.

4.3.2.4 Seed weight per fruit (g)

The data on seed weight per fruit as influenced by flower bud size, number of pollinations and their interactions are presented in Table 15.

The flower bud size influenced significantly the seed weight per fruit. Significantly more seed weight per fruit was noticed in the treatment of flower bud more than

Table 15: Effect of flower bud size and number of pollinations on fruit length, fruit girth, fruit weight per plant, seed weight per fruit and number of seeds per fruit in bhendi hybrid seed production

Treatment	Fruit length (cm)	Fruit girth (cm)	Fruit weight / plant (g)	Seed weight / fruit (g)	Number of seeds / fruit
Flower bud size (B)					
B_1: Less than 50 % open	22.34	5.40	22.58	2.79	41.37
B_2: More than 50 % open	26.21	6.21	37.72	3.89	58.74
SEm±	0.17	0.06	0.37	0.05	0.28
CD (5%)	0.52	0.18	1.11	0.14	0.86
Number of pollinations (N)					
N_1: One time	24.81	5.99	34.32	3.66	56.80
N_2: Two times	24.17	5.73	28.87	3.26	46.72
N_3: Three times	23.86	5.68	27.27	3.11	46.63
SEm±	0.21	0.07	0.45	0.06	0.35
CD (5%)	0.63	0.22	1.36	0.18	1.05
Interaction (B x N)					
B_1N_1	23.16	5.61	30.43	3.15	54.10
B_1N_2	22.29	5.36	20.44	2.81	35.18
B_1N_3	21.58	5.23	16.89	2.41	34.82
B_2N_1	26.45	6.38	38.21	4.16	59.51
B_2N_2	26.05	6.11	37.30	3.72	58.27
B_2N_3	26.13	6.13	37.65	3.80	58.44
MEAN	**24.28**	**5.80**	**30.15**	**3.34**	**50.05**
SEm±	0.30	0.10	0.64	0.08	0.49
CD (5%)	NS	NS	1.93	0.25	1.48

NS: Non significant

N_1: One time pollination (8:00 a.m.-10:00 a.m.)

N_2: Two time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m.)

N_3: Three time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m. + next day 8:00 a.m.-10:00 a.m.)

50 percent open in size B_2 (3.89). However, less seed weight per fruit was noticed in the treatment of flower bud less than 50 percent open in size B_1 (2.79).

The seed weight per fruit was significantly influenced by the number of pollinations. Significantly higher seed weight per fruit was recorded in the single pollination treatment N_1 (3.66). Lower seed weight per fruit was noticed in pollination for two times N_2 (3.26), which was on par with pollination for three times N_3 (3.11).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for seed weight per fruit. The B_2N_1 recorded higher seed weight per fruit (4.16), followed by B_2N_3 (3.80) which was on par with B_2N_2 (3.72). However, lower seed weight per fruit was observed in B_1N_1 (3.15) and B_1N_2 (2.81). The treatment B_1N_3 (2.41) recorded minimum seed weight per fruit.

4.3.2.5 Number of seeds per fruit

The data on number of seeds per fruit as influenced by flower bud size, number of pollinations and their interactions are presented in Table 15.

The flower bud size influenced significantly the seed weight per fruit. Significantly more number of seeds per fruit was noticed in the treatment of flower bud more than 50 percent open in size B_2 (58.74). However, less number of seeds per fruit was noticed in the treatment of flower bud less than 50 percent open in size B_1 (41.37).

The number of seeds per fruit was significantly influenced by the number of pollinations. Significantly higher number of seeds per fruit was recorded in the single pollination treatment N_1 (56.80). Lower number of seeds per fruit was noticed in pollination for two times N_2 (46.72), which was on par with pollination for three times N_3 (46.63).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for number of seeds per fruit. The B_2N_1 recorded higher number of seeds per fruit (59.51) which was on par with B_2N_3 (58.44) and B_2N_2 (58.27). However, lower number of seeds per fruit was observed in B_1N_1 (54.10). The treatment B_1N_3 (34.82) recorded minimum number of seeds per fruit and it was on par with B_1N_2 (35.18).

4.3.2.6 Hundred seed weight (g)

The data on hundred seed weight as influenced by flower bud size, number of pollinations and their interactions are presented in Table 16.

The flower bud size influenced significantly the hundred seed weight. Significantly higher hundred seed weight was noticed in the treatment of flower bud more than 50 percent open in size B_2 (7.05). However, lower hundred seed weight was noticed in the treatment of flower bud less than 50 percent open in size B_1 (5.70).

The hundred seed weight was significantly influenced by the number of pollinations. Significantly higher hundred seed weight was recorded in the single pollination treatment N_1 (6.71). Lower hundred seed weight was noticed in pollination for two times N_2 (6.24), which was on par with pollination for three times N_3 (6.18).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for hundred seed weight. The B_2N_1 recorded higher hundred seed weight (7.40), followed by B_2N_3 (6.99) and B_2N_2 (6.77). However, lower hundred seed weight was observed in B_1N_1 (6.02) and B_1N_2 (5.70). The treatment B_1N_3 (5.36) recorded minimum hundred seed weight.

4.3.2.7 Hybrid seed yield per plant (g)

The data on seed yield per plant as influenced by flower bud size, number of pollinations and their interactions are presented in Table 16 and Fig. 20.

The flower bud size influenced significantly the seed yield per plant. Significantly higher seed yield per plant was noticed in the treatment of flower bud more than 50 percent open in size B_2 (31.52). However, lower seed yield per plant was noticed in the treatment of flower bud less than 50 percent open in size B_1 (14.49).

The seed yield per plant was significantly influenced by the number of pollinations. Significantly higher seed yield per plant was recorded in the single pollination treatment N_1 (27.30). Lower seed yield per plant was noticed in pollination for two times N_2 (21.36), which was on par with pollination for three times N_3 (20.35).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for seed yield per plant. The B_2N_1 recorded higher seed yield per plant (32.59) which was on par with B_2N_2 (31.00) and B_2N_3 (30.97). However, lower seed yield per plant was observed in B_1N_1 (22.01) and B_1N_2 (11.72). The treatment B_1N_3 (9.73) recorded minimum seed yield per plant.

4.3.2.8 Hybrid seed yield per hectare (kg)

The data on seed yield per hectare as influenced by flower bud size, number of pollinations and their interactions are presented in Table 16 and Fig. 21.

The flower bud size influenced significantly the seed yield per hectare. Significantly higher seed yield per hectare was noticed in the treatment of flower bud more than 50 percent open in size B_2 (1926.43). However, lower seed yield per hectare was noticed in the treatment of flower bud less than 50 percent open in size B_1 (885.37).

The seed yield per hectare was significantly influenced by the number of pollinations. Significantly higher seed yield per hectare was recorded in the single pollination treatment N_1 (1668.55). Lower seed yield per hectare was noticed in pollination for two times N_2 (1305.41), which was on par with pollination for three times N_3 (1243.74).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for seed yield per hectare. The B_2N_1 recorded higher seed yield per hectare (1991.76) which was on par with B_2N_2 (1894.65) and B_2N_3 (1892.87). However, lower seed yield per hectare was observed in B_1N_1 (1345.35) and B_1N_2 (716.17). The treatment B_1N_3 (594.60) recorded minimum seed yield per hectare.

4.3.2.9 Seed recovery percentage

The data on seed recovery percentage as influenced by flower bud size, number of pollinations and their interactions are presented in Table 16 and Fig. 22.

The flower bud size influenced significantly the seed recovery percentage. Significantly higher seed recovery percentage was noticed in the treatment of flower bud more than 50 percent open in size B_2 (92.85). However, lower seed recovery percentage was noticed in the treatment of flower bud less than 50 percent open in size B_1 (83.35).

The seed recovery percentage was significantly influenced by the number of pollinations. Significantly higher seed recovery percentage was recorded in the single pollination treatment N_1 (89.38). However, lower seed recovery percentage was noticed in the treatment pollination for three times N_3 (86.83) and it was on par with N_2 (88.10).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for seed recovery percentage. The B_2N_1 recorded higher seed recovery percentage (93.43) which was on par with B_2N_3 (92.78) and B_2N_2 (92.35). However, lower seed recovery percentage was observed in B_1N_1 (85.33) and it was on par with B_1N_2 (83.86). The treatment B_1N_3 (80.88) recorded minimum seed recovery percentage.

Table 16: Effect of flower bud size and number of pollinations on 100 seed weight, seed yield per plant, seed yield per hectare and seed recovery percentage in bhendi hybrid seed production

Treatment	100 seed weight (g)	Seed yield/ plant (g)	Seed yield (kg/ha)	Seed recovery (%)
Flower bud size (B)				
B_1: Less than 50 % open	5.70	14.49	885.37	83.35 (66.00)*
B_2: More than 50 % open	7.05	31.52	1926.43	92.85 (74.57)
SEm±	0.04	0.38	22.93	0.32
CD (5%)	0.12	1.13	69.11	0.97
Number of pollinations (N)				
N_1: One time	6.71	27.30	1668.55	89.38 (71.39)
N_2: Two times	6.24	21.36	1305.41	88.10 (70.17)
N_3: Three times	6.18	20.35	1243.74	86.83 (69.29)
SEm±	0.05	0.46	28.08	0.39
CD (5%)	0.14	1.38	84.65	1.19
Interaction (B x N)				
B_1N_1	6.02	22.01	1345.35	85.33 (67.53)
B_1N_2	5.70	11.72	716.17	83.86 (66.35)
B_1N_3	5.36	9.73	594.60	80.88 (64.11)
B_2N_1	7.40	32.59	1991.76	93.43 (75.25)
B_2N_2	6.77	31.00	1894.65	92.35 (74.00)
B_2N_3	6.99	30.97	1892.87	92.78 (74.47)
MEAN	**6.37**	**23.00**	**1405.90**	**88.10 (70.28)**
SEm±	0.07	0.65	39.71	0.56
CD (5%)	0.20	1.96	119.71	1.68

*Figures in parenthesis indicate arcsine transformed values

N_1: One time pollination (8:00 a.m.-10:00 a.m.)

N_2: Two time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m.)

N_3: Three time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m. + next day 8:00 a.m.-10:00 a.m.)

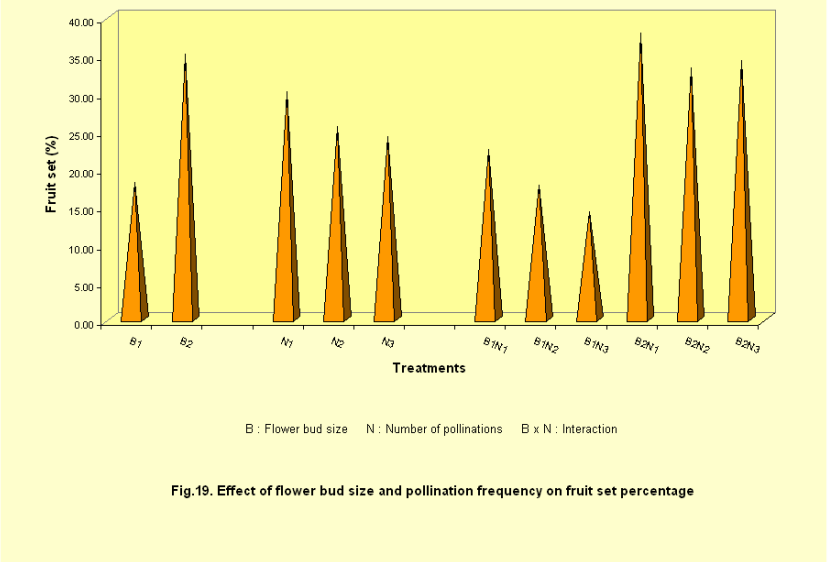


Fig.19. Effect of flower bud size and pollination frequency on fruit set percentage

Fig.19. Effect of flower bud size and pollination frequency on fruit set percentage

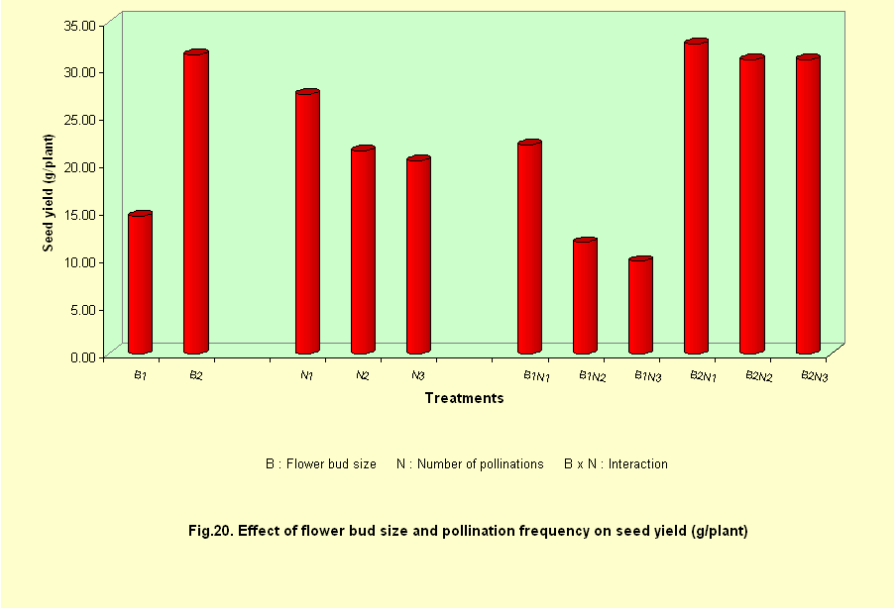


Fig.20. Effect of flower bud size and pollination frequency on seed yield (g/plant)

Fig.20. Effect of flower bud size and pollination frequency on seed yield (g/plant)

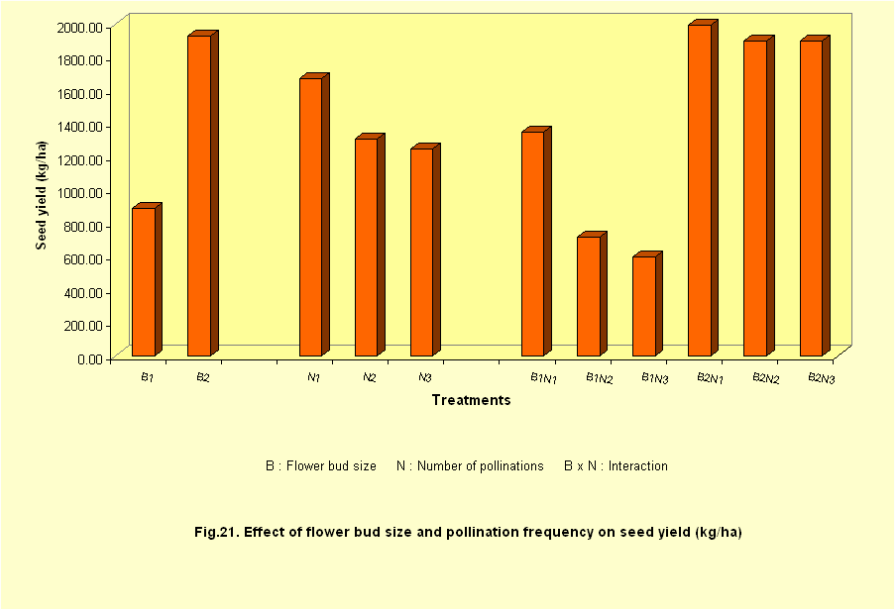


Fig.21. Effect of flower bud size and pollination frequency on seed yield (kg/ha)

Fig.21. Effect of flower bud size and pollination frequency on seed yield (kg/ha)

4.3.3 Seed quality parameters

4.3.3.1 Seed germination percentage

The data on seed germination percentage as influenced by flower bud size, number of pollinations and their interactions are presented in Table 17 and Fig. 23 (Plate 5).

The flower bud size influenced significantly the seed germination percentage. Significantly higher seed germination percentage was noticed in the treatment of flower bud more than 50 percent open in size B_2 (92.33). However, lower seed germination percentage was noticed in the treatment of flower bud less than 50 percent open in size B_1 (76.75).

The seed germination percentage was significantly influenced by the number of pollinations. Significantly higher seed germination percentage was recorded in the single pollination treatment N_1 (88.25). However, lower seed germination percentage was noticed in the treatment N_2 (82.75) which was on par with pollination for three times N_3 (82.63).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for seed germination percentage. The B_2N_1 recorded higher seed germination percentage (93.25) which was on par with B_2N_3 (92.50) and B_2N_2 (91.25). However, lower seed germination percentage was observed in B_1N_1 (83.25). The treatment B_1N_3 (72.75) recorded minimum seed germination percentage and it was on par with B_1N_2 (74.25).

4.3.3.2 Field emergence percentage

The data on field emergence percentage as influenced by flower bud size, number of pollinations and their interactions are presented in Table 17 and Fig. 24.

The flower bud size influenced significantly the field emergence percentage. Significantly higher field emergence percentage was noticed in the treatment of flower bud more than 50 percent open in size B_2 (81.83). However, lower field emergence percentage was noticed in the treatment of flower bud less than 50 percent open in size B_1 (69.92).

The field emergence percentage was significantly influenced by the number of pollinations. Significantly higher field emergence percentage was recorded in the single pollination treatment N_1 (80.38). However, lower field emergence percentage was noticed in the treatment N_2 (74.50) which was on par with pollination for three times N_3 (72.75).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for field emergence percentage. The B_2N_1 recorded higher field emergence percentage (84.50), followed by B_2N_3 (81.25) which was on par with B_2N_2 (79.75). However, lower field emergence percentage was observed in B_1N_1 (76.25) and B_1N_2 (69.25). The treatment B_1N_3 (64.25) recorded minimum field emergence percentage.

4.3.3.3 Shoot length (cm)

The data on shoot length as influenced by flower bud size, number of pollinations and their interactions are presented in Table 17 and Fig. 25.

The flower bud size influenced significantly the shoot length. Significantly higher shoot length was noticed in the treatment of flower bud more than 50 percent open in size B_2 (21.63). However, lower shoot length was noticed in the treatment of flower bud less than 50 percent open in size B_1 (16.13).

The shoot length was significantly influenced by the number of pollinations. Significantly higher shoot length was recorded in the single pollination treatment N_1 (20.49). However, lower shoot length was noticed in the treatment N_2 (18.13) which was on par with pollination for three times N_3 (18.03).

Table 17: Effect of flower bud size and number of pollinations on seed germination percentage, field emergence percentage, shoot length and root length in bhendi hybrid seed production

Treatment	Germination (%)	Field emergence (%)	Shoot length (cm)	Root length (cm)
Flower bud size (B)				
B_1: Less than 50 % open	76.75 (61.34)*	69.92 (56.85)*	16.13	6.33
B_2: More than 50 % open	92.33 (74.01)	81.83 (64.86)	21.63	11.07
SEm±	0.36	0.42	0.17	0.11
CD (1%)	1.42	#1.28	0.70	0.45
Number of pollinations (N)				
N_1: One time	88.25 (70.45)	80.38 (63.88)	20.49	10.35
N_2: Two times	82.75 (66.22)	74.50 (59.83)	18.13	7.89
N_3: Three times	82.63 (66.36)	72.75 (58.85)	18.03	7.85
SEm±	0.44	0.52	0.21	0.13
CD (1%)	1.74	#1.56	0.86	0.55
Interaction (B x N)				
B_1N_1	83.25 (65.89)	76.25 (60.88)	18.13	8.73
B_1N_2	74.25 (59.55)	69.25 (56.36)	16.03	5.53
B_1N_3	72.75 (58.57)	64.25 (53.32)	14.23	4.73
B_2N_1	93.25 (75.01)	84.50 (66.88)	22.85	11.98
B_2N_2	91.25 (72.89)	79.75 (63.30)	20.23	10.25
B_2N_3	92.50 (74.15)	81.25 (64.39)	21.83	10.98
MEAN	**84.54 (67.68)**	**75.88 (60.85)**	**18.88**	**8.70**
SEm±	0.62	0.73	0.29	0.19
CD (1%)	2.46	#2.21	1.22	0.78

*Figures in parenthesis indicate arcsine transformed values
#CD (5%)

N_1: One time pollination (8:00 a.m.-10:00 a.m.)
N_2: Two time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m.)
N_3: Three time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m. + next day 8:00 a.m.-10:00 a.m.)

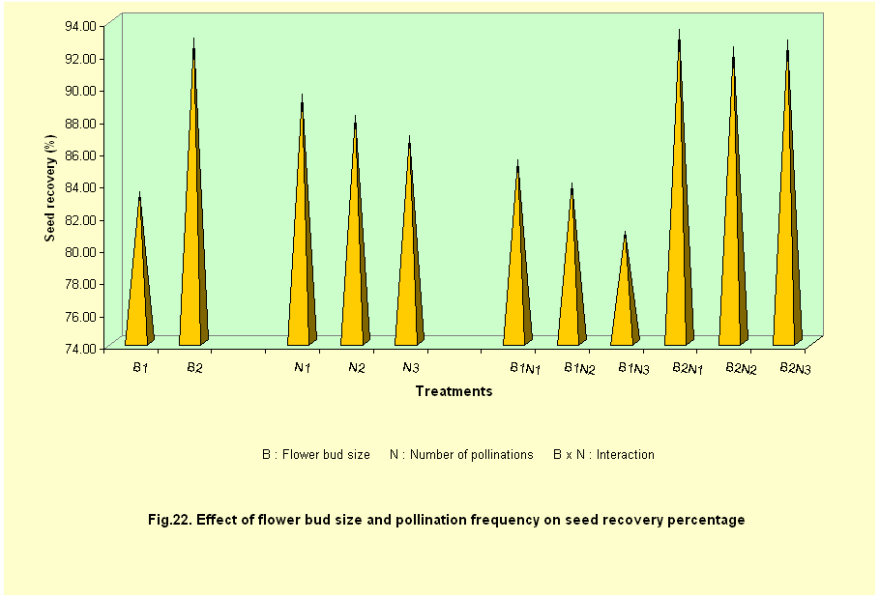


Fig.22. Effect of flower bud size and pollination frequency on seed recovery percentage

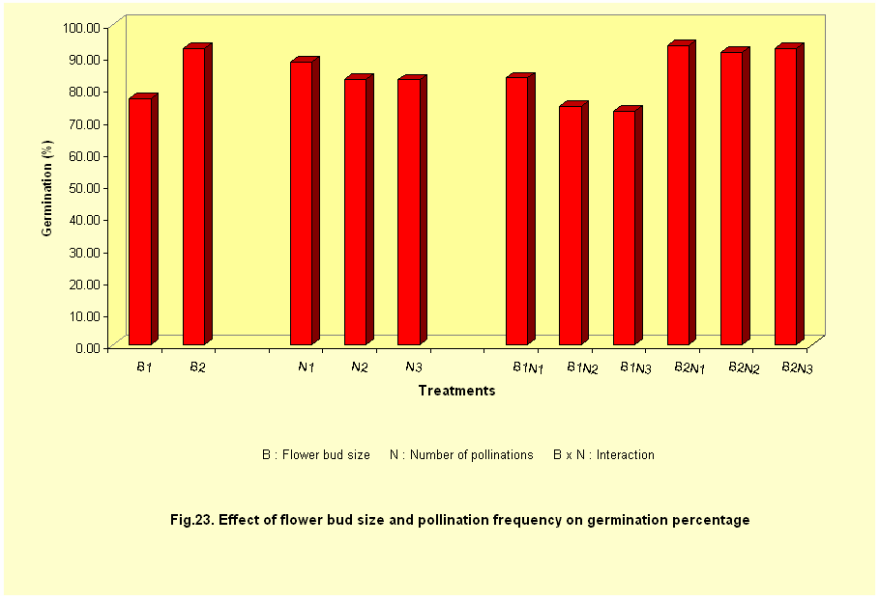


Fig.23. Effect of flower bud size and pollination frequency on germination percentage

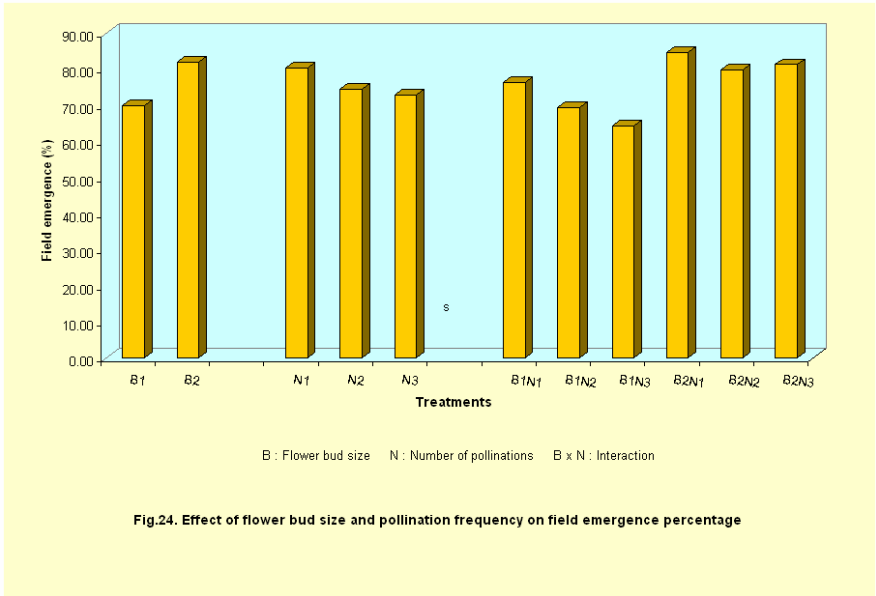


Fig.24. Effect of flower bud size and pollination frequency on field emergence percentage

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for shoot length. The B_2N_1 recorded higher shoot length (22.85) which was on par with B_2N_3 (21.83), followed by B_2N_2 (20.23). However, lower shoot length was observed in B_1N_1 (18.13) and B_1N_2 (16.03). The treatment B_1N_3 (14.23) recorded minimum shoot length.

4.3.3.4 Root length (cm)

The data on root length as influenced by flower bud size, number of pollinations and their interactions are presented in Table 17 and Fig. 26.

The flower bud size influenced significantly the root length. Significantly higher root length was noticed in the treatment of flower bud more than 50 percent open in size B_2 (11.07). However, lower root length was noticed in the treatment of flower bud less than 50 percent open in size B_1 (6.33).

The root length was significantly influenced by the number of pollinations. Significantly higher root length was recorded in the single pollination treatment N_1 (10.35). However, lower root length was noticed in the treatment N_2 (7.89) which was on par with pollination for three times N_3 (7.85).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for root length. The B_2N_1 recorded higher root length (11.98), followed by B_2N_3 (10.98), which was on par with B_2N_2 (10.25). However, lower root length was observed in B_1N_1 (8.73). The treatment B_1N_3 (4.73) recorded minimum root length which was on par with B_1N_2 (5.53).

4.3.3.5 Seedling vigour index

The data on seedling vigour index as influenced by flower bud size, number of pollinations and their interactions are presented in Table 18 and Fig. 27.

The flower bud size influenced significantly the seedling vigour index. Significantly higher seedling vigour index was noticed in the treatment of flower bud more than 50 percent open in size B_2 (3020). However, lower seedling vigour index was noticed in B_1 (1738).

The seedling vigour index was significantly influenced by the number of pollinations. Significantly higher seedling vigour index was recorded in the single pollination treatment N_1 (2740). However, lower seedling vigour index was noticed in the treatment N_2 (2190) which was on par with pollination for three times N_3 (2206).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for seedling vigour index. The B_2N_1 recorded higher seedling vigour index (3247), followed by B_2N_3 (3033) and B_2N_2 (2780). However, lower seedling vigour index was observed in B_1N_1 (2233) and B_1N_2 (1601). The treatment B_1N_3 (1379) recorded minimum seedling vigour index.

4.3.3.6 Seedling dry weight (mg)

The data on seedling dry weight as influenced by flower bud size, number of pollinations and their interactions are presented in Table 18.

The flower bud size influenced significantly the seedling dry weight. Significantly higher seedling dry weight was noticed in the treatment of flower bud more than 50 percent open in size B_2 (62.68). However, lower seedling dry weight was noticed in the treatment of flower bud less than 50 percent open in size B_1 (48.38).

The seedling dry weight was significantly influenced by the number of pollinations. Significantly higher seedling dry weight was recorded in the single pollination treatment N_1 (58.05). However, lower seedling dry weight was noticed in the treatment N_2 (54.56) which was on par with pollination for three times N_3 (53.98).

Table 18: Effect of flower bud size and number of pollinations on seedling vigour index, ten seedling dry weight and electrical conductivity of seed leachate in bhendi hybrid seed production

Treatment	Seedling vigour index	Ten Seedling dry weight (mg)	Electrical conductivity of seed leachate (dSm^{-1})
Flower bud size (B)			
B_1: Less than 50 % open	1738	48.38	0.760
B_2: More than 50 % open	3020	62.68	0.655
SEm±	17.00	0.30	0.004
CD (1%)	73.00	1.23	0.016
Number of pollinations (N)			
N_1: One time	2740	58.05	0.682
N_2: Two times	2190	54.56	0.718
N_3: Three times	2206	53.98	0.722
SEm±	21.00	0.36	0.005
CD (1%)	89.00	1.51	0.020
Interaction (B x N)			
B_1N_1	2233	51.87	0.722
B_1N_2	1601	47.35	0.767
B_1N_3	1379	45.91	0.791
B_2N_1	3247	64.22	0.641
B_2N_2	2780	61.77	0.668
B_2N_3	3033	62.06	0.654
MEAN	**2379**	**55.53**	**0.707**
SEm±	30.00	0.51	0.007
CD (1%)	126.00	2.13	0.028

N_1: One time pollination (8:00 a.m.-10:00 a.m.)
N_2: Two time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m.)
N_3: Three time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m. + next day 8:00 a.m.-10:00 a.m.)

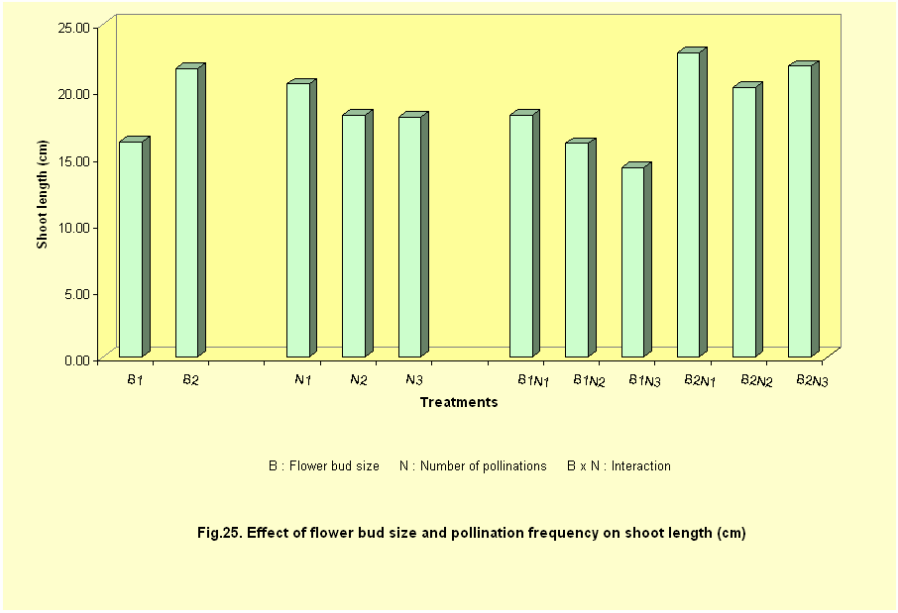


Fig.25. Effect of flower bud size and pollination frequency on shoot length (cm)

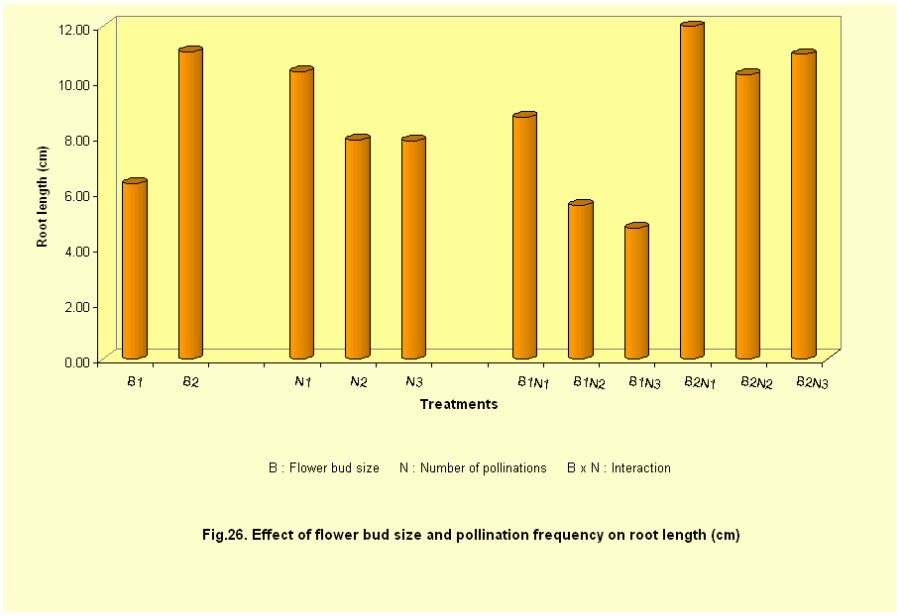


Fig.26. Effect of flower bud size and pollination frequency on root length (cm)

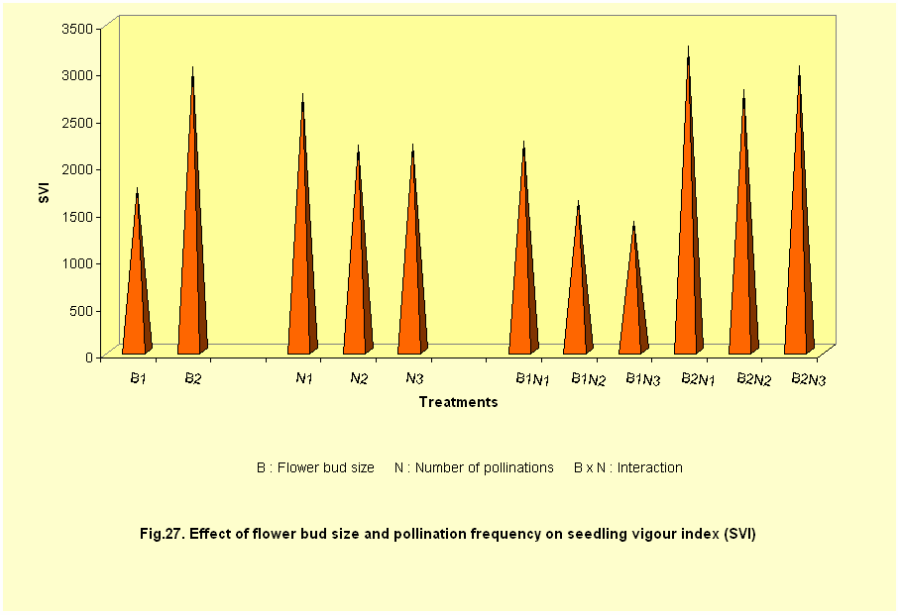


Fig.27. Effect of flower bud size and pollination frequency on seedling vigour index (SVI)

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for seedling dry weight. The B_2N_1 recorded higher seedling dry weight (64.22), followed by B_2N_3 (62.06) which was on par with B_2N_2 (61.77). However, lower seedling dry weight was observed in B_1N_1 (51.87). The treatment B_1N_3 (45.91) recorded minimum seedling dry weight and it was on par with B_1N_2 (47.35).

4.3.3.7 Electrical conductivity of seed leachate (dS/m)

The data on electrical conductivity of seed leachate as influenced by flower bud size, number of pollinations and their interactions are presented in Table 18.

The flower bud size influenced significantly the electrical conductivity of seed leachate. Significantly lower electrical conductivity of seed leachate was noticed in the treatment of flower bud more than 50 percent open in size B_2 (0.655). However, higher electrical conductivity of seed leachate was noticed in the treatment of flower bud less than 50 percent open in size B_1 (0.760).

The electrical conductivity of seed leachate was significantly influenced by the number of pollinations. Significantly lower electrical conductivity of seed leachate was recorded in the single pollination treatment N_1 (0.682). However, higher electrical conductivity of seed leachate was noticed in the treatment N_2 (0.718) which was on par with pollination for three times N_3 (0.722).

The interaction between flower bud size and number of pollinations (B x N) was found to be significant for electrical conductivity of seed leachate. The B_2N_1 recorded lower electrical conductivity of seed leachate (0.641) which was on par with B_2N_3 (0.654) followed by B_2N_2 (0.668). However, higher electrical conductivity of seed leachate was observed in B_1N_1 (0.722). The treatment B_1N_3 (0.791) recorded maximum electrical conductivity of seed leachate and it was on par with B_1N_2 (0.767).

5. DISCUSSION

Bhendi is one of the most important fruit vegetable crops of India. In recent times, the demand for bhendi as a fruit vegetable has grown rapidly due to high nutritive and medicinal values. To fulfill this demand, several improved varieties and hybrids are available for commercial cultivation. Among these, bhendi hybrids are gaining more popularity with farmers and consumers due to their high yielding ability, better fruit and nutritional qualities.

In bhendi, hybrid seed yield is influenced by several seed production techniques like stigma receptivity, day of emasculation, pollen viability, flower bud size and number of pollinations apart from improved agronomic practices. Obviously efforts are being made to enhance its hybrid seed yield by standardizing these seed production techniques.

However, literature available on standardizing the stigma receptivity, day of emasculation and pollination, pollen viability, size of flower bud for emasculation and numbers of pollinations etc. for hybrid seed production are scanty and inconsistent. Therefore, present investigation was carried out to study the effect of aforesaid various techniques on hybrid seed yield and seed quality in bhendi. Three field experiments were conducted during *kharif* season of 2008. The results of all the three experiments are discussed here under.

5.1 Experiment – I: Effect of stigma receptivity of seed parent on fruit set, seed yield and quality of hybrid bhendi

Bhendi is basically a self-pollinated crop but it exhibits some amount of cross-pollination, which varies from 4 to 19 percent in bhendi varieties of India, hence it is grouped under often cross-pollinated crop. In bhendi, the opening of flowers and anthesis normally happen together and occur in the morning between 6.30 am to 10.30 am with peak anthesis at 7.30 to 8.30 am. Anther dehiscence starts from 6:00 am to 9:00 am. Maximum anther dehiscence was observed between 7.00 am to 8.00 am (Srivastava, 1964). Srivastava and Sachin (1973) also observed maximum dehiscence between 8:00 am to 9:00 am. Generally, anthesis and anther dehiscence are influenced by day length, temperature and humidity which should be optimum during flowering to get maximum F_1 hybrid seed setting and yield in bhendi. However, systematic work on stigma receptivity was lacking in bhendi hybrid seed production. Hence, present investigation was carried out in bhendi hybrid seed production to find out suitable day for emasculation and pollination on hybrid fruit set, seed yield and quality. This experiment consisted of six treatments for day of emasculation and subsequent pollinations. The results of this experiment are discussed here under.

5.1.1 Fruit set, seed yield and its attributes

In the present investigation it was found that stigma becomes fully receptive, as revealed by the per cent fruit set, on the day of emasculation in female parent. The stigma receptivity declined up to two day after emasculation and two day before anthesis, beyond which stigma was found to be either non receptive or less receptive in most of the observations.

In this experiment, day of emasculation and subsequent pollination was found to be significant for number of fruits retained per plant, fruit set percentage, fruit length, fruit girth, fruit weight per plant, number of seeds per fruit, seed weight per fruit and seed yield per plant except for number of flowers pollinated per plant. On an average, the highest number of crossed fruits retained per plant, fruit set percentage, fruit weight per plant, number of seeds per fruit, seed weight per fruit and seed yield per plant were observed when pollination was done on the day of emasculation (3.50, 32.91 %, 33.17 g, 59.47, 4.04 g and 28.65 g, respectively).

This suggest that the peak stigma receptivity was reached on the day of emasculation at Dharwad condition and on the other hand early pollination, particularly pollination two days

before anthesis resulted in reduced fruit set. This may be due to immature stigma which could not respond positively to the pollination. However, delayed pollination, particularly pollination two days after emasculation also resulted in decline in fruit set. This may be due to the drying of stigmatic surface that led to the reduction in fruit set percentage. These findings are in agreement with the reports of Kivadasavnnavar *et al*. (2009) in chilli, while contrary to Jolli *et al*. (2007) in tomato.

5.1.2 Seed quality parameters

Seed produced from pollination on the day of emasculation recorded significantly higher seed germination (93.25%) and field emergence (83.75%) over pollination two day before anthesis and two and three days after emasculation. But it was on par with pollination one day before anthesis and one day after emasculation. This resulted in higher seed weight and also bolder seeds harvested from this treatment.

Pollination on the day of emasculation recorded the highest seed quality parameters like seedling root length (12.33 cm), shoot length (23.20 cm), seedling dry weight (63.96 mg), seedling vigour index (3312) and lower EC (0.642 dS/m). An increase in these seed quality parameters (shoot length, root length and vigour index) may be due to the maximum seed weight recorded in this treatment. The increase in seedling vigour can also be attributed to high per cent of germination, root length and shoot length.

From the above discussion, it can be concluded that the pollination on the day of emasculation was found to be more ideal by showing maximum fruit set, seed yield, number of seeds per fruit and better seed quality parameters such as germination, field emergence and vigour index as compared to early and delayed pollinations. The pollination can also be done one day before and one day after anthesis. But any pollination beyond this limit should be avoided.

5.2 Experiment – II: Influence of pollen storage condition and duration of pollen storage on fruit set, seed yield and quality of bhendi hybrid

Pollens are most essential and precious genetic material transmitting male gamete in sexual reproduction. Hybrid seed production of bhendi varies from varietal seed production by involving hand emasculation and pollination. Hence, success of any hybrid seed production depends upon seed setting percentage on female parent which is decided by pollen viability and its capacity of fertilization. It is also learnt from literature that pollen viability varies significantly from species to species.

The environmental factors particularly higher temperature and higher humidity greatly affect the pollen viability (Stanley and Linskens, 1974). Information about pollen storage conditions and safe duration of pollen storage are very essential in crops like bhendi for hybrid seed production. It becomes more important under unfavourable weather conditions. For achieving effective pollination, both parents should exhibit synchronous flowering. Any delay or earliness of flowering in male parent leads to problem in hybrid seed production. Hence, the need for pollen storage comes into foreplay. Further, it should be taken care of that excess pollens produced or unused pollens should be stored for at least few days for subsequent pollinations without registering any considerable decline in their viability. However, work pertaining to method and duration of pollen storage is inadequate in bhendi. Hence, the present investigation was undertaken which involved three different storage conditions for preserving the pollens and five periods of pollen age.

5.2.1 Viability of pollens as influenced by storage condition and duration

In vitro studies on pollen viability were conducted by using 2.0 per cent acetocarmine stain. The viability of fresh pollens was found to be superior to any of the storage conditions (ambient, refrigerated and earthen pot). However, pollens stored in refrigerator were statistically on par with fresh pollens. The storage of pollens in refrigerator can be

recommended according to the needs. Pollen storage in refrigerated conditions for one and two days recorded higher pollen viability of 93.14 and 93.00 per cent respectively when compared to one and two days storage of pollens at ambient conditions (86.48 and 85.29, respectively).

Pollen storage in refrigerator was also found superior by Sharma and Malik (1980) in *Amryllis vittata,* Vaknin and Deisikowitch (2000) in pistachio and Kivadasavnnavar *et al.* (2008) in chilli. The pollen storage in earthen pot, also called as farmer's method of pollen storage, was found superior over pollen storage at ambient conditions. Superiority of pollen storage in refrigerated conditions and storage in earthen pot was also confirmed by Kantharaju (2003) in sunflower and Kivadasavnnavar *et al.* (2008) in chilli.

5.2.2 Effect of pollen storage condition on fruit set, seed yield and quality

Significant differences between the pollen storage conditions were noticed in the field performance of pollen grains on female parent *Arka Anamika* during hybrid seed production of bhendi. Though the number of flowers crossed per plant showed non-significant difference, number of crossed fruits retained per plant (3.21), fruit set percentage (30.02), fruit weight per plant (31.26 g), number of seeds per fruit (50.93) seed weight per fruit (3.70 g) and seed yield per plant (24.63) were significantly higher in refrigerated condition as compared to ambient storage which showed lower values for these traits (2.56, 23.56%, 27.74 g, 47.70, 3.22 g, 20.55, respectively).

Significant increase in seed yield per plant as observed in the pollens stored in refrigerated condition as compared to those of ambient storage condition might be attributed to its higher fruit set percentage, fruit weight and number of seeds per fruit as noticed in this study. The presence of more quantity of viable and matured pollens found in the refrigerated condition resulted in higher fruit and seed yield components compared to ambient conditions. On the other hand, the lower values were recorded for fruit set percentage, fruit weight per plant, number of seeds per fruit, seed weight per fruit and seed yield per plant obtained from pollens stored in ambient condition. These results might be attributed to sufficient loss of pollen viability due to diurnal fluctuations in ambient temperature and relative humidity which affects fertilization of ovules and results in poor fruit set and seed yield parameters. These results are also confirmed by Jolli *et al*. (2008a) in tomato, Patil (2005) in brinjal and Kivadasavnnavar *et al.* (2008) in chilli.

These results are in accordance with findings of Rajashekhar (2000) in sunflower, who has observed no significant difference in seed set per cent with fresh pollen, one day stored pollen either in refrigerator or earthen pot. These results are also similar with the findings of Kantharaju (2003) in sunflower. But on the contrary, Kempegowda (1992) found better performance of stored pollens under ambient conditions up to 24 hours as regarding seed set. The present results pertaining to pollen viability at ambient condition are justified by the findings of Jawale *et al.* (1998) who have observed pollen viability of sunflower only for 22 hours though the stigma receptivity last for 3 days.

Seed quality attributes of F_1 hybrid seeds as influenced by application of stored pollens differed significantly. Seeds obtained through application of pollens stored under refrigerated conditions recorded significantly higher seed germination (88.60%), shoot length (20.07 cm), root length (9.58 cm), seedling vigour index (2636) and seedling dry weight (60.98 mg). Whereas, they were significantly lower in ambient storage condition (82.07%, 17.31 cm, 8.13 cm, 2119 and 52.74 mg respectively). The significant increase in germination and vigour index observed in the refrigerated condition of storage may be attributed to higher seed set and seed yield per plant along with heavier and bolder seeds with higher 100 seed weight as revealed from the present results. These results are in conformity with the similar findings in tomato by Jolli *et al*. (2008a), in brinjal by Patil (2005) and in chilli by Kivadasavnnavar *et al.* (2008).

5.2.3 Effect of duration of pollen storage on fruit set, seed yield and quality

Irrespective of pollen storage condition, the fruit and seed yield components showed significant differences except for number of flowers pollinated per plant, due to pollen storage duration.

The fresh pollens recorded maximum values for number of crossed fruits retained per plant (4.04), fruit set percentage (37.52), fruit weight per plant (38.41 g), number of seeds per fruit (59.51), seed weight per fruit (4.02 g), and seed yield per plant (33.19 g). It was followed by pollen storage for one and two days. All these parameters were lower in the four day old pollens (1.93, 37.52%, 19.38 g, 37.17, 2.97 g, 11.96 g).

Significant increase in seed yield per plant as observed in the fresh pollens may be attributed to its higher fruit set percentage, fruit weight per plant, number of seeds per fruit and seed weight per fruit. The availability of more number of matured and viable pollens resulting in better fertilization of ovules can also be considered as a possible reason for higher number of crossed fruits per plant, number of seeds and seed weight per fruit. These results are in agreement with those of Patil (2005) in brinjal and Kivadasavnnavar *et al.* (2008) in chilli.

Irrespective of pollen storage condition, significant variation in seed quality was noticed due to duration of pollen storage. Use of fresh pollens recorded significantly the highest values for seed germination (92.67%), shoot length (23.02 cm), root length (11.18cm), seedling vigour index (3169) and seedling dry weight (63.57 mg), followed by one and two day pollen storage. The minimum values for all these parameters were recorded in pollen storage for four days (78.56%, 16.58 cm, 6.37 cm, 1809 and 53.66 mg respectively). The increase in seed quality parameters as observed in fresh pollens may be due to higher seed weight and bolder seeds obtained from this treatment as compared to all other treatments. Similar findings were also confirmed by Patil (2005) in brinjal.

5.2.4 Interaction effect

The interactions between pollen storage conditions and number of days of pollen storage (C x P) was found to be significant for many of the seed yield and quality parameters studied. The fresh pollens in all the three storage conditions have shown better results than the pollens stored for longer duration in the respective treatments. The interaction C_2P_0 recorded higher values for number of crossed fruits retained per plant (4.07), fruit set percentage (38.30), number of seeds per fruit (59.98), seed weight per fruit (4.13 g), and seed yield per plant (33.08 g). All these values were on par with C_1P_0 and C_3P_0. The pollen storage for one day under refrigerated conditions has shown similar results as that of fresh pollens for the seed yield characters like number of seeds per fruit (58.88), seed weight per fruit (3.88 g), and seed yield per plant (32.50 g). It was followed by pollen storage for one day in earthen pot and for two days in refrigerated conditions. The four day old pollens under ambient conditions have shown significantly lower values for number of crossed fruits retained per plant, fruit set percentage, fruit weight per plant, number of seeds per fruit, seed weight per fruit and seed yield per plant (1.47, 13.82%, 16.77 g, 35.34, 2.83 g, 9.76 g respectively).

The fresh pollens recorded significantly higher values for seed germination, shoot length, root length, seedling vigour index and seedling dry weight as compared to other treatments. However, appreciable results were recorded when pollen storage was taken up to two days under refrigerated condition (C_2P_2) for seed quality parameters like seed germination (87.33%), shoot length (20.60 cm), root length (10.40 cm), seedling vigour index (2705) and seedling dry weight (61.07 mg), as compared to pollen storage for same duration under ambient conditions (C_1P_2) where lower values for these parameters were recorded (84.67%, 16.67 cm, 8.80 cm, 2153 and 52.02 mg respectively). The minimum values for all these parameters were recorded in pollen storage for four days under ambient conditions (73.67%, 14.97 cm, 5.43 cm, 1506 and 47.43 mg respectively). These results might be attributed to sufficient loss of pollen viability due to diurnal fluctuations in ambient temperature and relative humidity which affects fertilization of ovules and results in poor seed set and seed yield parameters. Also, the pollen viability decrease with increase in the age of pollen. When these two factors were coupled, they have shown effective interaction effect. Though the pollen deterioration occurs in all the storage conditions as the time passes, but in the refrigerated condition the rate of deterioration might have been comparatively lower as

compared to ambient condition, because in refrigerated conditions the fluctuations in the environmental factors like temperature and relative humidity are minimal. In earthen pot condition also, the environmental factors are controlled but only up to some extent, as it is revealed by the results on seed yield and quality parameters which have shown much better performance as compared to ambient storage, but inferior results as compared to refrigerated storage condition.

Hence, keeping in view the results from this study, it can be concluded that as far as possible, use of fresh pollens should be preferred for hybrid seed production in bhendi. If fresh pollens are not available, then the pollens stored under refrigerated condition can be used for hand pollination. Another best alternative is storage of pollens in earthen pots, depending upon the availability of resources. As far as possible the pollen storage under ambient conditions should be avoided. However, the pollen storage in earthen pot has got more practical utility and wider acceptability keeping in view the economical conditions of the farmers.

5.3 Experiment-III: Influence of flower bud size and number of pollinations on fruit set, seed yield and quality of bhendi hybrid

The success of any hybrid seed production programme which involves hand emasculation and pollination depends upon the selection of proper flower bud size. In case of bhendi, the flower bud appears in axil of each leaf above 6^{th} to 8^{th} leaf depending upon the cultivar. The crown of the stem at this time bears three to four under developed flowers but later on during the period of profuse flowering, there may be as many as ten under developed flowers on a single crown. As the stem elongates, lower most flower buds open into flowers. There may be a period of two to three or more days between the times of development of each flower but never does more than one flower appear on a single stem. The buds measuring 2.82 cm x 1.55 cm open into flowers (Purewal and Randhawa, 1947). Usually the buds likely to open next day are selected. The maximum pollen fertility is in the period between one hour before and one hour after opening of the flower and stigma is most receptive at the time of flower opening, hence, pollination at bud stage is not successful (Basavaraj, 2006). However, systematic work on flower bud size and number of pollinations was lacking in bhendi hybrid seed production. Hence, present investigation was carried out to find out the ideal flower bud size for emasculation and number of pollinations required in bhendi hybrid seed production their effect on fruit set, seed yield and quality. The experiment consisted of two different bud sizes and three pollination treatments. The results of this experiment are discussed here under.

5.3.1 Effect of flower bud size on fruit set, seed yield and quality

The number of crossed fruits retained per plant was higher in B_2 (3.78) as compared to B_1 (1.95), even though the number of flowers pollinated in both the treatments did not vary with each other. The pollination of more than 50 percent opened bud (B_2) recorded significantly higher fruit set (35.06%) as compared to (18.09%) in the pollination of less than 50 percent opened bud (B_1). Fruit weight per plant was also found to be significantly higher in bigger size buds (37.72) as compared to smaller sized buds (22.58). The significant increase in seed yield in B_2 over B_1 is influenced by higher fruit set percentage in the emasculation and subsequent pollination of the flower bud of more than 50 percent opened size. The higher fruit retention in B_2 indicates that matured buds were used for emasculation and subsequent pollination. On the other hand, lesser fruit yield in B_1 indicates that the smaller size buds were immature for emasculation and pollination. In the immature buds the ovary contains only few matured ovules which get fertilized after pollination and forms the seeds. Too much early pollination on the immature buds fails to result into fruit development and causes crossed buds dropping.

Significantly higher seed weight per fruit (3.89 g), number of seeds per fruit (58.74) and seed yield per plant (31.52 g) was recorded in B_2. However, B_1 recorded lower values for these parameters (2.79 g, 41.37 and 14.49 g respectively). The significant increase in yield

components might have contributed towards increase in the seed yield. Similar results were obtained by Jolli *et al*. (2008b) in tomato.

B_2 recorded significantly higher values for germination percentage (92.33), shoot length (21.63 cm), root length (11.07 cm), seedling vigour index (3020) and seedling dry weight (62.68 mg). The flower buds which were more than 50 percent open in size exhibited higher seed quality parameters over smaller sized flower buds (B_1). This may be due to better quality seeds harvested from B_2 as compared to B_1 treatment. The higher seed weight in B_2 might have contributed in better seed as it might have contained more reserved food materials which might have helped in vigourous seedling growth. These results are in agreement with the findings of Jolli (2004) in tomato where he reported that flower buds more than 50 percent open in size recorded significantly higher values for germination at second and fifth picking only, whereas, shoot length had shown significant increase at first, second, fourth and fifth picking in over flower buds less than 50 percent open in size. The bud with size more than 50 percent showed higher root length and vigour index over bud with size less than 50 percent at all pickings. Iwahori (1966) reported that polar nuclei do not fuse one or two days before anthesis. Hence fertilization at an early stage may be impossible.

5.3.2 Effect of number of pollinations on fruit set, seed yield and quality

Single pollination (8:00 a.m.-10:00 a.m.) treatment N_1 recorded higher values for number of fruits retained per plant, fruit set percentage and fruit weight per plant (3.25, 30.11% and 34.32 g respectively). Two times (N_2) pollination (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m.) and three times (N_3) pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m. + next day 8:00 a.m.-10:00 a.m.) had shown statistically non significant difference for fruit characters. However numerically higher values were obtained in N_2 than N_3.

Similarly, the seed yield traits have shown better results in single pollination treatments as compared to N_2 and N_3. The higher seed yield parameters may be attributed to higher fruit set in N_1. The possible reason for decline in values of fruit set and seed yield characters in two and three times pollination treatment may be the injury caused to the stigma during the process of hybridization. The stigma in bhendi exudes mucilaginous fluid which is sticky in nature. This in general causes the adherence of stigmatic surface with the butter paper bag which is used for covering the emasculated bud to avoid any foreign contamination. If this covering is not disturbed it leads to normal fertilization process, fruit and seed setting. However, in the repeated pollination treatments the higher frequency of reopening and recovering the stigmatic surface of the emasculated flower buds increases the chance of damage being done to the stigma. This in turn leads to poor fruit set and contributes for lesser values of seed yield.

The seed quality parameters like seed germination, shoot length, root length and seedling vigour index were found to be better in single pollination treatment (88.25%, 20.49 cm, 10.35 cm and 2740 respectively) as compared to two and three times repeated pollinations. This might be attributed to higher seed weight and much bolder seeds obtained in this treatment. However, these results are contrary to the findings of Jolli *et al*. (2008b) in tomato where they have reported that three times pollination gave better results than single pollination. The stigmatic surface area in tomato is much lesser compared to bhendi because of this fact might have attributed to the differences in the findings on number pollinations in these two crops.

5.3.3 Interaction effect

Interaction between flower bud size and number of pollinations were found to be significant for many of the characters like number of fruits retained per plant, fruit set percentage, fruit weight per plant, number of seeds per fruit and seed yield per plant. The treatment single pollination on the flower buds of more than 50 percent opened in size (B_2N_1) gave significantly higher values for all these fruit traits (4.05, 37.82%, 38.21 g, 59.51and 32.59 g respectively). However, the treatments of three times pollination on less than 50 percent open flower buds (B_1N_3) recorded lower values (1.50, 14.14%, 16.89 g, 35.18 and 9.73 g respectively) for these fruit and seed yield parameters.

The smaller size of buds coupled with repeated pollinations have shown greater decline in the fruit and seed yield parameters. The smaller buds in bhendi are mostly immature resulting in poor fruit and seed set because of less stigma receptivity or non receptive ovules or both. Also younger buds are more susceptible to any mechanical injuries or disturbances caused on the stigma. When these two factors are combined together they cause much more harm than anticipated to the buds capacity for fruit and seed set. While, on the other hand the flower buds which were more than 50 percent open in size have shown greater resistance to any damage caused to the stigma as revealed by the fruit set and seed yield parameters.

Similar trends were observed for many of the seed quality parameters. The higher values of seed germination percentage, shoot length, root length and seedling vigour index might be attributed to the higher seed weight components which provided more reserve food material for the vigourous growth of seedling.

Hence, from this study it can be concluded that for hybrid seed production in bhendi, the flower buds which are more than 50 percent open in size could be considered as ideal with single pollination in the morning hours between 8:00 to 10:00 am.

Practical applications of the results

The following practical applications are indicated on the basis of results obtained in the present studies.

1. Higher fruit set, fruit yield, seed yield, number of seeds per fruit and higher seed quality parameters such as germination, field emergence and vigour index can be obtained with pollinating female parent on the day of emasculation.
2. For hybrid seed production in bhendi, the use fresh pollens gives better fruit set, seed yield and quality.
3. In bhendi crop, pollen can be safely stored in refrigerated condition upto two days and one day in earthen pot (kept in moist sand) for further use in supplementary pollination during hybrid seed production.
4. Pollens stored in ambient condition should be utilized within a day as they are susceptible to adverse conditions and loose viability.
5. The flower buds which are more than 50 percent open in size are best suited for emasculation and subsequent pollinations in bhendi hybrid seed production.
6. Only one time pollination in the morning hours between 8:00 to 10:00 am is sufficient for proper seed setting in bhendi hybrids.

Future line of work

1. The work pertaining to know the effect of pollen collection from the flowers at different nodal positions on the main stem of the male parent on seed yield and quality may be taken up.
2. Efforts can be made to increase the pollen viability of bhendi through manipulation of storage conditions (temperature and RH) and containers.
3. Studies can be taken up for finding suitable blending mixture to enhance the pollen use efficiency during bhendi hybrid seed production.

6. SUMMARY AND CONCLUSIONS

Bhendi is one of the most important fruit vegetable crops of India. In recent times, the demand for bhendi as a fruit vegetable has grown rapidly due to high nutritive and medicinal values. To fulfill this demand, several improved varieties and hybrids are available for commercial cultivation. In bhendi, hybrid seed yield is influenced by several seed production techniques like stigma receptivity, day of emasculation, pollen viability, flower bud size and number of pollinations apart from improved agronomic practices. Therefore, present investigation was carried out to study the effect of aforesaid various techniques on hybrid seed yield and seed quality in bhendi. Three field experiments were conducted during *kharif* season of 2008. The results of these three experiments are summarized here under.

6.1 Effect of stigma receptivity of seed parent on fruit set, seed yield and quality of hybrid seeds in bhendi

1. Crossed fruits retained per plant (3.50), fruit set (32.91%), fruit weight per plant (33.17g), seed weight per fruit (4.04 g), number of seeds per fruit (59.47) and seed yield per plant (28.65 g) were significantly higher in the treatment of pollination on the same day of emasculation (S_0) compared to pollination done two days before anthesis (S_{-2}) and two days after emasculation (S_2).

2. Higher seed quality parameters such as 100 seed weight (7.27 g) field emergence (83.75%), root length (12.33 cm), shoot length (23.20 cm) seedling vigour index (3312) and seedling dry weight (63.96 mg) were observed in pollination on the day of emasculation compared to the rest of the treatments.

6.2 Effect of pollen storage condition and duration of pollen storage on fruit set, seed yield and quality of bhendi hybrid

1. Irrespective of the pollen storage duration the number of crossed fruits retained per plant (3.21), fruit set percentage (30.02), fruit weight per plant (31.26 g), number of seeds per fruit (50.93) seed weight per fruit (3.70 g) and seed yield per plant (24.63) were significantly higher in refrigerated condition as compared to earthen pot condition and ambient storage.

2. Seeds obtained through application of pollens stored under refrigerated conditions recorded significantly higher seed germination (88.60%), shoot length (20.07 cm), root length (9.58 cm), seedling vigour index (2636) and seedling dry weight (60.98 mg).

3. The fresh pollens recorded higher values for number of crossed fruits retained per plant (4.04), fruit set percentage (37.52), fruit weight per plant (38.41 g), number of seeds per fruit (59.51), seed weight per fruit (4.02 g), and seed yield per plant (33.19 g) followed by pollen storage for one and two days.

4. Use of fresh pollens recorded significantly higher values for seed germination (92.67%), shoot length (23.02 cm), root length (11.18cm), seedling vigour index (3169) and seedling dry weight (63.57 mg), followed by one and two day pollen storage.

5. The interaction of fresh pollen under refrigerated condition (C_2P_0) recorded higher values for number of crossed fruits retained per plant (4.07), fruit set percentage (38.30), number of seeds per fruit (59.98), seed weight per fruit (4.13 g) and seed yield per plant (33.08 g). All these values were on par with C_1P_0 and C_3P_0. The pollen storage for one day under refrigerated conditions has shown similar results as that of fresh pollens for the seed yield characters like number of seeds per fruit (58.88), seed weight per fruit (3.88 g), and seed yield per plant (32.50 g). It was followed by pollen storage for two days in refrigerated conditions and one day in earthen pot.

6.3 Effect of flower bud size and number of pollinations on fruit set, seed yield and quality of bhendi hybrid

1. Significantly higher number of crossed fruits retained per plant (3.78), fruit set (35.06%), fruit weight per plant (37.72), seed weight per fruit (3.89 g), number of seeds per fruit (58.74) and seed yield per plant (31.52 g) was recorded in the flower bud which were more than 50 percent open in size (B_2).

2. Flower bud more than 50 % open in size (B_2) recorded significantly higher values for germination percentage (92.33), shoot length (21.63 cm), root length (11.07 cm), seedling vigour index (3020) and seedling dry weight (62.68 mg).

3. Single pollination (8:00 a.m.-10:00 a.m.) treatment N_1 recorded higher values for number of fruits retained per plant, fruit set percentage and fruit weight per plant (3.25, 30.11% and 34.32 g respectively)

4. The seed quality parameters like seed germination percentage, shoot length, root length and seedling vigour index were found to be better in single pollination treatment (88.25%, 20.49 cm, 10.35 cm and 2740 respectively) as compared to two and three times repeated pollinations.

5. The treatment of single pollination on the emasculated flower buds more than 50 percent opened in size (B_2N_1) gave significantly higher values for number of fruits retained per plant, fruit set percentage, fruit weight per plant, number of seeds per fruit and seed yield per plant (4.05, 37.82%, 38.21 g, 59.51and 32.59 g respectively).

Conclusion

1. The pollination on the day of emasculation was found to be more ideal by recording higher fruit set, seed yield, number of seeds per fruit and better seed quality parameters such as germination, field emergence and vigour index as compared to early and delayed pollinations.

2. Use of fresh pollens should be preferred for hybrid seed production in bhendi. If fresh pollens are not available, then the pollens stored under refrigerated condition can be used for hand pollination. Another best alternative is the storage of pollens in earthen pots, depending upon the availability of resources. As far as possible the pollen storage under ambient conditions should be avoided. However, the pollen storage in earthen pot has got more practical utility and wider acceptability keeping in view the economical conditions of the farmers

3. For hybrid seed production in bhendi, the emasculation of the flower buds which are more than 50 percent open in size could be considered as ideal with single pollination in the morning hours between 8:00 to 10:00 am.

REFERENCES

Abdul-Baki, A.A. and Anderson, J.E., 1973, Vigour determination in soybean seed by multiple criteria. *Crop Sci.*, 13 : 630-635.

Ahmed, N., Hakim, M.A., Gandroo, M.Y., 1999, Exploitation of hybrid vigour in okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Hort.*, 56(3): 247-251.

Al. Wandawi, Heterosis, 1983, Chemical composition of seeds of two okra cultivars. *J. Agr. Food Chem.,* 31: 1355-1358.

Anonymous, 1999, International rules for seed testing. *Seed Sci. Tech.,* 32 : 1-334.

Anonymous, 2007, Agricultural Output, *Centre for Monitoring Indian Econ.,* pp. 267-268.

Basavaraj, M., 2006, Studies on hybrid seed production of bhendi (*Abelmoschus esculentus* L. Moench). *M. Sc. (Agri.) Thesis*, Uni. Agril. Sci., Dharwad.

Berry, S.K., Kalra, C.L., Sehgal, R.C., Kulkarni, S.G., Arora, S.K. and Sharma, B.R., 1988, Quality characteristics of seed of five okra cultivars. *J. Food Sci. Tec.,* 25: 303-305.

Borikar, S. T., Choulwar, S. B., Singh, A. R., Solunke, B. R. and More, P. R., 1993, Stigma receptivity and pollen viability in sunflower. *Seed Tech. News*, 23(2): 10-11.

Chauhan, S., Yudhvir, S., and Singh, Y., 2002, Heterosis studies in okra (*Abelmoschus esculentus* (L.) Moench). *Veg. Sci.*, 29(2): 116-118.

Chen, N. C., 2003, *Eggplant seed production*. Asian Vegetable Research and Development Centre. Training Guide, Taiwan. pp. 10-14.

Deshpande, K.A., Deshpande, L.A., Deosarkar, D.B. and Kurrhade, N.G., 1999, Time of emasculation and pollination in hybrid seed production of desi cotton (*G. arboretum*). *Seed Res.,* 27 (1): 122-124.

Dev, H., 1988, Advances in hybrid seed production technology of tomato. Breeding and seed production centre of advanced studies Horticulture Department of Vegetable Crops, pp.173-230.

Dev, H., 1998, Heterosis in Tomato, *Centre of Advanced Studies Horticulture (Vegetables)*, Department of Vegetable Crops, Univ. of Horti. and Forestry, Nauni Solan (HP), pp. 87-93.

Dhankar, B.S. and Dhankar, S.K.,2002, Heterosis and combining ability studies for some economic characters in okra. *Haryana J. Hort. Sci.*, 30 (3-4): 230-233.

Dhankar, S.K., Dhankar, B.S. and Tewatia, A.S., 1998, A note on heterosis and combining ability in okra (*Abelmoschus esculentus* (L.) Moench). *Haryana J. Hort. Sci.*, 27 (3): 211-214.

Doddagoudar, S.R., 2005, Standardization of planting ratio, staggered sowing of male parent and crossing period for pre-release cotton hybrids DHH-543 and DHB-290). *Ph. D. Thesis*, Uni. Agril. Sci., Dharwad

Dutta, O.P., 1984, Breeding of okra for resistance to yellow vein mosaic virus and okra leaf curl virus. *Annual Report 1983-84*, IIHR, Banglore, p. 43.

Eevera, T. and Vanangamudi, K., 2007, Tomato. *Quality Seed Production in Vegetables, Advances in Seed Science and Technology*, published by Agrobios (India), Vol.2: 159-186

Gayathri, N. K., Reddy, M. B., Zabeen, F., Ankaih, R. and Lawrence, J., 1993, Studies on stigma receptivity and pollen viability in parental lines of two sorghum hybrids. *Seed Res.*, 21 (2): 82-85.

Hazra, P., Mandal, J. and Mukhopadhyay, T.P., 2003, Pollination behaviour and natural hybridization in *Solanum melongena* L. and utilization of the functional male sterile line. *Annals of Applied Bot.*, 22: 143-146

Herrero, M. P. and Johnson, R.R., 1980 High temperature, stress and pollen viability of maize. *Crop Sci.*, 20 : 800 -816.

Islam, S. and Khan, S., 1998, Pollen viability of *Momordica diocia* Roxy as influenced by storage period and temperature. *Bangladesh J. Bot.*, 27(2): 153-155.

Iwahori, S., 1966, High Temperature injury in tomato.V. Fertilization and development of embryo with special reference to the abnormalities caused by high temperature. *J. Japanese Soc. Hort. Sci.*, 35: 379-860.

Jackson,M.L., 1973, *Soil Chamical Analysis.* Prentice Hall India Pvt. Ltd., New Delhi.

Jambhale, N.D. and Nerkar, Y.S., 1986, 'Parbhani Kranti' a yellow vein mosaic resistant okra. *Horti. Sci.*, 21: 1470-1471.

Jankulovski, D., Gjorgievska, M., Martinovski., G. Krskov, J., Georgievska, M., Martinovski, D., Lazic, B. and Jevtic, S., 1997, Influence of pollination duration on yield and quality of tomato hybrid seed. *Acta Hort.*, 46: 187-190.

Jawale, L. N., Sudewad, S.M., Barure, D.T and Mahajan, R.C. , 1998, Studies on stigma receptivity and pollen viability in sunflower. *J. Maharashtra Agril. Uni.*, 23(3):3121.

Jolli, R. B., 2004, Standardization of hybrid seed production techniques in tomato (*Lycopersicon esculentum* Mill.). *Ph.D Thesis,* Uni. Agril. Sci., Dharwad (India).

Jolli, R. B., Vyakarnahal, B. S., Shekharagouda, M., Dharmatti, P. R. and Patil, A. A., 2007, Studies on stigma receptivity of female parent in tomato hybrid seed production. *Seed Res.,* 35 (2) : 151-155.

Jolli, R.B., Vyakaranahal, B.S., Shekharagouda, M., Dharmatti, P.R. and Patil, A.A., 2008a, Studies on pollen viability of male parent in tomato hybrid seed production. *Seed Res.*, 36(1): 18-23.

Jolli, R.B., Lakshmana, D., Gurumurthy, R., Sajjan, A.S. and Wali, S.Y., 2008b, Influence of stage of bud for emasculation and number of pollinationon seed yield and quality in tomato hybrid seed production. *National Seed Congress-2008, December 22-23, 2008*, organized by Univ. Agri. Sci., Bangalore and National Seed Research and Training Centre, Varanasi, Uttar Pradesh.

Joshi, B.S., Singh, H.B. and Gupta, P.S., 1958, Studies in hybrid vigour. III. *Bhindi* (*Abelmoschus esculentus* (L) Moench). *Indian J. Genet. Pl. Breed.* 18(1): 1-12.

Kalloo, G., 1986, Tomato. *Breeding Habits Selection Bases and Breeding Methods,* Allied Publisher Pvt. Ltd., New Delhi, p: 92.

Kalloo, G., 1988, *Vegetable Breeding,* Vol. 1. CRC Press, Inc. Florida, p: 16.

Kalloo, G., 1991, In: Genetic Improvement of Tomato, Springer-Verlag, Berlin Heidelber, p: 46.

Kantharaju, G., 2003, Studies on parental vigour and pollen use efficiency on seed yield and quality of hybrid sunflower DSH-1. *M. Sc. (Agri.) Thesis*, Uni. Agril. Sci., Dharwad (India).

Kaul, M.L.H., 1991, Reproductive Biology in Tomato. Monographs on *Theoretical and Applied Genetics* 14, *Genetic Improvement of Tomato*, pp. 50-55.

Kempegowda, H . ,1992, Effect of planting design and staggered sowing of parental lines on seed yield and quality in KBSH-1 Hybrid sunflower (*Helianthus annuus* L.). *M.Sc (Agri.) Thesis*, Uni. Agril. Sci., Dharwad (India).

Khadi, B. M., Janagowdar, B. S., Prakash Rao, Yenjenenarappa, S. T and Eshanna, M. R., 1995, Study on planting techniques for synchronization of flowering in desi hybrid cotton seed production. *J. Indian Soc. Cotton Impr*., 20(2):120.123.

Kivadasannavar, P., Deshpande, V.K. and Vyakaranahal, B.S., 2008, Standardization of hybrid seed production techniques in chilli (*Capsicum annuum* L.) hybrid HCH-9646. *National Seed Congress-2008, December 22-23, 2008*, organized by Univ. Agri. Sci., Bangalore and National Seed Research and Training Centre, Varanasi, Uttar Pradesh.

Kivadasannavar, P., Deshpande, V.K., Vyakaranahal, B.S., Mohankumar, H.D. and Lambani, K.D., 2009, Effect of emasculation and pollination time in hybrid seed production in chillies (*Capsicum annuum* L.). *National workshop on "Current trends and future prospects in production and export of spice crops with special reference to chillies"*, *27-28 February, 2009*, organized by CSS-NHM Project, Division of Horticulture, MARS, Univ. Agril. Sci., Dharwad.

Malarkodi, K., Srimathi, P. and Sasthri, G., 2007, Brinjal. *Quality Seed Production in Vegetables, Advances in Seed Science and Technology*, published by Agrobios (India), Vol.2: 187-216.

Mandal, S. C., Singh, Y. V. and Harihar Ram, 1997, Effect of pollination time on fruit setting in hybrid seed crop of Brinjal. *Haryana J. Horti. Sci*., 26 (1-2) : 140-142.

Martin, F.W., 1982, A second edible okra species and its hybrid with common okra. *Ann. Bot.,* 50: 277-283.

Martin, F.W. and Rhodes, A.M., 1983, Seed characteristics of okra and related Abelmoschus species qualities plantarum. *Plant Foods Human Nutr.,* 33: 41-49.

McGuire, D.C., 1952, Storage of tomato pollen. *Proceedings of American Society of Horti. Sci*., 60: 419-421.

Murugesan, P. and Vanangamudi, K., 2006 Okra*, Quality Seed Production in Vegetables, Advances in Seed Science and Technology*, published by Agrobios (India), Vol.2: 295-329

Nascimento, W.M., Torres, A.C. and Lima, L.B., 2000, Pollen viability in hybrid production of eggplant under tropical conditions. *ISHS, Acta Horti., IX International Symposium on Timing of Field Production in Vegetable Crops*., 607: 1-5.

Padda, D.S., Saibhi, M. S. and Singh, K., 1971, Genotypic and phenotypic variabilities and correlation in quality characters of tomato (*Lycopersicon esculentum Mill*) *Indian J. Agric. Sci.*41:199-202.

Panse, V. G. and Sukhatme, P. V., 1978, Statistical methods for agricultural workers published by Indian Council of Agricultural Research, New Delhi, India.

Patil, S. B., Merwade, M. N., Vyakaranahal, B. S. and Deshpande, V. K., 2008, Effect of pollination time and crossing ratio on seed yield and quality of brinjal hybrid under Dharwad region of Karnataka. *Indian J. Agril. Res.,* 42 (1) : 7-12.

Patil, S.B., 2005, Standardization of hybrid seed production techniques in brinjal (*Solanum melongena* L.). *Ph.D. Thesis*, Uni. Agril. Sci., Dharwad (India).

Piper, C.S., 1966, *Soil and Plant Analysis,* Academic Press, New York (U.S.A.).

Prakash, M., Kannan, K., Kumar, J.S., Bharathiveeramani, B., Balaji, P. and Ganesan, J., 2001, Studies on the genetics of certain quantitative characters with particular reference to seed production in okra. *Annals of Agril. Res*., 22(1): 80-82.

Prasad, A. and Batham, R.D., 1975, Studies on pollen morphology, viability and germination in tomato (*Lycopersicon esculentum*), 5: 71-75.

Presley, J.J., 1958, Relations of protoplast permeability to cotton seed viability and pre-deposition of seedling disease. *Plant Dis. Report*, 42: 582.

Purewal, S.S and Randhawa, G.S., 1947, Chromosome and pollination studies in okra. *Indian J. Agri. Sci*., 17: 129-136.

Rai, N. and Rai, M., 2006a, Malvceous crops, *Heterosis breeding in vegetable crops*. published by New India Publishing Agency, New Delhi (India) p: 295-301.

Rai, N. and Rai, M., 2006b, Solanaceous crops, *Heterosis breeding in vegetable crops*. published by New India Publishing Agency, New Delhi (India) p: 259-293.

Rajashekhar, 2000, Studies on seed production in relation to seed vigour on seed production and pollen viability on KBSH-1 hybrid sunflower. *M. Sc. (Agri.) Thesis,* Uni. Agril. Sci., Bangalore (India).

Rajmony, L., Jessy Kutty, P.C. and Mohanakumaran, N., 1995, Resistance to yellow vein mosaic virus of bhendi in Kerala. *Veg. Sci*., 22: 116-119

Reddy, P.P., Naik, L.B. and Prabhakar, M., 2002, Prospects and challenges of vegetable seed production. *XI National Seed Seminar on "Quality seed to enhance agricultural profitability", January 18-20, 2002,* organized by Indian Society of Seed Technology, New Delhi and Uni. Agril. Sci., Dharwad (India).

Rewale, V.S., Bendal, V.W., Bhave, S.G., Madav, R.R. and Jadhav, B.B., 2003, Heterosis for yield and yield components in okra. *J. Maharastra Agri. Uni*., 28 (3): 247-249.

Rick, C.M. and Dempsey, W.H., 1969, Position of the stigma in relation to fruit setting of the tomato. *Botanical Gazette*, 130: 180-186.

Sahar, N. and Roy, S. P., 1980, Citrus pollen storage. *Horti. Sci*., 15: 24-28.

Sharma, B.R., 1982, 'Punjab Padmini'- A new variety of okra. *Prog. Farm*., 82: 15-16

Sharma, D.R. and Arora, S.K., 1993, Improvement of okra. In : *Advances in Horticulture Vegetable Crops,* Part I, Malhotra Publishing House, New Delhi., 343-364

Sharma, R. and Malik, C. P., 1980, Effect of storage on viability and some biochemical components of *Amarillys vittala* pollen. *J. Poloynology*,16 (1&2) : 125-126.

Shete, D. M., Siddiqui, M. A. and Audge, V. S., 1994, Studies on pollen viability period in pollinator lines of sunflower .*J. Soils and Crops*, 4 (1):86-87.

Shull, G.H.,1908, What is heterosis?. *Genetics*, 33: 430-446

Sidhu, A.S., Kallo, G and Pandita, M.C., 1980, Studies on some important aspects of floral biology in vegetable crops - A review. *Haryana J. Horti. Sci.,* 9: 207-217.

Singh, A.K., Sonia Sood, and Sood, S., 1999, Heterosis and inbreeding depression in okra. *Indian J. Hort.*, 56(1): 67-72.

Singh, H.B., Joshi, A.B., Khanna, P.P. and Gupta, P.S., 1962, Breeding for field resistance to yellow vein mosaic in bhendi. *Indian J. Genetics*, 22: 137-144.

Singh, S.P., Srivastava, J.P. and Singh, H.N., 1975, Studies in *bhindi*. *Prog. Hort*., 7 (2): 5-15.

Srivastava, L.S. and Sachin, S., 1973, Studies on floral biology of okra (*Abelmoschus esculentus* (L.) Moench). *Allahabad Farm,* 47: 63-65.

Srivastava, V.K., 1964, Studies on floral biology of (*Abelmoschus esculentus* (L.) Moench). *Indian J. Hort.,* 21: 165-169.

Stanley, R. G. And Linskens, H. F., 1974, *Pollen: Biology, Biochemistry and Management.* Springer Verlag, Berlin. New York.

Subbaiaah, V.V. and Asija, G.L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Curr. Res*., 25: 259-260.

Sudhir, P., 1994, Influence of season and supplementary pollination on seed yield and quality of sunflower KBSH-1. *M. Sc. (Agri.) Thesis,* Uni. Agril. Sci., Dharwad (India).

Sundararajan, N., Naharaj, S., Venkataramu, A. N. and Jagannath, N. K., 1972, Design and analysis of field experiment published by Uni. Agril. Sci., Bangalore.

Vaknin, Y. and Deisikowitch, 2000, Effect of short term storage on germinability of pistachio pollen. *Plant Breed.,* 119 (4) : 347-350.

Valdes, R.V., 1995, Optimum time of hand pollination in tomato. *Ciencia. E. Investigacium. Agaria*, 22: 143-149.

Van Ravestijn, W., 1970, Setting of fruit in tomatoes, peppers and strawberries. *Annual Report of the Glass House Crops Research and Experimental Station for* 1969, Naaldwijk, 57-62.

Venkataramani, K.S., 1952, A preliminary study on some intervarietal crosses and hybrid vigour in *Hibiscus esculentus* (L.). *J. Madras Uni.,* 22: 183-200.

Vijayraghavan, C. and Warrier, V.A., 1946, Evaluation of high yielding hybrid bhendi (*Hibiscus esculentus*). *Proceedings of the 33rd Indian Science Congress*, 33: 165.

Waghmode, D. B., Jadhav, A. S. and Chavan, D. A., 2000, Influence of crossing time and male to female ratio on production of hybrid cotton seed (NHH-44). *J. Maharashtra Agril. Uni.,* 25 (2) : 216-217.

Xanthopoulas, F. P., 1991, Seed set and pollen tube growth in sunflower styles. *Helia*, 14 (14) : 69:72.

Yogeesha, H. S., Nagaraja, A. and Sharma, S. P., 1999, Pollination studies in hybrid tomato seed production. *Seed Sci. and Technol.,* 27: 115-122.

Appendix I: Monthly meteorological data during crop growth period (2008-09) and the average of 58 years (1950-2008) at Main Agricultural Research Station, UAS, Dharwad

Months	Rainfall (mm)		Temperature (^{o}C)				Relative humidity (%)	
	2008-09	1950-2008	Mean maximum		Mean minimum		2008-09	1950-2008
			2008-09	1950-2008	2008-09	1950-2008		
April	28.8	49.3	34.7	37.3	20.4	19.8	80.4	75.6
May	55.8	80.2	35.1	33.7	20.6	21.3	85.1	66.2
June	101.6	114.2	28.7	28.8	21.0	22.4	91.8	81.1
July	121.0	152.4	28.2	29.1	20.7	21.0	91.3	87.1
August	213.2	98.5	26.9	26.9	20.1	20.0	91.5	86.0
September	162.4	104.9	27.8	28.5	20.0	19.9	91.4	82.1
October	60.4	126.9	30.3	30.0	18.9	18.4	83.5	75.8
November	72.2	33.0	29.3	30.1	15.9	15.9	79.4	68.0
December	0.0	5.2	28.6	29.3	13.8	12.5	75.4	63.2
January	0.0	0.1	29.8	29.6	13.3	14.6	66.6	63.1
February	0.0	1.1	33.2	31.2	16.8	16.3	57.5	51.5
March	29.0	2.3	35.0	32.4	19.9	19.5	73.0	56.0
Total	**844.4**	**768.4**						

Appendix II: Physical and chemical properties of the soil of the experimental site

Sl. No.	Particulars	Value obtained	Method employed
I	**Physical composition**		
A	Mechanical composition		
	Course sand (%)	5.80	Hydrometer method (Piper,1966)
	Fine sand (%)	14.20	Hydrometer method (Piper,1966)
	Silt (%)	28.00	Hydrometer method (Piper,1966)
	Clay (%)	51.90	Hydrometer method (Piper,1966)
	Textural class	Clay loam	Hydrometer method (Piper,1966)
B	Bulk density (g cm^{-3})	1.2	Core sample method (Jackson,1967)
II	**Chemical properties**		
	Total nitrogen (%)	0.056	Subbaiah and Asija (1956)
	Available phosphorus (kg/ha)	42.00	Olsen's method (Jackson,1967)
	Available potassium (kg/ha)	325.00	Flame photometer (Jackson,1967)
	Soil pH (1:2.5 soil: water)	7.5	pH meter (Piper,1966)
	Organic carbon (%)	0.76	Wet oxidation method (Jackson,1967)

Appendix III Plant height and number of internodes at different growth stages of seed parent in experimental block-1

Treatment	Plant height (cm)				Number of internodes			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
$S_{(-2)}$	18.79	59.01	91.44	94.06	4.10	9.45	15.45	18.20
$S_{(-1)}$	18.15	56.89	88.61	92.11	3.95	8.95	15.55	18.25
$S_{(0)}$	18.73	57.65	86.85	90.10	4.00	9.10	14.75	17.75
$S_{(1)}$	18.24	56.01	87.93	91.13	3.90	8.85	15.35	18.35
$S_{(2)}$	17.97	56.40	88.84	91.99	3.85	9.15	15.50	18.40
$S_{(3)}$	18.56	57.23	90.71	93.71	4.10	9.10	15.85	18.75
MEAN	**18.41**	**57.20**	**89.06**	**92.18**	**3.98**	**9.10**	**15.41**	**18.28**
SEm±	0.44	1.00	1.04	0.92	0.23	0.20	0.22	0.20
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS

NS: Non significant DAS: Days after sowing

$S_{(-2)}$: Pollination two days before anthesis

$S_{(-1)}$: Pollination one day before anthesis

$S_{(0)}$: Pollination on the day of emasculation

$S_{(1)}$: Pollination one day after emasculation

$S_{(2)}$: Pollination two days after emasculation

$S_{(3)}$: Pollination three days after emasculation

Appendix IV: Days to initiation of flowering and days to 50 % flowering in male and female parent in experimental block-1

Treatment	Days to initiation of flowering				Days to 50% flowering			
	Male (DAS)	Female (DAS)	Difference (Male-Female)	Early flowering parent	Male (DAS)	Female (DAS)	Difference (Male-Female)	Early flowering parent
$S_{(-2)}$	43.50	43.50	0.00	Synchronized	46.25	46.50	-0.25	Male
$S_{(-1)}$	43.25	44.00	-0.75	Male	46.00	46.75	-0.75	Male
$S_{(0)}$	43.25	44.25	-1.00	Male	46.25	47.25	-1.00	Male
$S_{(1)}$	43.00	44.00	-1.00	Male	46.00	46.75	-0.75	Male
$S_{(2)}$	43.50	43.75	-0.25	Male	46.50	46.75	-0.25	Male
$S_{(3)}$	43.50	44.00	-0.50	Male	46.25	47.00	-0.75	Male
MEAN	**43.33**	**43.92**	**-**	**-**	**46.21**	**46.83**	**-**	**-**
SEm±	0.26	0.27	-	-	0.22	0.28	-	-
CD (5%)	NS	NS	-	-	NS	NS	-	-

NS: Non significant DAS: Days after sowing Minus sign indicate early in flowering of male parent

$S_{(-2)}$: Pollination two days before anthesis

$S_{(-1)}$: Pollination one day before anthesis

$S_{(0)}$: Pollination on the day of emasculation

$S_{(1)}$: Pollination one day after emasculation

$S_{(2)}$: Pollination two days after emasculation

$S_{(3)}$: Pollination three days after emasculation

Appendix V: Plant height at different growth stages of seed parent in experimental block-2

Treatment	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	Harvest
Storage condition (C)				
C_1 : Ambient	18.74	59.48	91.10	94.20
C_2 : Refrigerated	18.88	60.09	88.86	91.96
C_3 : Earthen pot	18.41	58.86	90.79	93.89
SEm±	0.14	0.43	0.61	0.61
CD (5%)	NS	NS	NS	NS
Storage duration (P)				
P_0 : Fresh pollens	18.68	59.79	89.65	92.75
P_1 : One day	18.92	60.06	90.87	93.97
P_2 : Two days	18.79	59.88	91.27	94.37
P_3 : Three days	18.28	58.08	89.65	92.75
P_4 : Four days	18.71	59.57	89.80	92.90
SEm±	0.21	0.69	0.97	0.97
CD (5%)	NS	NS	NS	NS
Interaction (C x P)				
C_1P_0	18.52	59.29	90.24	93.34
C_1P_1	18.52	58.20	91.06	94.16
C_1P_2	18.95	60.10	92.30	95.40
C_1P_3	18.32	57.64	90.90	94.00
C_1P_4	19.40	62.16	90.99	94.09
C_2P_0	18.77	59.95	89.24	92.34
C_2P_1	19.15	61.03	89.74	92.84
C_2P_2	19.48	62.15	88.86	91.96
C_2P_3	18.59	59.05	87.39	90.49
C_2P_4	18.40	58.27	89.07	92.17
C_3P_0	18.74	60.14	89.48	92.58
C_3P_1	19.09	60.95	91.82	94.92
C_3P_2	17.94	57.37	92.64	95.74
C_3P_3	17.93	57.56	90.67	93.77
C_3P_4	18.34	58.30	89.35	92.45
MEAN	**18.68**	**59.48**	**90.25**	**93.35**
SEm±	0.30	0.97	1.37	1.37
CD (5%)	NS	NS	NS	NS

NS: Non significant DAS: Days after sowing

Appendix VI: Number of internodes at different growth stages of seed parent in experimental block-2

Treatment	Number of internodes			
	30 DAS	60 DAS	90 DAS	Harvest
Storage condition (C)				
C_1 : Ambient	4.03	9.21	15.25	17.41
C_2 : Refrigerated	3.93	9.56	15.61	17.75
C_3 : Earthen pot	3.92	9.35	14.96	17.15
SEm±	0.05	0.13	0.15	0.14
CD (5%)	NS	NS	NS	NS
Storage duration (P)				
P_0 : Fresh pollens	4.00	9.58	14.93	17.04
P_1 : One day	3.91	9.13	15.16	17.36
P_2 : Two days	3.91	9.36	15.11	17.36
P_3 : Three days	3.93	9.29	15.53	17.67
P_4 : Four days	4.04	9.51	15.64	17.76
SEm±	0.07	0.21	0.24	0.22
CD (5%)	NS	NS	NS	NS
Interaction (C x P)				
C_1P_0	4.00	9.40	15.07	17.20
C_1P_1	4.07	8.80	15.07	17.00
C_1P_2	4.00	9.33	14.93	17.40
C_1P_3	4.00	8.93	15.47	17.60
C_1P_4	4.07	9.60	15.73	17.87
C_2P_0	4.00	9.60	14.73	16.87
C_2P_1	3.87	9.53	15.33	17.47
C_2P_2	3.80	9.80	15.67	17.80
C_2P_3	4.00	9.33	16.20	18.33
C_2P_4	4.00	9.53	16.13	18.27
C_3P_0	4.00	9.73	15.00	17.07
C_3P_1	3.80	9.07	15.07	17.60
C_3P_2	3.93	8.93	14.73	16.87
C_3P_3	3.80	9.60	14.93	17.07
C_3P_4	4.07	9.40	15.07	17.13
MEAN	**3.96**	**9.37**	**15.28**	**17.44**
SEm±	0.10	0.29	0.34	0.32
CD (5%)	NS	NS	NS	NS

NS: Non significant DAS: Days after sowing

Appendix VII: Days to initiation of flowering in male and female parents in experimental block-2

Treatment	Days to initiation of flowering			
	Male (DAS)	Female (DAS)	Difference (Male-Female)	Early flowering parent
Storage condition (C)				
C_1 : Ambient	43.53	43.93	-0.40	Male
C_2 : Refrigerated	43.67	43.73	-0.07	Male
C_3 : Earthen pot	43.80	43.80	0.00	Synchronized
SEm±	0.19	0.08	-	-
CD (5%)	NS	NS	-	-
Storage duration (P)				
P_0 : Fresh pollens	43.44	43.89	-0.44	Male
P_1 : One day	43.78	43.78	0.00	Synchronized
P_2 : Two days	43.67	43.78	-0.11	Male
P_3 : Three days	43.33	43.89	-0.56	Male
P_4 : Four days	44.11	43.78	0.33	Female
SEm±	0.30	0.13	-	-
CD (5%)	NS	NS	-	-
Interaction (C x P)				
C_1P_0	43.33	43.67	-0.33	Male
C_1P_1	44.00	44.00	0.00	Synchronized
C_1P_2	43.67	44.00	-0.33	Male
C_1P_3	43.33	44.00	-0.67	Male
C_1P_4	43.33	44.00	-0.67	Male
C_2P_0	43.67	44.00	-0.33	Male
C_2P_1	44.00	43.67	0.33	Female
C_2P_2	43.33	43.33	0.00	Synchronized
C_2P_3	42.67	44.00	-1.33	Male
C_2P_4	44.67	43.67	1.00	Female
C_3P_0	43.33	44.00	-0.67	Male
C_3P_1	43.33	43.67	-0.33	Male
C_3P_2	44.00	44.00	0.00	Synchronized
C_3P_3	44.00	43.67	0.33	Female
C_3P_4	44.33	43.67	0.67	Female
MEAN	**43.67**	**43.82**	**-**	**-**
SEm±	0.43	0.18	-	-
CD (5%)	NS	NS	-	-

NS: Non significant DAS: Days after sowing
Minus sign indicate early in flowering of male parent

Appendix VIII: Days to fifty percent flowering in male and female parents in experimental block-2

Treatment	Days to 50% flowering			
	Male (DAS)	Female (DAS)	Difference (Male-Female)	Early flowering parent
Storage condition (C)				
C_1 : Ambient	46.53	47.13	-0.60	Male
C_2 : Refrigerated	46.73	47.07	-0.33	Male
C_3 : Earthen pot	46.80	47.00	-0.20	Male
SEm±	0.20	0.13	-	-
CD (5%)	NS	NS	-	-
Storage duration (P)				
P_0 : Fresh pollens	46.44	47.11	-0.67	Male
P_1 : One day	46.78	47.00	-0.22	Male
P_2 : Two days	46.67	47.11	-0.44	Male
P_3 : Three days	46.44	47.22	-0.78	Male
P_4 : Four days	47.11	46.89	0.22	Female
SEm±	0.31	0.20	-	-
CD (5%)	NS	NS	-	-
Interaction (C x P)				
C_1P_0	46.33	47.00	-0.67	Male
C_1P_1	47.00	47.33	-0.33	Male
C_1P_2	46.67	47.00	-0.33	Male
C_1P_3	46.33	47.00	-0.67	Male
C_1P_4	46.33	47.33	-1.00	Male
C_2P_0	46.67	47.00	-0.33	Male
C_2P_1	47.00	47.00	0.00	Synchronized
C_2P_2	46.33	47.00	-0.67	Male
C_2P_3	46.00	47.67	-1.67	Male
C_2P_4	47.67	46.67	1.00	Female
C_3P_0	46.33	47.33	-1.00	Male
C_3P_1	46.33	46.67	-0.33	Male
C_3P_2	47.00	47.33	-0.33	Male
C_3P_3	47.00	47.00	0.00	Synchronized
C_3P_4	47.33	46.67	0.67	Female
MEAN	**46.69**	**47.07**	**-**	**-**
SEm±	0.44	0.28	-	-
CD (5%)	NS	NS	-	-

NS: Non significant DAS: Days after sowing
Minus sign indicate early in flowering of male parent

Appendix IX: Plant height and number of internodes at different growth stages of seed parent in experimental block-3

Treatment	Plant height (cm)				Number of internodes			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
Flower bud size (B)								
B_1: Less than 50 % open	19.14	59.99	90.92	93.99	4.03	9.22	15.63	17.58
B_2: More than 50 % open	19.11	60.81	88.94	91.89	3.93	9.57	16.10	18.02
SEm±	0.11	0.42	0.73	0.71	0.07	0.16	0.19	0.16
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS
Number of pollinations (N)								
N_1: One time	18.97	60.18	88.95	91.95	4.00	9.40	15.58	17.38
N_2: Two times	19.05	60.31	90.46	93.51	4.00	9.43	16.10	18.10
N_3: Three times	19.36	60.70	90.38	93.36	3.95	9.35	15.93	17.93
SEm±	0.14	0.51	0.90	0.87	0.08	0.19	0.23	0.20
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (B x N)								
B_1N_1	19.02	60.02	89.81	92.91	4.00	9.20	15.50	17.35
B_1N_2	19.04	59.64	91.03	94.03	4.05	9.45	15.65	17.65
B_1N_3	19.36	60.30	91.93	95.03	4.05	9.00	15.75	17.75
B_2N_1	18.92	60.33	88.09	90.99	4.00	9.60	15.65	17.40
B_2N_2	19.06	60.98	89.90	93.00	3.95	9.40	16.55	18.55
B_2N_3	19.35	61.11	88.84	91.69	3.85	9.70	16.10	18.10
MEAN	**19.12**	**60.40**	**89.93**	**92.94**	**3.98**	**9.39**	**15.87**	**17.80**
SEm±	0.19	0.73	1.27	1.23	0.12	0.27	0.33	0.28
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS

NS: Non significant DAS: Days after sowing Minus sign indicate early in flowering of male parent

N_1: One time pollination (8:00 a.m.-10:00 a.m.)

N_2: Two time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m.)

N_3: Three time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m. + next day 8:00 a.m.-10:00 a.m.)

Appendix X: Days to initiation of flowering and days to 50 % flowering in male and female parents in experimental block-3

Treatment	Days to initiation of flowering				Days to 50 % flowering			
	Male (DAS)	Female (DAS)	Difference (M - F)	Early flowering	Male (DAS)	Female (DAS)	Difference (M - F)	Early flowering
Flower bud size (B)								
B_1: Less than 50 % open	43.42	43.83	-0.42	Male	46.42	46.92	-0.50	Male
B_2: More than 50 % open	43.75	43.67	0.08	Female	46.75	47.25	-0.50	Male
SEm±	0.23	0.12	-	-	0.23	0.19	-	-
CD (5%)	NS	NS	-	-	NS	NS	-	-
Number of pollinations (N)								
N_1: One time	43.75	43.88	-0.13	Male	46.75	47.13	-0.38	Male
N_2: Two times	43.75	43.88	-0.13	Male	46.75	47.00	-0.25	Male
N_3: Three times	43.25	43.50	-0.25	Male	46.25	47.13	-0.88	Male
SEm±	0.28	0.20	-	-	0.28	0.23	-	-
CD (5%)	NS	NS	-	-	NS	NS	-	-
Interaction (B x N)								
B_1N_1	43.75	43.75	0.00	Sync	46.75	46.75	0.00	Sync
B_1N_2	43.25	44.00	-0.75	Male	46.25	46.75	-0.50	Male
B_1N_3	43.25	43.75	-0.50	Male	46.25	47.25	-1.00	Male
B_2N_1	43.75	44.00	-0.25	Male	46.75	47.50	-0.75	Male
B_2N_2	44.25	43.75	0.50	Female	47.25	47.25	0.00	Sync
B_2N_3	43.25	43.25	0.00	Sync	46.25	47.00	-0.75	Male
MEAN	**43.58**	**43.75**	**-**	**-**	**46.58**	**47.08**	**-**	**-**
SEm±	0.40	0.20	-	-	0.40	0.33	-	-
CD (5%)	NS	NS	-	-	NS	NS	-	-

NS: Non significant DAS: Days after sowing Minus sign indicate early in flowering of male parent Sync: Synchronized M –F: Male - Female

N_1: One time pollination (8:00 a.m.-10:00 a.m.)

N_2: Two time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m.)

N_3: Three time pollination of same bud (8:00 a.m.-10:00 a.m. + 3:00 p.m.-5:00 p.m. + next day 8:00 a.m.-10:00 a.m.)

INVESTIGATIONS ON STIGMA RECEPTIVITY, POLLEN STORAGE, BUD SIZE AND POLLINATION FREQUENCY FOR HYBRID SEED PRODUCTION IN BHENDI (*Abelmoschus esculentus* (L.) Moench)

AVNEESH KUMAR SINGH 2009 Dr. B. S. VYAKARANAHAL
Major Advisor

ABSTRACT

An investigation was carried out with three different field experiments simultaneously for studying hybrid seed production techniques in bhendi using Arka Abhay as male parent and Arka Anamika as female parent, at Main Agricultural Research Station, College of Agriculture, University of Agricultural Sciences, Dharwad during *kharif* 2008.

The pollination on the day of emasculation recorded higher fruit set (32.91%), seed yield per plant (28.65 g), field emergence (83.75%) and vigour index (3312) as compared to early and delayed pollinations.

Pollens stored under refrigerated conditions recorded higher fruit set (30.02%), seed yield per plant (24.63 g), germination (88.60%) and vigour index (2636) as compared to earthen pot condition and ambient storage. The fresh pollens recorded higher fruit set (37.52%), seed yield per plant (33.19 g), germination (92.67%) and vigour index (3169) followed by pollen storage for one and two days. The interaction of pollen storage for one day under refrigerated conditions has shown similar results as that of fresh pollens for seed yield per plant (32.50 g). It was followed by two days storage in refrigerated conditions and one day in earthen pot.

Significantly higher fruit set (35.06%), seed yield per plant (31.52 g), germination (92.33%) and vigour index (3020) was recorded in the flower buds which were more than 50 percent open in size as compared to smaller sized buds. Single pollination (8:00 a.m.-10:00 a.m.) treatment recorded higher values for fruit set (30.11%), seed germination (88.25%) and seedling vigour index (2740) as compared to two and three times repeated pollinations.

Hence, it is recommended that single pollination with fresh pollens between 8:00 am to 10:00 am on the same day of emasculation should be done on buds which are more than 50 percent open in size. For storage of pollens refrigerated conditions should be maintained.