

**STUDIES ON STANDARDIZATION OF HYBRID SEED
PRODUCTION TECHNIQUES IN BELL PEPPER**
(Capsicum annuum L.)

SRIKRISHNA SRINGERI, V. A.

**DIVISION OF HORTICULTURE
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE**

1994

**STUDIES ON STANDARDIZATION OF HYBRID SEED
PRODUCTION TECHNIQUES IN BELL PEPPER**
(Capsicum annuum L.)

SRIKRISHNA SRINGERI, V. A.

Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements
for the award of the Degree of

Master of Science (HORTICULTURE)

in
OLERICULTURE

BANGALORE

FEBRUARY 1994

ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ
ವಿಶ್ವವಿದ್ಯಾನಿಲಯ ಕ್ರೀಡಾಭವನ
ಸಾ.ಕ.ಸಿ.ಕೆ, ಬೆಂಗಳೂರು-65

29 APR 1994

ಅಧ್ಯಕ್ಷರು, ಸಂ. **Th.3316**

ಕೆ.ಸಿ.ಕೆ.

Dedicated to
My Parents, Sister
and
Dr. N. Anand


DIVISION OF HORTICULTURE
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE

CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON STANDARDIZATION OF HYBRID SEED PRODUCTION TECHNIQUES IN BELL PEPPER [*CAPSIUM ANNUUM* L.] submitted by Mr. Srikrishna Sringeri, V.A. for the degree of MASTER OF SCIENCE (HORTICULTURE) IN OLERICULTURE to the University of Agricultural Sciences, Bangalore, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title.

BANGALORE

FEBRUARY 25, 1994


(Dr. O.P. DUTTA)
Principal Scientist
Division of Vegetable Crops
IIHR, BANGALORE

MAJOR ADVISER

APPROVED BY :

Chairman :


(Dr. O. P. Dutta)

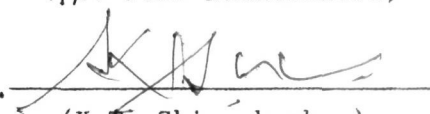
Co-Chairman :


(Dr. M. M. Khan)

Members : 1.

(Mr. P.R. Ramachandra)

2.


(K.T. Shivashankar)

3.


(Mr. A. A. Deshpande)

ACKNOWLEDGEMENT

At the outset, I am implicitly indebted to revered Dr. O.P. Dutta, Principal Scientist, Division of Vegetable Crops, Indian Institute of Horticultural Research, Hessarghatta, Bangalore and Chairman of my Advisory Committee for impeccable guidance, untiring assistance, valuable advice and serving as a source of inspiration during the course of my studies.

I owe my heartfelt thanks and gratitude to Dr. M.M. Khan, Professor, Division of Horticulture, University of Agricultural Sciences, Bangalore, Mr. Ramachandra, Principal Scientist & Head, Division of Statistics & Economics, IIHR, Bangalore, Mr. K.T. Shivashankar, Assoc. Professor, Division of Horticulture, GKVK, Bangalore and Mr. A.A. Deshpande, Scientist (SG), Division of Vegetable Crops, IIHR, Bangalore, members of my Advisory Committee, for their suggestions and critical scrutiny of the manuscript.

I am highly thankful to Dr. Anand, N., Capsicum Breeder, PHI Biogene, Bangalore, who oriented me to this problem for my research programme and for the inimitable suggestions made by him.

I am very much grateful to Dr. A.T. Sadashiv, Mrs. Madvi Reddy, Mr. H.V. Satyanarayana, Mr. K. Muniyappa, Mr. Channarayappan and other staff of Division of Vegetable Crops, IIHR, Bangalore, for their suggestions and timely help during the course of this investigation.

I am extremely thankful to Mr. Rajashekar, Mr. Ganeshaiha and Mr. Tamilarasu for their help during the period of my research work.

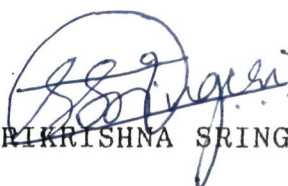
I extend my sincere thanks to Dr. K.R. Thimma Raju, Professor and Head, Division of Horticulture, University of Agricultural Sciences, Bangalore and Dr. R.M. Pandey, Director, IIHR, Bangalore, for providing the facilities for the present investigation.

I would like to thank Mr. Vasudeva, Mrs. Radhamani, Mr. B. Venkatesh Bhat, Mr. Sreenivas, V., Mr. Mahanthesh, B. Hanji, Mr. Satheesh, B.P., Mr. Suresh, P., Mr. Raghunath, Mr. Nataraj, M., Miss Shyamamma, Mr. Vasudevamurthy, Mr. Manjunath and other friends, who proved to be more than smiling friends and helped in carrying out the investigation.

I am highly indebted to my beloved parents and sister for their unbroken inspiration and support at all times.

BANGALORE,

FEBRUARY 25th, 1994

 25/4/94
(SRIKRISHNA SRINGERI, V.A.)

CONTENTS

Chapter	Titles		Page
I	INTRODUCTION	..	1
II	REVIEW OF LITERATURE	..	4
III	MATERIALS AND METHODS	..	11
IV	EXPERIMENTAL RESULTS	..	21
V	DISCUSSION	..	38
VI	SUMMARY	..	47
VII	REFERENCES	..	50

LIST OF TABLES

Table	Title	Page
4.1	Effect of flower bud bearing pattern on pollen size, viability and germination	21
4.2	Effect of flower age on pollen size, viability and germination	24
4.3	Flower bearing pattern and its effect on fruit set, number of seeds per fruit and 100 seed weight	26
4.4	Flower bearing pattern and its effect on seed germination and vigour index	27
4.5	Effect of repeated pollination and mixed pollen on number of seeds per fruit and 100 seed weight	30
4.6	Effect of repeated pollination and mixed pollen on seed germination and vigour index	31
4.7	Pollen load on stigma and its effect on number of seeds per fruit and seed weight	35
4.8	Pollen load on stigma and its effect on seed germination and vigour index	36

LIST OF FIGURES

Figure	Title	Between pages
3.1	Schematic representation of typical bell pepper plant : Biparus cymose inflorescence	13-14
4.1	Effect of flower bud bearing pattern on pollen size, viability and germination	21-22
4.2	Effect of flower age on pollen size, viability and germination	24-25
4.3	Effect of flower bearing pattern on fruit set and number of seeds per fruit	26-27
4.4	Effect of flower bearing pattern on 100 seed weight	26-27
4.5	Effect of flower bearing pattern on seed germination and vigour index	27-28
4.6	Effect of repeated pollination and mixed pollen on number of seeds per fruit and 100 seed weight	30-31
4.7	Effect of repeated pollination and mixed pollen on seed germination and vigour index	31-32
4.8	Effect of pollen load on stigma and number of seeds per fruit and 100 seed weight	35-36
4.9	Effect of pollen load on stigma on seed germination and vigour index	36-37

INTRODUCTION

I INTRODUCTION

Bell pepper (*Capsicum annuum* L.) is one of the most popular and highly remunerative vegetable crops grown in China, Mexico, Spain, Romania, Italy, Yugoslavia, Bulgaria, USA, Hungary, India, Hongkong and in other European, Central and South American countries. Being a high value crop in India, it fetches higher returns. Capsicum is extensively cultivated in Karnataka, Maharashtra, Tamil Nadu, Himachal Pradesh and hilly areas of Uttar Pradesh. The area under bell pepper cultivation in India is estimated to be 4,780 hectares with a total production of 42,230 tonnes. The area under this crop in Karnataka is 1,983 hectares with a total production of 19,830 tonnes (Gill and Tomar, 1991). Its delicate taste and pleasant flavour make the bell pepper a favourable vegetable throughout India.

Bell pepper is also known by the name sweet pepper and capsicum. In India, it is grown for its mature green fruits. They are widely used in stuffing and baking. It is also used as salad and in soup preparation. Capsicum is a rich source of ascorbic acid and considered as better than tomato in this respect. High market price for bell pepper is attributed to increasing demand by urban consumers and limited supply which is due to low productivity. Despite its economic importance, the growers are unable to take up the cultivation of this crop mainly due to the non-

availability of quality seeds. The seeds obtained through various seed agencies are found to be poor in their germination and vigour resulting in poor stand and lower yield. So, understanding the techniques of bell pepper seed production is of great importance to increase the productivity and production of this crop.

Moreover, the cost of quality seeds of bell pepper is very high at present. Supply of quality seeds at a reasonable price is an important aspect of vegetable seed industry. Any study aiming at increasing the seed yield per hectare may help the farmer assuring him of quality seeds at reasonable cost.

One of the reasons for poor productivity is non-availability of varieties adaptable to tropical conditions. Though few high yielding commercial hybrids are presently grown in India, yet area under F_1 s is very meagre. One of the reasons for this is the high cost of F_1 hybrid seeds.

Information on production of hybrid seeds in capsicum for getting maximum yield and quality is limited. Generating such information would certainly help in reducing the F_1 seed cost.

The present study dealing with the standardization of hybrid seed production techniques in bell pepper (*Capsicum annuum* L.) was thus undertaken with the following objectives:

1. To standardize the stage of pollen development affecting seed yield and quality.
2. To study the effect of pollen grains load on seed set and maturity.
3. To study the optimum nodal position of flower bud for effecting crosses, fruit set and seed yield.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

An attempt has been made in this chapter to collect the literature on pollen morphology, viability and germination, fruit set, seed set, seed germination and seedling vigour of bell pepper. Due to inadequacy of relevant literature on bell pepper, efforts were made to include work done in other crops on these aspects.

2.1 Pollen morphology, viability and germination

Palynologically the genus *Capsicum* is homogeneous having the *Solanum* type of pollen grains, Basak (1967) studied the pollen morphology in four species of *Capsicum* and also recorded homogeneity. Raghuvanshi (1976) reported that *Capsicum annuum* var. *floragem* has pollen of subprolate spheroidal shape with size ranging from 22 to 30 μ having exine thickness 1.6 μ . Vijay et al. (1979) observed that in sweet pepper varieties California Wonder and Selection-5, the pollen size ranged from 26.6-39.9 μ and 26.6-32.25 μ , respectively.

In bell pepper, pollen fertility of 98 per cent was observed by Saccarado and Ramalu (1977). Aventikyan and Stepanyan (1973) noticed that fertility of fresh pollen ranged from 72 to 91 per cent in sweet pepper. Pollen viability and stigma receptivity were found to be affected by the stage of development of the flowers of both pollen and maternal parent (Popova and Mihailov, 1978). In *Luffa cylindrica* pollen collected from flowers of late phase of

blooming were sterile and produced abnormal pollen tubes (Brink, 1924; Vasil, 1960, Nair and Deshpande, 1968).

Vijay *et al.* (1979) reported that in sweet pepper varieties California Wonder and Selection-5, pollen grains became fertile one day before anthesis and remained so under two days after anthesis. Pollen remained viable for 48 hours after anthesis (Barai and Roy, 1986). No successful pollination was obtained using pollen taken from flower buds two days prior to anthesis or from flowers, 3 days after anthesis (Rylski, 1986). Maximum fruit set was observed when flowers were pollinated with pollen collected from flowers on the day of anthesis. Highest successful pollination was obtained when pollen from either newly dehisced anthers or a day old were used to pollinate flowers (Popova, 1959; Kiss, 1970). In *Capsicum* fresh pollen had highest viability and generally gave best performance in hybrid seed production (Kismova, 1968). He also pointed out positive relation between pollen viability and the quality of hybrid seed production and also increase in production from F₁ plants.

2.2 Fruit Set

Il'enko (1969) reported that the best fruit set was obtained when flowers were emasculated at the ripe bud stage and pollinated on the same day. Kalyagina and Pugachev (1986) suggested that crossing in hybridization of peppers should be carried out during first peak of flowering. Fruit set was the highest in the early stages of the crop and

subsequently declined as majority of the flowers aborted (Khah and Passam, 1992). Fruit set and flower production in *Capsicum annum* L., *Capsicum* spp. and *Solanum melangena* are positively correlated with the amount of fruits already developing on plants (Free, 1975).

Daskalov and Popova (1962) identified that flower bud with pistil above the anthers give the highest fruitset and should be emasculated just before anthesis. Most of the fruits were obtained from 3rd and 4th tiers on the plant (Cirkova-Gorgievska, 1966). They also noticed heaviest fruits from lower tiers of pepper plants.

Random variation in pollination level, young fruits survived and resource level could cause decrease in flower to fruit ratio especially when the cost of young fruits or flowers is low relative to that of mature fruits (Cochen and Dukas, 1990). Pyke (1982) reported that limited resource availability within the plant could also cause very low fruit set.

In cultivars of domesticated and wild common bean (*Phaseolus vulgaris*), Nakamura (1986) observed that early cohorts were more likely to produce mature pods indicating that the beans abort their fruits in a manner that conserves parental investment but do not discriminate the genetic quality of the offspring. A similar observation in wild radish (*Raphanus raphanistrum*) was reported by Mazer (1987) that variation in fruit abortion and ovule abortion rates was due to the date on which a flower was pollinated,

relative to other flowers on the same plant and due to maternal identity. Wyatt (1981) observed that the most important factor determining fruit set in *Asclepias tuberosa* was the competition for resource among ovaries within umbles. Umbles closer to the source of resources (main stem) had higher probabilities of setting fruit as evident from the decreasing success of umbles further out along a branch. Resource moves towards the strongest sink and competition occurs at hierarchy of levels between branches when the strength of the sink is affected by the number and vigour of the fruits on the branches : between fruits on a branch when the strength of the sink is affected by the number and vigour of developing seeds in a fruit; between offspring within a fruit, when the strength of the sink is affected by the vigour of each developing offspring. Thus mother could cause limited investment to be directed to better offspring genotypes of seed plants (Westby and Rice, 1992).

2.3 Seed set, germination and seedling vigour

The best procedure for obtaining high seed set in crosses, was by emasculating the female parent plants just before flower opening, without removing corolla and pollinating the emasculated flowers immediately afterwards (Rylski, 1986). Gikalo and Studenceva (1967) obtained the best yield of hybrid seed when pollination was carried out immediately after emasculation. Guaglitti (1977) suggested the best stage for picking fruits to get a high yield of

viable seeds per plant is that of red or yellow ripe stage. The best seeds are obtained from ripe fruits on the lower portion of the plants (Petrov Ho, 1965). According to Khah and Passam (1922) and Nandapuri et al. (1970), over all fruit weight was correlated with seed weight and seed number and declined throughout the life of the crop. Berry yield is directly proportional to 100 seed weight (Singh et al., 1970). Bozhkhova (1973) found that the 100 seed weight in cotton was strongly influenced by the position of the boll on the plant and the weight decreased from the bottom of the plant upwards. Decrease in seed weight with increase in plant age might be due to reduced net assimilation rate (Farbrother, 1954). Seed set was strongly affected by the maternal parent and pollen fertility (Betlach and Novak, 1973). Seeds and fruits found on the main stem were larger and had higher germination capacity. They also gave rise to seedlings with greater disease resistance and higher yield (Gikalo, 1966). The above difference may be due to lesser degree of maturity of seeds on side branches. Hill and Lord (1986) observed in wild radish (*Rayphanus raphanistrum*) that ovules are arranged in linear manner in ovary wherein middle position could be fertilized first through transmitting tissues in the ovary which allows pollen tubes to pass ovules while inside the septum and fertilize ovules lower in the ovary. This is a mechanism whereby the maternal parent regulates the sequence of ovule fertilization. In *Passiflora vitifolia* seed set was pollen limited and varied with pollination intensity (Snow, 1986).

McDade (1986) observed that pollination limited the seed set in *Trichanthera czigematea*.

Tomato plants of same variety when pollinated by adding pollen from egg plants or pepper had a favourable effect on the 1000 seed weight (Popova and Mihailov, 1968). Samigullina (1987) also reported that pollinating tomato plants with pollen mixtures including some foreign pollen like *Capsicum annuum* or *Solanum melongena* had a beneficial effect on both self and cross pollination. Wojciechowski and Andrzejewski (1986) crossed *Capsicum* cultivar with tomato pollen and noticed poor pollen germination and no fertilization. Pollinations with mixtures incorporating the pollen of tomato and other species on pepper had no effect on pollen germination or seed set, but mixing with tomato pollen increased early and total yield in hybrids (Hristov and Gencevo, 1965).

In peppers mixtures of pollen collected from many plants of pollen parent showed more marked heterosis for vigour, earliness and yield than the F_1 from seeds produced by pollination in normal way (Popova and Mihailov, 1972). In wit loof chicory (*Chicorium intibus*) gametic competition after mixed or double pollinations with self and foreign pollen was investigated by Eenink, 1992. Number of pollen grains placed upon a stigma influences both the development of pollen tubes and subsequently the progeny which resulted from fertilization by gametes (Ter-Avanessian, 1978). He also reported seeds from limited pollination showed a higher boll

weight seed weight and increased hairiness in cotton. Popova and Mihailov (1978) reported that pollination with large quantities of pollen from many plants was preferable to the use of pollen from a single plant. Seed set and seed production were improved by pollination with a large amount of pollen or pollination with mixed pollen from many plants of male cultivar (Rylski, 1986). Davis et al. (1987) reported that seeds from high pollen loads were more likely to emerge more rapidly and also tended to produce more flowers and fruits in early stage than seeds from low pollen load. A surplus of pollen grains is necessary both for ensuring the proper physiological conditions for fertilization as also for the maintenance of mean characters of the variety (Ter-Avanesian, 1959).

Bertin (1990) reported large pollen load on stigma were more likely to initiate fruit production with more seeds and a greater total seed mass. Schichting et al. (1987) who worked on *Louts corniculatus* and *Cucurbita* spp. reported that offspring derived from conditions of intense pollen competition were more vigorous than those derived from conditions of little or no competition and also showed reduced gametic variation. Bertin (1989) reported that in *Campsis radicaus*, the fruit production and number of seeds per fruit increased with pollen load on stigma but rate of germination did not differ.

MATERIAL AND METHODS

III MATERIALS AND METHODS

The investigations dealing with "Studies on standardization of hybrid seed production techniques in Bell pepper (*Capsicum annuum* L.) were carried out at the Division of Vegetable Crops, Indian Institute of Horticultural Research, Hessaraghatta, Bangalore, during kharif (June-September) of 1993. The experimental field is located at an altitude of 890 M above mean sea level and 13°N latitude and 77-37°E. The objectives were to standardize optimum nodal position of flower bud for pollen collection and effecting crosses and to study the effect of pollen grain load on seed set and quality.

3.1 Materials and Methods

1. *Female parents* : Two high yielding varieties namely Arka Basant and Arka Gaurav developed at the Indian Institute of Horticultural Research were used as female parents during the present investigations.

Arka Basant is a creamy white conical erect fruited variety with thick flesh and prolific continuous bearing. It has very good keeping and cooking qualities. It yields on an average of 150-200 quintals per hectare within 125-140 days.

Arka Gaurav is an indeterminate variety with dark green, blocky erect, 3-4 lobed, medium sized fruits (70-80 g). It yields 180-250 quintals per hectare within 125-150 days.

2. *Male parents* : PMR-1 is an indeterminate line with dark green, blocky erect, 3-4 lobed, excellent size and shape (120 g/fruit). It yields 1.2 kg per plant that is around 40 to 45 tonnes per hectare.

PMR-2 is also indeterminate line with dark green, blocky, pendant, 3-4 lobed, excellent size and shaped fruits. It yields 1 to 1.2 Kg per plant that is around 40 to 45 tonnes per hectare.

3. *Pollen staining and germination* :

A versatile stain was developed at IIHR, Hessaraghatta, Bangalore, by Alexander (1980). This was used to stain pollen grains and study their viability. The stain consists of Ethyl alcohol (95%) (20 ml), Melachite green (20 g), distilled water (50 ml), Glycerol (40 ml) and Acid fuchsin (100 mg).

Pollen germination was done using improved cellophane method (Alexander and Ganeshan, 1989). A sucrose medium was used to germinate pollen grains. It consisted 15 per cent sucrose solution, 300 ppm calcium nitrate, 200 ppm magnesium sulfate, 100 ppm potassium nitrate, 100 ppm boric acid and 50 ppm gibberellic acid 3.

4. *Effect of foreign pollen on seed set and seed quality*

Brinjal pollen (var. West-coast Green Round) and tomato pollen (Var. Pusa Ruby) were used with capsicum pollen (1:1) during pollination to study their effect on seed set and quality.

5. Seed germination test

The germination test was conducted using paper towels. A total of 4x100 seeds were randomly counted for each plot and uniformly placed in paper towel folds lined with polythene sheet. The seeds were allowed to germinate in a seed germinator maintained at $28\pm 1^{\circ}\text{C}$ temperature and 85 per cent relative humidity. Germination count was taken twice. The first count was taken on 7th day of incubation and the second test 14 days interval of incubation. The cumulative germination percentage was calculated on the basis of normal seedlings obtained on 7th and 14th day of incubation.

6. Measurement of root and shoot length

Ten seedlings from each replication were taken at random from the standard germination test to work out the mean root and shoot length. The root length was measured from the collar region to the tip of the primary root and shoot length from collar region to the tip of the leaf and was expressed in centimetre.

3.1.1 Effect of nodal position of flower bud on pollen size, viability and germination

The experiment was undertaken to study the effect of flower bearing pattern on pollen size, viability and germination.

A factorial CRD was used with 2x7 treatment combinations and 3 replications. The bell pepper flowers borne in a inflorescence are called biparus cyme where main

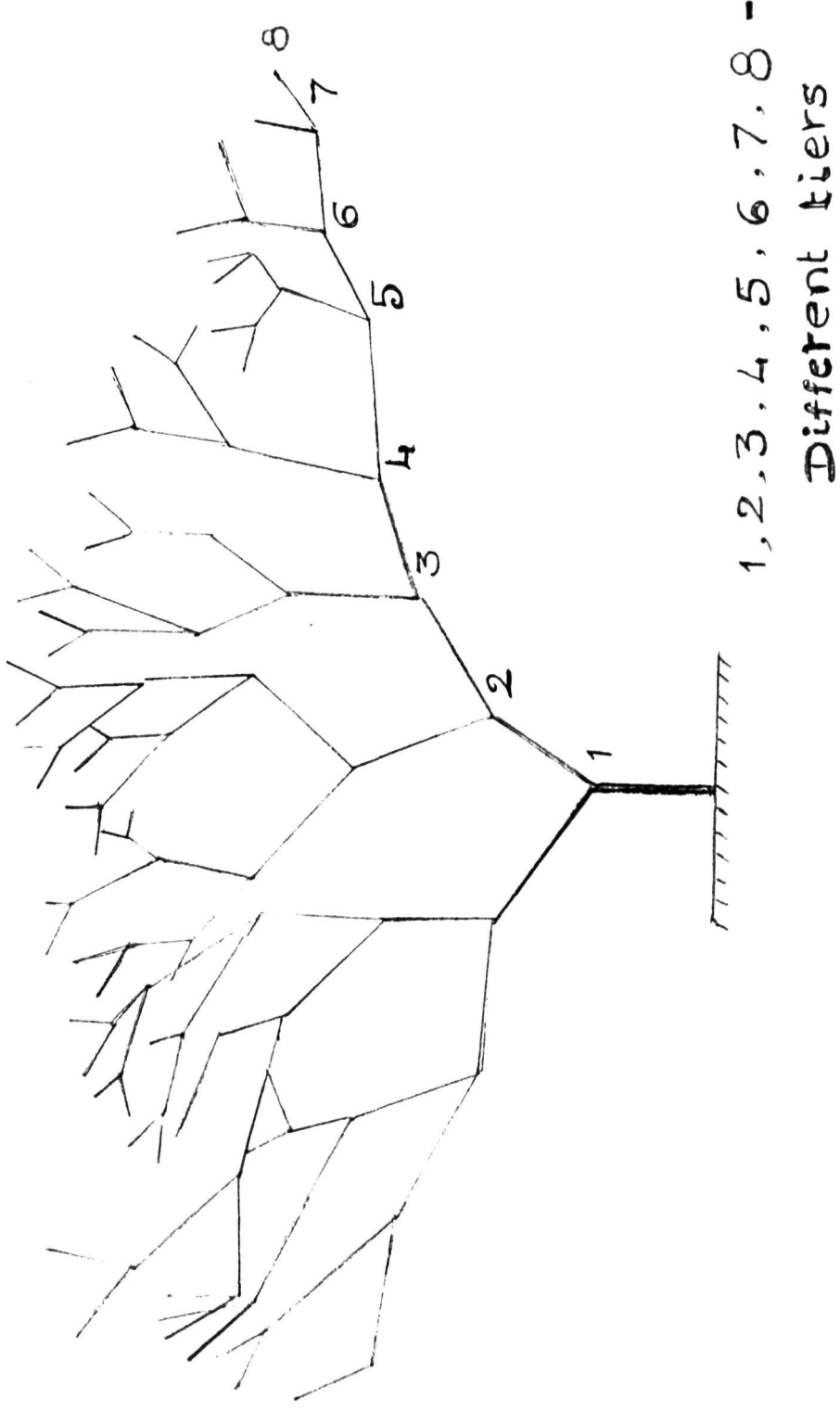


Fig 3.1 Schematic representation of typical
Bell Pepper plant : Biparus cymose inflorescence

axis ends in a flower and at the same time it produces two lateral younger shoots. The laterals and succeeding flowers develop in the same manner (Fig. 3.1).

The details of the treatment combinations are as follows :

Main treatments : Breeding lines PMR-1 and PMR-2.

Sub-treatments :

T₁ - Pollen collected from first tier flowers

T₂ - Pollen collected from second tier flowers

T₃ - Pollen collected from third tier flowers

T₄ - Pollen collected from fourth tier flowers

T₅ - Pollen collected from fifth tier flowers

T₆ - Pollen collected from sixth tier flowers

T₇ - Pollen collected from seventh tier and above flowers.

The following observations were recorded under microscope with three replications, each replication consisting of ten microscopic field with 15X x 10X magnification.

1. *Pollen size* : Ocular and stage micro meters were used to measure the size of pollen. Pollen grains were observed randomly under each microscopic field and mean pollen size was expressed in Micron (μ).

2. *Pollen viability (Stainability index)* : Pollen viability was estimated using a versatile stain as suggested by Alexander (1980). Under each microscopic field shrivelled

and stained green pollen grains were recorded as non-viable and other which were round and creamy red in colour were recorded as viable. The average viable pollen grains were estimated and expressed in percentage.

3. *Pollen germination* : Number of pollen grains germinated and the total number of viable pollen grains observed in each microscopic field were recorded. Pollen germination percentage was calculated by using the following formula :

$$\text{Pollen germination (\%)} = \frac{\text{Number of pollen grains germinated}}{\text{Total number of viable pollen grains}} \times 100$$

3.1.2 *Effect of flower age on pollen size, viability and germination (Flower/buds collected from 1 to 6 tiers on the plants)*

Factorial CRD with 2x4 treatment combinations and 3 replications was employed to study the above mentioned parameters. The details of the treatment combinations are as follows :

Main treatments : Breeding lines PMR-1 and PMR-2

Sub-treatments :

- T₁ - Pollen collected from flower buds a day prior to anthesis
- T₂ - Pollen collected from flowers on the day of anthesis
- T₃ - Pollen collected from flowers one day after anthesis
- T₄ - Pollen collected from flowers two days after anthesis

Observations pertaining to pollen size, viability and germination were recorded as described previously.

3.1.3 Studies pertaining to optimum nodal position of flower bud for effecting crosses

The freshly opened flowers (emasculated a day prior to anthesis) of Arka Basant and Arka Gaurav borne at third tier and above were cross pollinated by using pollen collected from PMR-2 at the time of anthesis. Such of the crossed flowers were wrapped with a thin layer of cotton to avoid contamination. Fruits were harvested when they were fully red or yellow ripe stage and seeds extracted.

A factorial RCBD was used with 2x3 treatment combinations and 4 replications. Each replication consists of ten crossed flowers. The descriptions of treatment combinations are as follows:

(A) Main treatments: Varieties : V_1 Arka Basant
 V_2 Arka Gaurav

Sub-treatments :

T_1 - Flowers borne at 3-4th tiers on the plants
 T_2 - Flowers borne at 5-6th tiers on the plants
 T_3 - Flowers borne at 7th tier and above on the plants

The percentage fruit set, number of seeds per fruit, 100 seed weight, percentage of seed germination and seedling vigour under each treatment were recorded and analysed using standard statistical procedures.

3.1.4 Effect of repeated pollination and mixed pollen on seed set and seed yield

[Flowers (emasculated a day prior to anthesis) from 3rd to 6th tiers on the plant were used to pollinate and seeds were extracted from red or yellow ripe fruits]

The freshly opened flowers of Arka Basant and Arka Gaurav were cross pollinated using pollen collected from PMR-2 according to various treatments as mentioned below :

A factorial RCBD was used with 2x7 treatment combinations and 3 replications. Each replication consists of ten crossed flowers.

(A) Main treatments : Varieties : V1 - Arka Basant and
V2 - Arka Gaurav

Sub-treatments :

- T₁ - Cross pollination one day prior to anthesis plus on the day of anthesis
- T₂ - Cross pollination on the day of anthesis plus next day of anthesis
- T₃ - Cross pollination with a mixture of capsicum plus brinjal pollen (1:1) on the day of anthesis
- T₄ - Cross pollination with mixture of Capsicum plus tomato pollen (1:1) on the day of anthesis
- T₅ - Cross pollination using a mixture of pollen collected from five plants of the same breeding line PMR-2 in equal proportion
- T₆ - Open pollination
- Y₇ - Cross pollination on the day of anthesis using pollen collected from a single plant

Observations were recorded on number of seeds per fruit, 100 seed weight, percentage of seed germination and seedling vigour under each treatment and data were analysed using standard procedure.

3.1.5 Pollen load on stigma and its effect on seed set and quality parameters

Freshly opened flowers (flowers borne on 3rd-6th tiers) of Arka Basant and Arka Gaurav (emasculated a day prior to anthesis) were cross pollinated using pollen of PMR-2 according to various treatments as mentioned below:

Factorial RCBD was used with 2x3 treatment combinations and 4 replications for statistical analysis. Each replication consists of crossing ten flowers.

- T₁ - Cross pollination, once on the day of anthesis
- T₂ - Cross pollination twice on the day of anthesis
- T₃ - Open pollination.

Observations were recorded on number of seeds per fruit, 100 seed weight, percentage of seed germination and seedling vigour under each treatment and data were analysed using standard statistical procedure.

Methods of recording observations on various parameters are detailed below :

1. *Percentage fruit set* : The number of fruits developed after seven days of crossing was recorded. This was expressed as percentage.

$$\text{Fruit set \%} = \frac{\text{Total number of fruits obtained}}{\text{Total number of flowers pollinated}} \times 100$$

2. *Number of seeds per fruit* : The mean number of seeds per fruit was worked out by extracting seeds from total number of ripe fruits harvested per replication divided by number of fruits harvested.

$$\text{Mean No. of seeds/fruit} = \frac{\text{Number of seeds obtained from 'N' number of fruits per replication}}{\text{'N' number of fruits per replication}}$$

3. *100 seed weight* : 100 seeds were counted per treatment replication wise and recorded in grams. The mean 100 seed weight was calculated over the replications.
4. *Seedling vigour* : Mean length of seedlings (shoot and root length) was calculated. Seedling vigour was expressed in terms of vigour index as suggested by Abdul Baki and Anderson (1973).

$$\text{Vigour index (V.I.)} = \frac{\text{Mean percentage germination of seeds}}{\text{Mean of seedling length}} \times$$

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

Various experiments were conducted in order to standardize optimum nodal position for effective pollination, effect of time of pollination, repeated pollination and pollination using mixture of pollen on seed set and seed quality.

4.1 Effect of bearing pattern of flower bud on pollen size, viability and germination

The effect of bearing pattern of flowers on pollen size, viability and germination was studied in two breeding lines PMR-1 and PMR-2 in different treatment combinations (Table 4.1). The results are as follows :

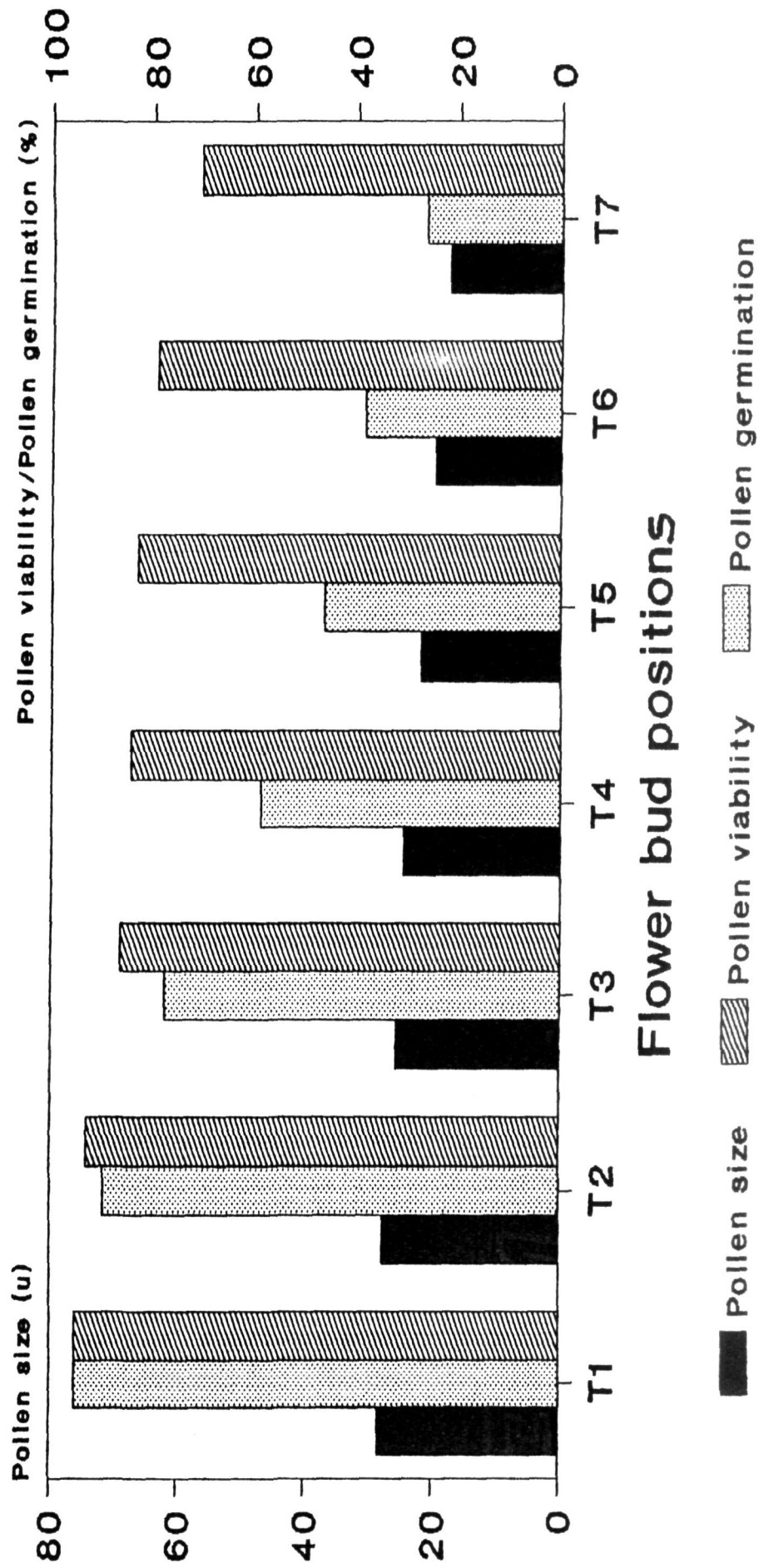
4.1.1 *Effect of treatment combinations (Factor A x B)*

The mean pollen size differed significantly among different treatment combinations. However, pollen viability and mean pollen germination percentage did not differ significantly (Table 4.1). Maximum pollen size (34.33 μ) was noticed in pollen collected from flowers borne on first tier of line PMR-1 and it was followed by 34 μ size observed in pollen collected from second tier flower of the same line PMR-1. Response of these two treatment combinations differed significantly from the remaining treatment combinations. Maximum pollen viability (97.52%) was observed in pollen collected from first tier of the line PMR-1 and the poorest (67.74%) obtain in pollen collected

Table 4.1 : Effect of flower bud bearing pattern on pollen size, viability and germination

Treatment combinations	Pollen size (μ)	Pollen viability (stainability index) (%)	Pollen germination (%)
<u>Factor A</u> : L ₁ PMR-1	28.3095a	87.3a	47.77
L ₂ PMR-2	18.9643b	81.59b	50.92
F-test	**	**	NS
SEM	0.416	1.095	
CD at 1%	1.143	4.277	
<u>Factor B</u> : T ₁ : 1st tier flower buds	28.41a	95.00a	76.00a
T ₂ : 2nd tier flower buds	27.75ab	92.76ab	71.63a
T ₃ : 3rd tier flower buds	25.71b	86.25b	62.00ab
T ₄ : 4th tier flower buds	24.50bc	84.36bc	47.00b
T ₅ : 5th tier flower buds	21.87d	82.96c	37.07bc
T ₆ : 6th tier flower buds	19.71e	79.31c	30.64bc
T ₇ : 7th tier flower buds	17.50f	70.73cd	21.29c
F-test	**	**	**
SEM	0.50	2.048	4.548
CD at 1%	2.150	8.001	17.76
<u>Interaction (AxB)</u> : L ₁ T ₁	34.33a	98.00	70.00
L ₁ T ₂	34.00a	97.52	65.41
L ₁ T ₃	30.16b	84.93	63.02
L ₁ T ₄	28.50b	86.37	49.44
L ₁ T ₅	25.25c	87.45	37.06
L ₁ T ₆	23.41cd	83.60	33.97
L ₁ T ₇	22.50cd	73.73	15.52
L ₂ T ₁	22.50cd	92.00	82.00
L ₂ T ₂	21.50de	88.00	77.86
L ₂ T ₃	21.25de	87.58	60.98
L ₂ T ₄	20.50de	82.36	44.56
L ₂ T ₅	18.50ef	78.48	37.09
L ₂ T ₆	16.0f	75.02	27.32
L ₂ T ₇	12.50g	67.74	27.07
F-test	**	NS	NS
SEM	0.778		
CD at 1%	3.040		

Fig 4.1 Effect of flower bud bearing pattern on pollen size, viability and germination



from seventh and above tiers on the breeding line PMR-2. Maximum pollen germination (82%) was observed in pollen collected from first tier on the breeding line PMR-2 and minimum (15.52%) was noticed in pollen collected from seventh and above tiers on line PMR-1.

4.1.2 *Response of main factors (Breeding lines) on pollen size, viability and germination*

The mean pollen size and viability differed significantly between two lines but not the pollen germination (Table 4.1). The maximum pollen size (28.30 μ) and pollen viability (87.3%) was observed in breeding line PMR-1. Pollen germination varied from 47.77 to 50.92 per cent in these lines.

4.1.3 *Response of sub-factors (different flower positions) on pollen size, viability and germination*

The mean pollen size, viability and germination varied significantly among the treatments (Table 4.1). The maximum pollen size (28.41 μ) and viability (95%) was observed in flowers borne on first tier and the results differed significantly from all other treatments (T₃-T₇) except the one borne on second tier (T₂). Maximum pollen germination was observed in flowers borne on first tier (76%), followed by second tier flowers (71.63%) and differed significantly from all other treatments except the flowers borne on third tier. The smallest pollen size (17.5 μ) and the poorest pollen viability (70.73%) and germination (21.29%) was observed in flowers borne on seventh tiers and above.

4.2 Optimum age of flower bud for pollen collection

The effect of different age of flower bud on pollen size, viability and germination was studied in two breeding lines PMR-1 and PMR-2 in different treatment combinations. The experimental results are presented below :

4.2.1 *Effect of treatment combinations (AxB)*

The mean pollen size differed significantly among different treatment combinations but not pollen viability and pollen germination (Table 4.2). Maximum pollen size (33.66 μ) was noticed in pollen collected from line PMR-1 on the day of anthesis and it differed significantly from all other treatment combinations. Maximum pollen viability (89.83%) was observed in breeding line PMR-1 on the day of anthesis and poorest pollen viability (82.20%) was observed in line PMR-2 two days after anthesis. Pollen germination varied from 11.5 to 65.4 per cent in different treatment combinations.

4.2.2 *Response of main factors (PMR-1 and PMR-2) on pollen size, viability and germination*

The mean pollen size and pollen germination differed significantly between the two breeding lines but not the pollen viability (Table 4.2). The largest pollen size (25.85 μ) was observed in PMR-1 followed by PMR-2 (19.13 μ). The maximum pollen germination (39.65%) was in PMR-2 followed by PMR-1 (29.58%). Pollen viability varied from 84.57 per cent in PMR-2 to 87.34 per cent in PMR-1.

Table 4.2 : Effect of flower age on pollen size, viability and germination

Treatment combinations	Pollen size (μ)	Pollen viability (stainability index) (%)	Pollen germination (%)
Factor A : L ₁ PMR-1	25.85a	87.34	29.57b
L ₂ PMR-2	19.13b	84.57	39.65a
F-test	**	NS	**
SEM	0.521		2.773
CD at 1%	2.1498		11.454
Factor B :			
T ₁ : A day prior to anthesis	20.50c	88.25	12.45b
T ₂ : On the day of anthesis	27.83a	88.92	62.50a
T ₃ : One day after anthesis	24.00b	86.43	47.05a
T ₄ : Two days after anthesis	17.62c	82.24	16.45
F-test	**	NS	**
SEM	0.736		3.92
CD at 1%	3.040		16.198
Interaction (AxB)			
L ₁ T ₁	23.00c	89.22	11.50
L ₁ T ₂	33.66a	89.83	60.00
L ₁ T ₃	28.00b	88.05	38.32
L ₁ T ₄	18.75cde	82.28	8.50
L ₂ T ₁	18.00de	83.27	13.40
L ₂ T ₂	22.00cd	88.00	65.40
L ₃ T ₃	20.00cde	84.81	55.80
L ₄ T ₄	16.50e	82.20	24.40
F-test	**	NS	NS
SEM	1.041		
CD at 1%	4.299		

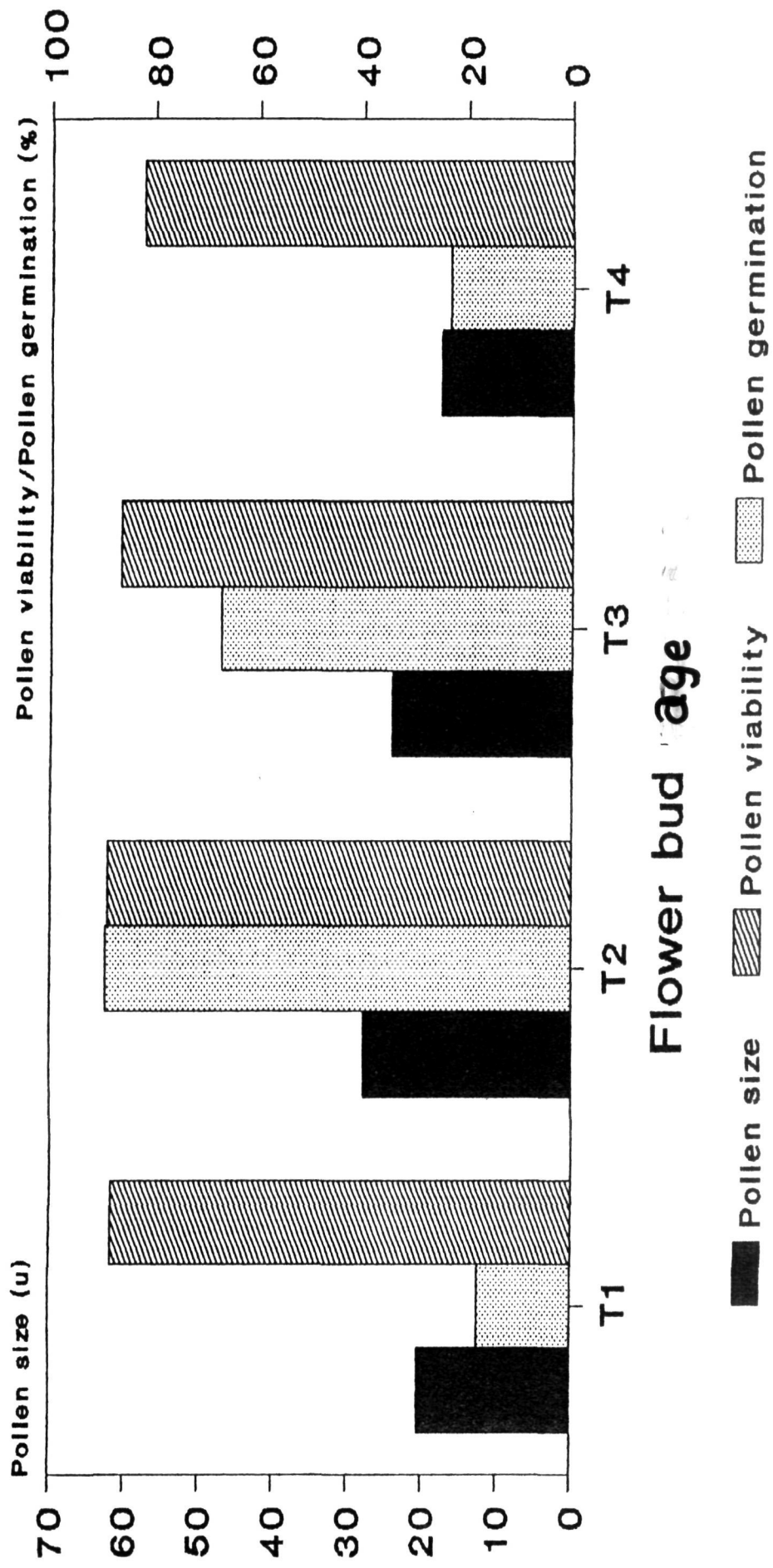


Fig 4.2 Effect of flower age on pollen size, viability and germination

4.2.3 *Response of sub-factors (age of flowers) on pollen size, viability and germination*

The mean pollen size and germination percentage varied significantly among treatments but not pollen viability (Table 4.2). The maximum size (27.83 μ) was observed in pollen grain collected on the day of anthesis and it differed significantly from rest of the treatments. The pollen germination was maximum (62.50%) in pollen collected on the day of anthesis followed by those a day after anthesis (47.05%) and it differed significantly from the remaining treatments.

4.3 *Flower bearing pattern and its effect on fruit set, number of seeds per fruit, 100 seed weight, seed germination and seedling vigour*

The effect of different position of flower bud on fruit set, number of seeds per fruit, 100 seed weight, percentage seed germination and seedling vigour (vigour index) was studied in two varieties Arka Basant and Arka Gaurav using pollen from breeding line PMR-2. The results are given below (Table 4.3 and 4.4).

4.3.1 *Effect of treatment combinations (AxB)*

The fruit set percentage, number of seeds per fruit, 100 seed weight, percentage of seed germination and vigour index did not differ significantly in different treatment combinations (Table 4.3 and 4.4). However, the maximum fruit set (77.5%), number of seeds per fruit (242.113), 100 seed weight (0.476 g) and vigour index (915) were observed in fruits collected from third and fourth tiers on the

Table 4.3 : Flower bearing pattern and its effect on fruit set, number of seeds per fruit and 100 seed weight

Treatment combinations	Fruit set (%)	No. of seeds per fruit	100 seed weight (g)
Factor A :			
V ₁ - Arka Basant	40.83	87.95b	0.3377a
V ₂ - Arka Gaurav	47.50	145.57a	0.4262b
F-test	NS	**	**
SEM		8.409	0.012
CD at 5%		25.339	0.037
Factor B :			
T ₁ : 3rd to 4th tiers	75.00a	183.53a	0.4628a
T ₂ : 5th to 6th tiers	40.00b	98.12b	0.4017b
T ₃ : 7th tier and above	17.50c	68.65c	0.281c
F-test	**	**	**
SEM	3.87	10.30	0.015
CD at 5%	11.67	31.03	0.046
Interaction (AxB) :			
V ₁ T ₁	72.50	124.94	0.450
V ₁ T ₂	37.50	83.13	0.343
V ₁ T ₃	12.50	55.80	0.221
V ₂ T ₁	77.50	242.11	0.476
V ₂ T ₂	42.25	113.12	0.461
V ₂ T ₃	22.50	81.50	0.342
F-test	NS	NS	NS
SEM			
CD at 5%			

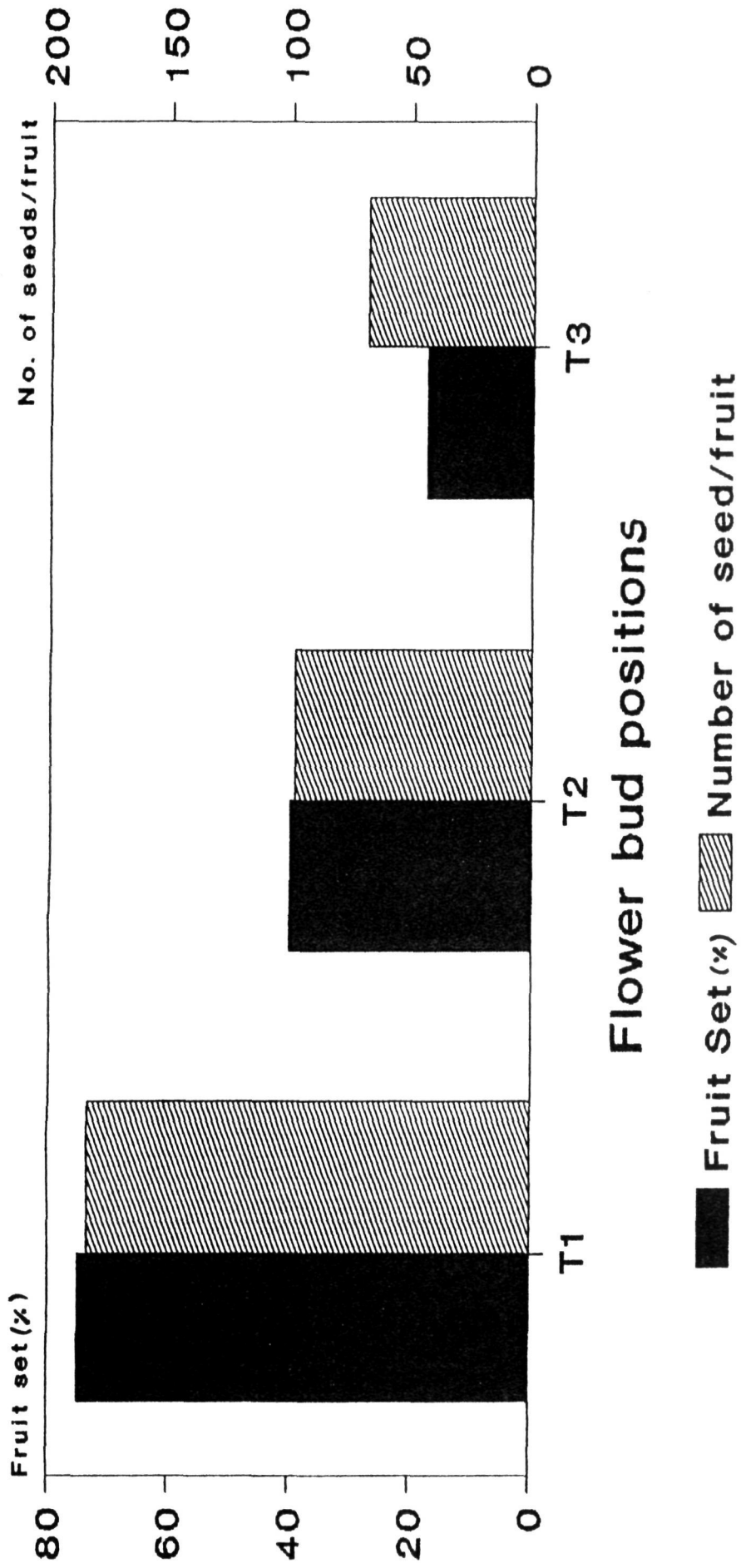
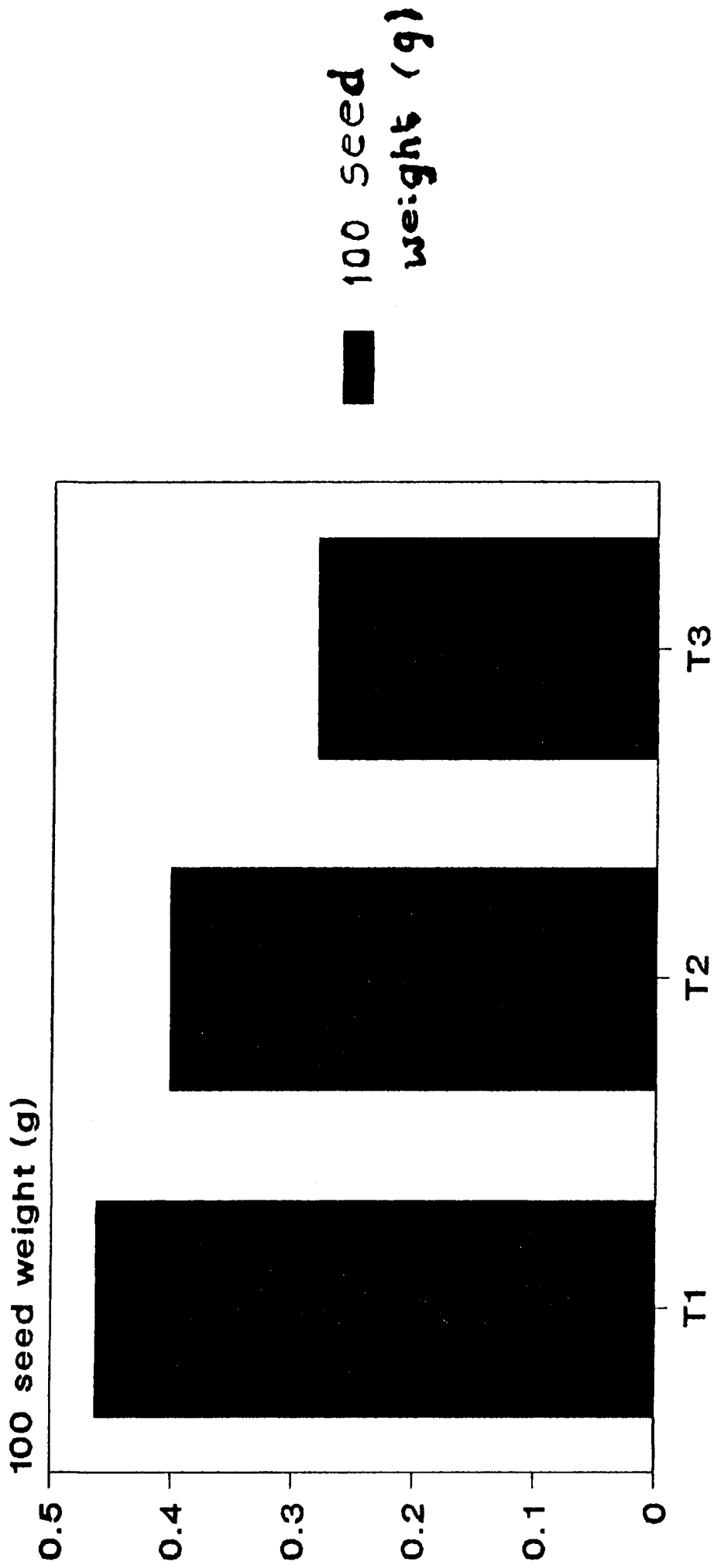


Figure 4.3 Effect of flower bearing pattern on fruit set and number of seeds per fruit



Flower bud positions

Fig 4.4 Effect of flower bearing pattern on 100 seed weight (g)

Table 4.4 : Flower bearing pattern and its effect on seed germination and vigour index

Treatment combinations	Seed germination (%)	Vigour index
<u>Factor A :</u>		
V ₁ - Arka Basant	56.67	360.28
V ₂ - Arka Gaurav	53.33	575.81
F-test	NS	**
SEM	34.56	
CD at 5%	104.16	
<u>Factor B :</u>		
T ₁ : 3rd to 4th tiers	65.00a	725.53a
T ₂ : 5th to 6th tiers	57.00b	453.83b
T ₃ : 7th tier and above	42.5c	224.78c
F-test	**	**
SEM	5.162	42.334
CD at 5%	7.30	127.564
<u>Interaction</u>		
V ₁ T ₁	71.00	536.05
V ₁ T ₂	59.00	377.60
V ₁ T ₃	40.00	167.20
V ₂ T ₁	60.00	915.00
V ₂ T ₂	55.00	530.06
V ₂ T ₃	45.00	282.38
F-test	NS	
SEM		
CD at 5%		

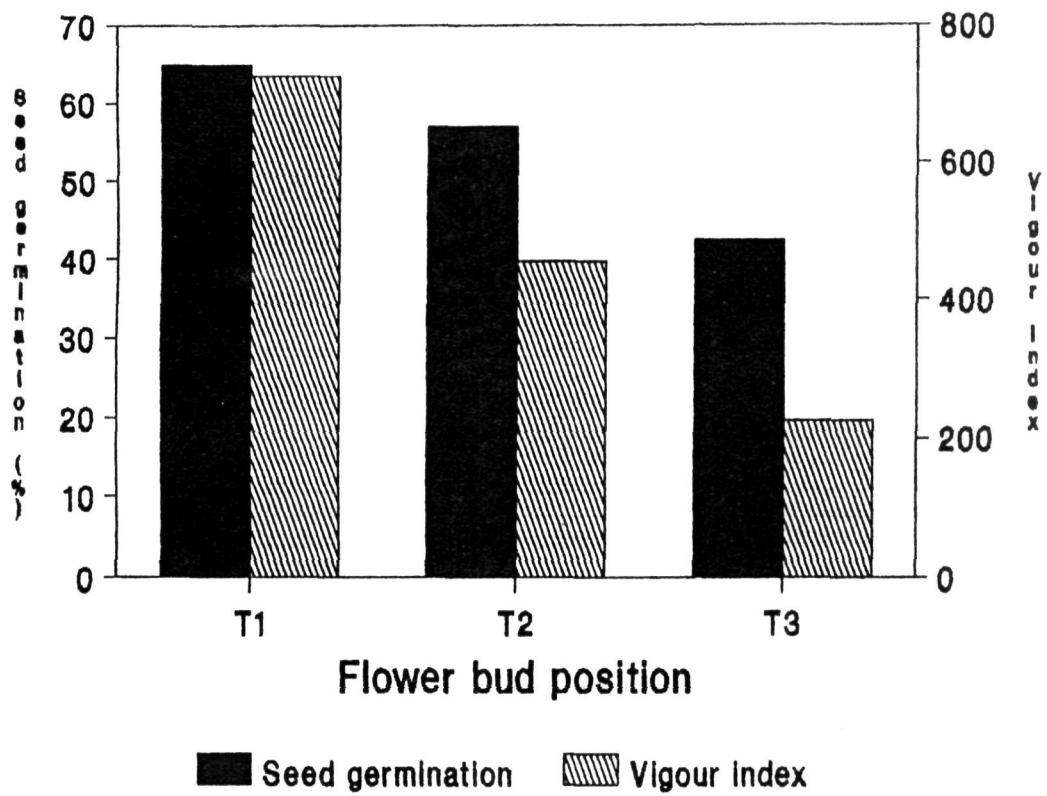


Fig 4.5 Effect of flower bearing pattern on seed germination and vigour index

variety Arka Gaurav. Maximum seed germination was observed in fruits collected from third and fourth tiers on the variety Arka Basant. Minimum percentage fruit set (12.5%), number of seeds per fruit (55.80), 100 seed weight (0.221 G), seed germination (40%) and vigour index (167.2%) was observed in fruits collected from seventh and above tiers in the variety Arka Basant.

4.3.2 Response of main factor (varieties) on fruit set, seeds per fruit, 100 seed weight, seed germination and vigour index

The number of seeds per fruit, 100 seed weight and vigour index differed significantly between two varieties but not in parameters like percentage fruit set, number of seeds per fruit and percentage seed germination. Maximum number of seeds per fruit (145.57), 100 seed weight (0.4262 g) and vigour index (575.81) was recorded in Arka Gaurav, followed by Arka Basant in above mentioned parameters. Percentage of fruit set and percentage of seed germination varied from 40.8 to 47.5 and 53.33 to 56.66 respectively.

4.3.3 Response of sub-factor (flower bearing pattern) on percentage of fruit set, number of seeds per fruit, 100 seed weight, percentage of seed germination and vigour index

Flowers borne on third ^{and fourth} tiers gave maximum fruit set (75%), number of seeds per fruit (183.53), 100 seed weight (0.4628 g), percentage of seed germination (65) and vigour index (725) differed significantly from those borne on rest of the tiers in above mentioned parameters.

4.4 Effect of repeated pollination and pollination using mixture of pollen on seed set and quality

The effect of repeated pollination and pollination using mixture of pollen on number of seeds per fruit, 100 seed weight, percentage of seed germination and vigour index was studied in two varieties Arka Basant and Arka Gaurav using pollen from Capsicum variety PMR-2 as well as pollen from brinjal (West coast green round) and tomato (Pusa Ruby). The results are described below (Table 4.5 and 4.6).

4.4.1 Effect of treatment combinations (AxB)

Number of seeds per fruit and vigour index differed significantly but not 100 seed weight and percentage seed germination among treatment combinations (Table 4.5 and 4.6).

Maximum number of seeds per fruit (319.417) was observed in V_2T_6 (open pollination in Arka Gaurav) followed by 228.75 and 213.107 in V_1T_6 (open pollination in Arka Basant) and V_2T_2 (pollinating twice i.e on the day of anthesis plus a day after anthesis in Arka Gaurav). Response of these treatment combinations differed significantly from all other treatment combinations except V_1T_2 (pollinating twice i.e on the day plus next day of anthesis in Arka Basant). Vigour index was maximum (1720) in treatment combination V_2T_5 (pollination with a mixture of pollen from five plants) and its response differed significantly from the remaining treatment combinations

Table 4.5 : Effect of repeated pollination and mixed pollen on number of seeds per fruit and 100 seed weight

Treatment combinations	No. of seeds per fruit	100 seeds weight (g)
<u>Factor A</u> :		
V ₁ - Arka Basant	143.63	0.4180
V ₂ - Arka Gaurav	173.18	0.4461
F-test	**	NS
SEM	5.917	
CD at 5%	17.201	
<u>Factor B</u> :		
T ₁ - Pollinating twice (one day prior + on the day of anthesis)	171.21c	0.3696c
T ₂ - Pollinating twice (one day of anthesis + next day of anthesis)	205.69b	0.5321a
T ₃ - Pollination on the day of anthesis using mixture of capsicum + brinjal pollen (1:1)	90.29d	0.4491ab
T ₄ - Pollination on the day of anthesis using mixture of capsicum + tomato pollen (1:1)	95.41d	0.5353a
T ₅ - Pollination on the day of anthesis using mixture of pollen from 5 plants of PMR-2 with equal proportion	158.08c	0.4202b
T ₆ - Open pollination	274.08a	0.3269d
T ₇ - Pollination on the day of anthesis using pollen from single plant	112.90d	0.3915bc
F-test	**	**
SEM	11.06	0.03
CD at 5%	32.18	0.087
<u>Interaction(AxB)</u> :		
V ₁ T ₁	134.48def	0.345
V ₁ T ₂	198.29bc	0.563
V ₁ T ₃	22.92fg	0.410
V ₁ T ₄	97.92fg	0.556
V ₁ T ₅	148.463de	0.344
V ₁ T ₆	228.75b	0.311
V ₁ T ₇	102.55fg	0.39
V ₂ T ₁	207.55bc	0.393
V ₂ T ₂	213.11b	0.502
V ₂ T ₃	87.67g	0.488
V ₂ T ₄	92.92fg	0.515
V ₂ T ₅	168.42cd	0.496
V ₂ T ₆	319.42a	0.342
V ₂ T ₇	123.25ef	0.387
F-test	**	NS
SEM	15.65	
CD at 1%	45.50	

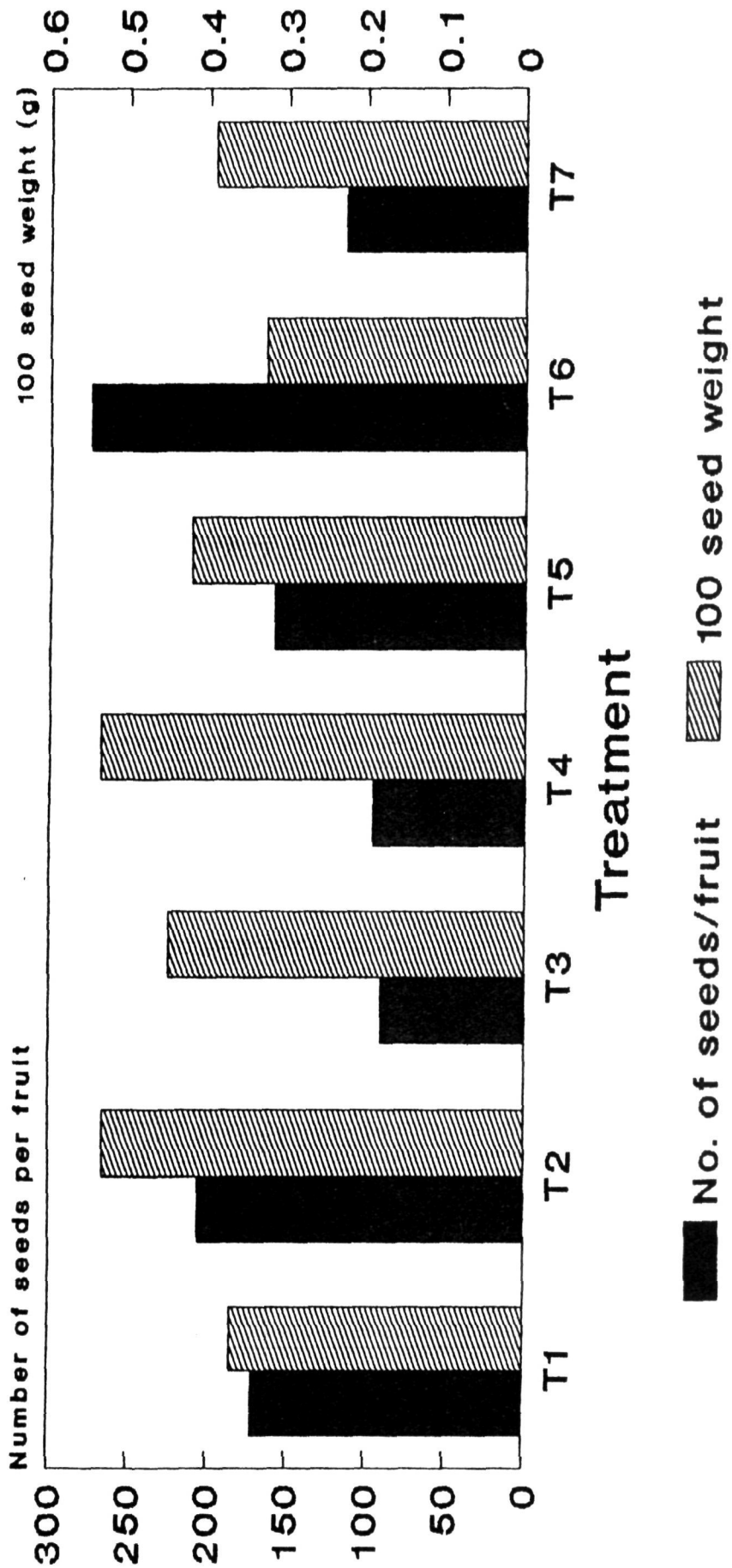


Fig 4.6 Effect of repeated pollination and mixed pollen on number of seeds per fruit and 100 seed weight (g)

Table 4.6 : Effect of repeated pollination and mixed pollen on seed germination and vigour index

Treatment combinations	Seed germination (%)	Vigour index
<u>Factor A</u> :		
V ₁ - Arka Basant	72.78	682.18b
V ₂ - Arka Gaurav	69.57	1018.20a
F-test	NS	**
SEM		45.806
CD at 5%		126.95
<u>Factor B</u> :		
T ₁ - Pollinating twice (one day prior + on the day of anthesis)	43.00c	295.74e
T ₂ - Pollinating twice (one day of anthesis + next day of anthesis)	91.00a	1039.06bc
T ₃ - Pollination on the day of anthesis using mixture of capsicum + brinjal pollen (1:1)	89.00a	1368.52a
T ₄ - Pollination on the day of anthesis using mixture of capsicum + tomato pollen (1:1)	67.50b	898.96c
T ₅ - Pollination on the day of anthesis using mixture of pollen from 5 plants of PMR-2 with equal proportion	82.00a	1256.13ab
T ₆ - Open pollination	65.00b	557.03d
T ₇ - Pollination on the day of anthesis using pollen from single plant	60.75b	535.85d
F-test	**	**
SEM	4.537	85.69
CD at 5%	12.573	237.50
<u>Interaction(AxB)</u> :		
V ₁ T ₁	41.00	271.42h
V ₁ T ₂	90.00	772.87def
V ₁ T ₃	95.00	1226.45
V ₁ T ₄	75.00	784.68bc
V ₁ T ₅	82.00	791.30de
V ₁ T ₆	62.00	485.92de
V ₁ T ₇	64.00	442.63efgh
V ₂ T ₁	45.00	320.06gh
V ₂ T ₂	92.00	1305.25bc
V ₂ T ₃	83.00	1510.60ab
V ₂ T ₄	60.00	1013.25cd
V ₂ T ₅	82.00	1720.97a
V ₂ T ₆	68.00	628.15efg
V ₂ T ₇	57.00	629.08efg
F-test	NS	**
SEM		121.19
CD at 1%		335.87

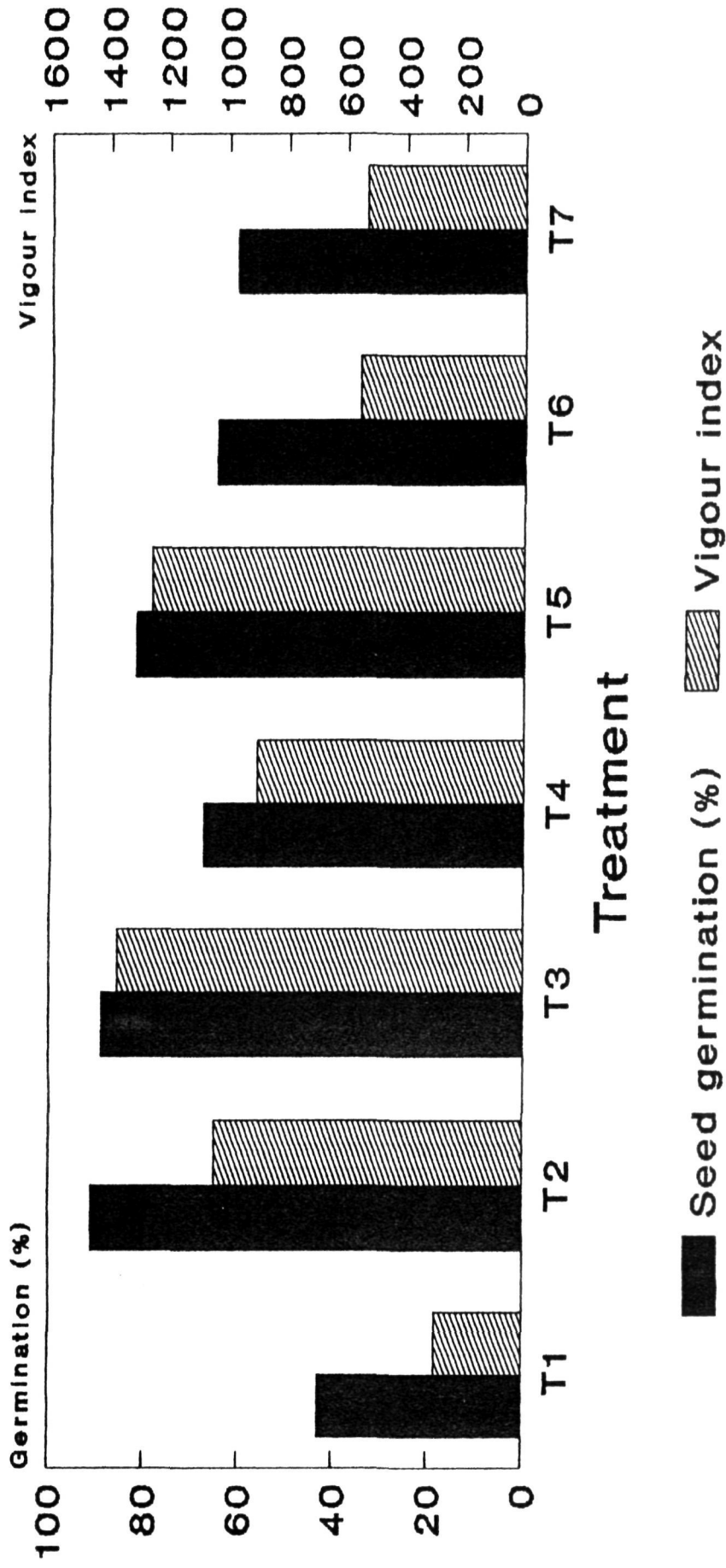


Fig 4.7 Effect of repeated pollination and mixed pollen on seed germination and vigour index

except V₂T₃ (pollinating with mixture of pollen from capsicum + brinjal). 100 seed weight and seed germination varied from 0.563 to 0.245 g and 47 to 95 per cent respectively.

4.4.2 *Response of main factor (varieties) on number of seeds per fruit, 100 seed weight, seed germination percentage and vigour index*

Number of seeds per fruit and vigour index differed significantly between varieties but not 100 seed weight and seed germination (Table 4.5 and 4.6).

Maximum number of seeds per fruit (158.90) and vigour index (1018.19) observed in variety Arka Gaurav and differed significantly from variety Arka Basant. 100 seed weight and seed germination varied from 0.4037 to 0.4318 g and 69.57 to 72.78 per cent respectively.

4.4.3 *Response of sub-factor (repeated pollinations pollination using mixture of pollen grains, open pollination and pollination on the day of anthesis) on number of seeds per fruit, 100 seed weight, seed germination and vigour index*

Number of seeds per fruit, 100 seed weight, seed germination percentage and vigour index varied significantly among treatments (Table 4.5 and 4.6). Maximum number of seeds per fruit (274) was observed in open pollination followed by 205 seeds per fruit in a treatment where pollination was done twice (on the day plus next day of anthesis). Response of both these treatments differed significantly from the remaining treatments. Maximum 100 seed weight was observed when pollination was done using mixture of pollen from tomato plus capsicum (0.5353 g)

followed by pollinating twice that is on the day of anthesis plus next day after anthesis (0.5321 g). Response of these treatments differed significantly from the remaining treatments except in a treatment where a mixture of pollen from capsicum plus brinjal was used for pollination. Maximum seed germination of 91 per cent was observed in a treatment where pollination was done twice i.e. on the day of anthesis plus next day of anthesis, followed by 89 per cent seed germination achieved by using a mixture of capsicum plus brinjal pollen used for pollination and 82 per cent seed germination where a mixture of pollen collected from five plants of the same breeding line PMR-2 was used for pollination. Response of these above mentioned treatments differed significantly from remaining treatments. Vigour index was maximum (1368.52) in treatment involving pollination using capsicum plus brinjal pollen. Response of this differed significantly from the remaining treatments except one treatment where pollination was done with a mixture of pollen from five plants of the same breeding line PMR-2.

4.5 Pollen load on stigma and its effect on number of seeds per fruit, 100 seed weight, seed germination and seedling vigour

Pollen load on stigma and its effect on number of seeds per fruit, 100 seed weight, percentage of seed germination and vigour index were studied in both varieties Arka Basant and Arka Gaurav. Pollen for crossing was collected from breeding line PMR-2. The results are given below.

4.5.1 *Effect of treatment combinations (AxB)*

Mean number of seeds per fruit varied significantly among treatment combinations but not the 100 seed weight, percentage of seed germination and vigour index. Maximum number of seeds per fruit (312) was noticed in open pollinated of Arka Gaurav. Response of this treatment combination differed significantly from rest of treatment combinations. 100 seed weight, seed germination and vigour index varied from 0.291 to 0.457g, 62 to 79 per cent and 73.27 to 1265.97, respectively.

4.5.2 *Response of main factors (Arka Basant and Arka Gaurav) on number of seeds per fruit, 100 seed weight, seed germination and vigour index*

Mean number of seeds per fruit and vigour index varied significantly between the varieties but not the 100 seed weight (Table 4.7 and 4.8). Maximum number of seeds per fruit (195.365) and vigour index (831.28) was noticed in Arka Gaurav followed by number of seeds per fruit (141.70) and vigour index (548.20) in Arka Basant.

4.5.3 *Response of sub-factors (different load of pollen), number of seeds per fruit, 100 seed weight, seed germination and vigour index*

Number of seeds per fruit, 100 seed weight and vigour index varied significantly among different treatments but not in seed germination (Table 4.7 and 4.8).

Maximum number of seeds per fruit (244.94) was observed in open pollination and minimum (97.14) was observed in one

Table 4.7 : Pollen load on stigma and its effect on number of seeds per fruit and 100 seed weight

Treatment combinations	No. of seeds per fruit	100 seed weight (g)
Factor A :		
V ₁ - Arka Basant	141.70	0.3682
V ₂ - Arka Gaurav	195.3675	0.3753
F-test	**	NS
SEM	6.178	
CD at 5%	18.617	
Factor B :		
T ₁ - One time pollination	97.145c	0.3778b
T ₂ - Two time pollination	163.5137b	0.445a
T ₃ - Open pollination	244.94a	0.2927c
F-test	**	**
SEM	7.567	0.014
CD at 5%	22.801	0.042
Interaction (AxB) :		
V ₁ T ₁	92.00c	0.379
V ₁ T ₂	155.215b	0.432
V ₁ T ₃	177.895b	0.294
V ₂ T ₁	102.29c	0.377
V ₂ T ₂	171.81b	0.457
V ₂ T ₃	312.00a	0.291
F-test	**	NS
SEM	10.701	
CD at 5%	32.245	

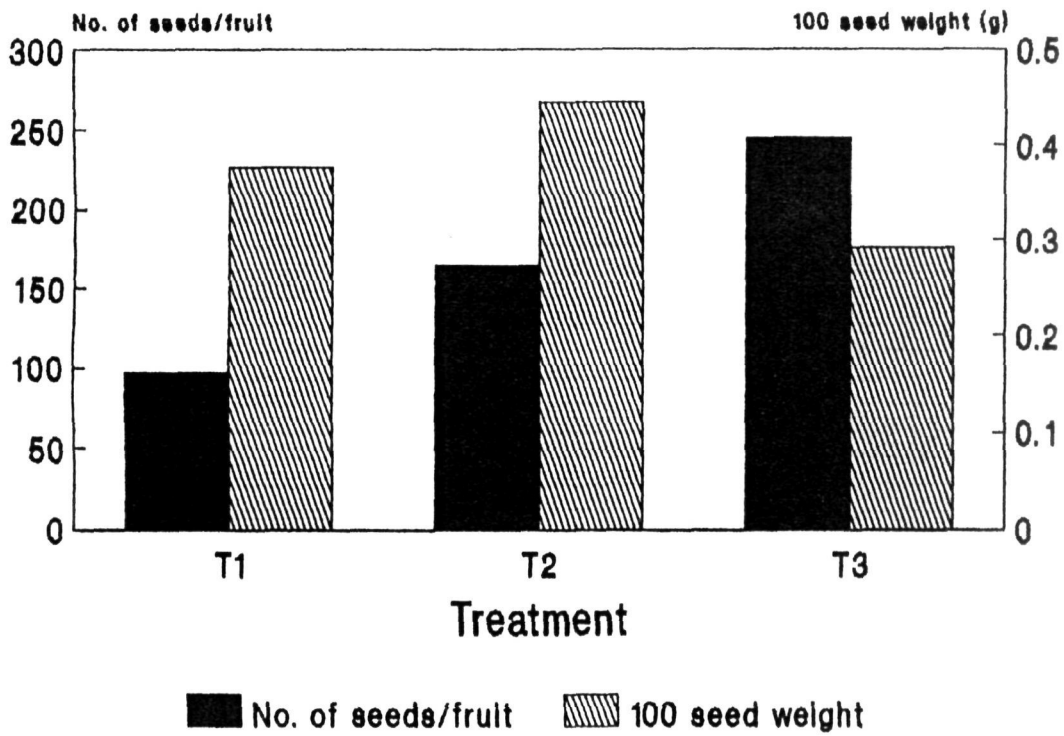


Fig 4.8 pollen load on stigma *and its effect*
 on number of seeds per fruit and
 100 seed weight (g)

Table 4.8 : Pollen load on stigma and its effect on seed germination and vigour index

Treatment combinations	Seed germination (%)	Vigour index
<u>Factor A :</u>		
V ₁ - Arka Basant	67.50	548.20b
V ₂ - Arka Gaurav	69.25	831.28a
F-test	NS	**
SEM		59.82
CD at 5%		180.267
<u>Factor B :</u>		
T ₁ - One time pollination	63.00	492.56b
T ₂ - Two time pollination	77.00	1015.02a
T ₃ - Open pollination	64.50	561.65b
F-test	NS	**
SEM		73.27
CD at 5%		220.78
<u>Interaction (AxB) :</u>		
V ₁ T ₁	65.00	394.63
V ₁ T ₂	75.00	764.06
V ₁ T ₃	62.00	485.92
V ₂ T ₁	61.75	590.48
V ₂ T ₂	79.00	1265.97
V ₂ T ₃	67.00	637.38
F-test	NS	NS
SEM		
CD at 5%		

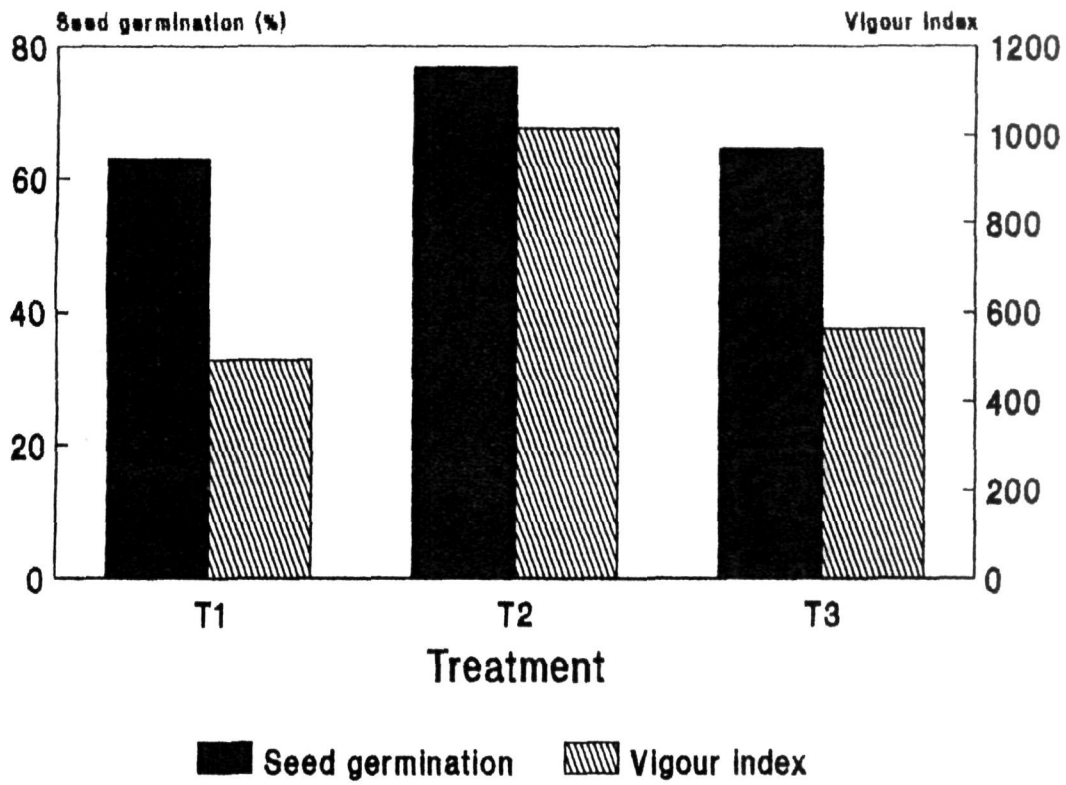


Fig 4.9 pollen load on stigma and its effect on seed germination and vigour index

time pollination treatment. Maximum 100 seed weight(0.445 g) was found in seeds collected from fruits where pollination was done twice. Minimum (0.2927 g) was observed in seeds obtained from open pollinated fruits. The highest vigour index (1015) was obtained from seeds of twice pollinated fruits. Response of this treatment differed significantly with the remaining treatments. Seed germination varied from 63 to 77 per cent among treatments.

DISCUSSION

V DISCUSSION

Bell pepper (*Capsicum annuum* L.) is one of the most popular and highly remunerative vegetable crops of India. Though several F₁ hybrid varieties have been developed in capsicum yielding (23.2 to 46.79 per cent) more than the better parent (Singh et al., 1993), yet those hybrids are not within the easy economic access of marginal farmer because of poor seed yield as well as high cost of hybrid seed production. Flower and fruit bearing pattern in capsicum have a strong effect on pollen fertility, fruit and seed set. Seed set is further influenced by pollen load on the stigma, time of pollination and the number of times a female flower is pollinated. Result obtained during the present investigations pertaining to the above mentioned parameters affecting fruit set and seed set in capsicum are discussed below :

5.1 *Effect of flower bearing pattern and flower age on pollen germination, pollen size and pollen viability (staining index)*

The effect of flower bearing pattern and flower age on *in vitro* pollen germination, viability and pollen size was studied in two capsicum breeding lines PMR-1 and PMR-2. Flowers in these lines are borne in a biparus cyme forming seven and more tiers (Fig.3.1). Superior pollen germination was observed in flower borne on first, second and third tiers (62 - 76%), pollen germination was less than 50 per cent in flowers borne on fourth tier onwards. Similar trend

was observed in pollen viability and pollen size during the present investigation. Somewhat similar results were obtained by Brink (1924), Vasil (1960) and Nair and Deshpande (1968) working with *Luffa cylindrica* in which late blooming flowers were found sterile. Low pollen germination in flowers borne on the fourth tier onwards might be due to the strong sink imposed by the developing fruits on lower tiers (1st-3rd tiers), thus diverting maximum photosynthates towards them, causing partial starvation of these flowers borne on higher tiers. Similar suggestions were given by Westboy and Rice (1992) working with seed plants.

Age of flower had significant effect on pollen germination which ranged from 47 to 62.5 per cent when pollen were collected from anthers on the day of anthesis and a day after anthesis. Poor pollen fertility was observed a day prior to anthesis and two days after anthesis. Rylski (1986) observed that no successful pollination in capsicum was obtained using pollen taken from flower buds two days prior to anthesis, or from flowers 3 days after anthesis. Popova (1959) and Kiss (1970) reported that successful pollination was obtained when pollen from newly dehisced anther or a day old are used to pollinate flowers. In Capsicum fresh pollen had the highest viability and generally gave the best performance in hybrid seed production (Kismova, 1968). During the present investigation the stainability index did not differ significantly with the age of the flower. Shivanna and

Johri (1985) reported that stainability index is not the only criteria to judge viability of pollen. Pollen viability can be confirmed either through pollen germination or enzymatic test. The enzymatic test depends on activity of some enzymes like amylase and phosphatases. Pollen size, differed significant at different age of flower bud and ranged 17.62 μ (two days after anthesis) to 27.83 μ (on the day of anthesis). Reason may be due to desiccation of pollen as reported by Rylski (1986). He also identified that desiccation of capsicum pollen starts very rapidly that is 4 to 6 hrs after anthesis.

5.2 *Flower bearing pattern and its effect on fruit set, number of seeds per fruit, 100 seed weight, seed germination and seedling vigour*

During the present investigation, first two tier flowers were pinched off because as the early fruits enlarge on the plant, even vegetative growth and flower production. On the subsequent tiers, are inhibited as reported by Berny (1970). Further studies by Kato and Tanaka (1971) revealed that only after first fruit matures, the subsequent vegetative growth flowering and fruit setting will resume, thus repeating the cycle. Khah and Passam (1992) also observed lesser number of seeds per fruit and lower seed weight in .1st formed fruits of capsicum.

After emasculation, each flower was wrapped with a thin layer of cotton to avoid contamination since cross pollination in capsicum has been observed to range from 1 to 46 per cent as reported by Green Leaf (1986).

Results from the present investigation indicated that maximum fruit set (75%), number of seeds per fruit (183.525), 100 seed weight (0.4628 g), seed germination (65%) and vigour index (725.525) was obtained from flowers borne on third and fourth tiers of the plant. Cirkova-Gorgievska (1966) observed that in *Capsicum* most of the fruits are borne on third to fourth tiers of the plant. Daskalov and Popava (1962), Free (1975), Kalyangina and Pugachev (1986) and Khah and Passam (1992) noticed significant decrease in fruit set with the increase in number of tiers on the plant. Reason may be due to limited resource allocations available within the plant to support fruits on later formed tiers (Pyke, 1982).

In cultivars of domesticated and wild common bean (*Phaseolus vulgaris*), Nakamura (1986) observed that early cohorts were much more likely to produce mature pods indicating that the beans would abort their fruits in a manner that conserves parental investment but do not discriminate the genetic quality of the offspring. Westoby and Rice (1992) observed in seed plants, resource moves towards the strongest sink. Competition occurs at hierarchy of levels : between branches when the strength of the sink is affected by the number and vigour of the fruits on the branches, between fruits on a branch when the strength of the sink is affected by the number and vigour of developing seeds in a fruit, between offspring within a fruit when the

strength of the sink is affected by the vigour of each developing offspring. Thus mother can cause limited investment to be directed selectively to better offspring genotypes. Wyatt (1981) observed that the most important factor determining fruit set in *Asclepias tuberosa* is the competition for resource among ovaries within umbles. Umbles closer to the source of resources that is main stem have higher probabilities of setting fruit as evident from the decreasing success of umbles further out along a branch.

Khah and Passam (1992) got the best seeds in *Capsicum* from ripe fruits on the lower portion of pepper plants. They also noticed decrease in number of seeds per fruit with increase in number of tiers on the plant. Nandapuri *et al.* (1970) also observed in *Capsicum* decreased in number of seed per fruit with the increase in age of plant. They also obtained maximum 100 seed weight from fruits collected from third-fourth tiers of the plant. The 100 seed weight decreased with the increase in plant age. Bozhkhova (1973) found that the 100 seed weight in cotton was strongly influenced by the position of the ball on the plant and the weight decreased from bottom of the plant upwards. This might be due to the decrease in net assimilation rate (Farbrother, 1954). Gikalo (1966) reported that seeds from fruits formed on the main stem were larger and had a higher germination capacity. The possible reason suggested for above difference was due to lesser degree of maturity of seeds on side branches.

5.3 *Effect of repeated pollination and pollination using mixture of pollen on number of seeds per fruit, 100 seed weight, seed germination and seedling vigour*

Maximum number of seeds per fruit (274) was obtained in open pollinated fruits (control). Same results were also observed by Mulge (1992) in capsicum. One of the reasons may be due to intermittent pollination by natural agents like honey bee or ants. A total of 112 seeds per fruit were obtained with one time pollination on the day of anthesis in Capsicum. However, 75 per cent increase in number of seeds per fruit was observed when pollination was done twice (once on the day of anthesis and second next day of anthesis). This indicates that all ovules in the female parent probably do not mature at the same time. Repeated pollination was thus beneficial. Green Leaf (1986) reported that fertilization in pepper occurs only after 3 days of anthesis. Rylski (1986) reported that fertilization in pepper generally takes place within 56 to 72 hrs. He also investigated that stigma receptivity is maximum on the day of anthesis and is dependent on temperature lasting for 4 days under cool conditions and in some cultivars upto maximum of 7 days. This suggested that additional pollination increased number of seeds per fruit. In the linear arrangement of ovules in the ovary of *Raphanus raphanistrum* (wild radish), Hill and Lord (1986) Observed that ovules in middle portion could be fertilized first by pollen through transmitting tissues in the ovary which allows pollen tubes to pass ovules while inside the septum

and fertilize ovules lower in the ovary. This is a mechanism whereby the maternal parent regulates the sequence of ovule fertilization. Snow (1982) observed in *Passiflora vitifolia* that seed set is pollen limited and varied within pollination intensity. In another instance, McDade (1983) observed that pollination limits seed set in *Trichanthera gigantea*.

Mixed pollen collected from five different plant of the same variety when used for cross pollination resulted in increase of 40.33 per cent in number of seeds per fruit, 7.3 per cent in 100 seed weight, 35 per cent in seed germination and 135 per cent in vigour index when compared to pollination treatment involving pollen collected from a single pollen parent. Rylski (1986) reported that seed set and seed production in pepper were improved with mixed pollen from many plants of the pollinating cultivar. Mixture of pollen collected from many plants of pollen parent showed marked heterosis for vigour, earliness and yield than the F_1 from seed produced by pollination in normal way (Popova and Mihailov, 1972). Mixed pollen may provide wider gametic diversity and better competition resulting in to better seed set and vigour as observed by Eenink (1992) in wit loof chicory (*Chicorum intibus*).

Treatments involving pollinations with mixture of capsicum plus tomato pollen or capsicum plus brinjal pollen reduced number of seeds per fruit but increased the 100 seed

weight. Popava and Mihailov (1968) reported that tomato plants of same variety when pollinated by adding pollen from egg plants or pepper had a favourable effect on 1000 seed weight. Pollination of tomato plants with pollen mixtures including some foreign pollen like *Capsicum annuum* or *Solanum melongena* had beneficial effect.

Hristov and Gencevo (1965) found an increase in early and total yield in hybrids of pepper after pollination using mixture of capsicum plus tomato pollen. Mixed pollination (mixture of capsicum plus brinjal or tomato), thus reduced the number of seeds per fruit, but helped in increasing the 100 seed weight, seed vigour and germination. Ter Avanesian (1978) also got higher seed weight, boll weight and increased hairiness in cotton with limited pollination.

5.4 Pollen load on stigma and its effect on number of seeds per fruit and 100 seed weight

Maximum number of seeds per fruit was obtained in open pollinated fruits (control) but 100 seed weight and seedling vigour was less compared to those observed in hand pollination. It may be due to intermittent pollination and competition among the large number of seeds developing in fruit for food.

Increase of 68.5 per cent in number of seeds per fruit, 18 per cent in 100 seed weight, 21 per cent in germination of seeds and 105 per cent seedling vigour was observed in treatment involving double pollination simultaneously

compared to treatment involving single pollination. Davis et al. (1987) reported that seeds from high pollen loads were more likely to emerge more rapidly and tended to produce more flowers and fruits in early stage than seeds from low pollen load. Ter-Avanesian (1959) observed surplus of pollen grains is necessary for ensuring the proper physiological conditions for fertilization. Bertin (1989) also noticed in *Campsis radicans* the fruit production and number of seeds per fruit increased with pollen load on stigma. He also noticed large pollen load on stigma are more likely to initiate fruit production with more seeds and a greater total seed mass.

SUMMARY

VI SUMMARY

The investigations on "Studies on standardization of hybrid seed production techniques in Bell pepper (*Capsicum annuum* L.)" were carried out at the Division of Vegetable Crops, Indian Institute of Horticultural Research, Hessaraghatta, Bangalore, during the kharif season of 1993. The objectives were to standardize optimum nodal position of flower bud for pollen collection and effecting crosses and to study the effect of pollen grain load on seed set and quality.

Results pertaining to pollen size, pollen viability and *in vitro* pollen germination in pollen parent PMR-1 and PMR-2 and fruit set, seed set, seed germination and seedling vigour in female parent Arka Basant and Arka Gaurav are summarized below :

1. The mean pollen size, viability and germination in pollen parent varied considerably among flowers borne on different tiers of the plants. The maximum pollen size (28.41 μ), viability (95%) and germination (76%) was observed in flowers borne on first tier. The lowest pollen size (17.5 μ), viability (70.73%) and germination (21.29%) was recorded in flowers borne on seventh tier and above.
2. The mean pollen size, viability and germination varied significantly with the different development stages of

flowers. The maximum pollen size (27.83 μ), viability (88.91%) and germination (62.50%) was found in pollen collected from flowers on the day of anthesis. The lowest pollen size (17.62 μ), viability (82.4%) and germination (16.45%) was observed in pollen collected from flowers two days after anthesis.

3. Maximum fruit set (75%), number of seeds per fruit (183.52), 100 seed weight (0.4628 g), seed germination (65%) and seedling vigour (725.25) was observed in flowers borne at third and fourth tiers of plant and different significantly in these parameters from those borne on the subsequent tiers.
4. Maximum number of seed per fruit (205) and seed germination (91%) were observed in treatment involving pollinating the female parents twice, i.e., once on the day of anthesis and the second on the next day of anthesis. Percentage of seed germination also did not differ significantly in treatments involving pollination with a mixture of capsicum plus brinjal pollen (1:1) (89%) and pollination with mixture of pollen from five plants of breeding line PMR-2 (82%). Hundred seed weight was maximum (0.5353 g) in a treatment involving pollination with a mixture of capsicum plus tomato pollen (18%) which is followed by treatment involving pollination once on the day of anthesis and second on the next day of anthesis (0.5321

g). Seedling vigour was maximum in a treatment involving pollination with mixture of capsicum plus brinjal pollen (1368.52) which differed significantly from the rest of treatments except the one where pollination was done with a mixture of pollen collected from five plants of the same breeding line in equal proportion.

5. In a treatment involving two time pollination simultaneously on the day of anthesis, increase of 68.5 per cent in number of seeds per fruit, 18 per cent in 100 seed weight, 21 per cent in seed germination and 105 per cent of seedling vigour was observed when compared with treatment involving one time pollination.

Future line of work

1. Effect of seasonal difference in pollen viability and germination in bell pepper (*Capsicum annuum* L.) at different tiers of the plant.
2. Correlation studies with the duration of stigma receptivity and duration of ovule viability.
3. Use of vital dye for assessing pollen viability.

REFERENCES

VII REFERENCES

- Abdul Baki, A.A and Anderson, J.D., 1973, Vigour determination in soyabean seeds by multiple criteria. *Crop Sci.*, 13 : 630-633.
- Alexander, M.P., 1980, Versatile stain for pollen, fungi, yeast and bacteria. *Stain Technol.*, 55 : 13-18.
- Alexander, M.P. and Ganeshan, S., 1989, An improved cellophane method for *in vitro* germination of recalcitrant pollen. *Stain Technol.*, 64(5) : 225-227.
- Anonymous, 1966, International rules for seed testing. *Proc. Int. Seed Test Assoc.*, 31 : 1-152.
- Anonymous, 1969, Minimum seed certification standards for capsicum. Minimum Seed Certification Standards, New Delhi.
- *Aventikyan, N.L. and Stepanyan, S.S., 1973, Duration of viability in the pistil and pollen of sweet pepper. *Referativny Zhurnal.*, 9 : 58-63.
- Barai, B. and Roy, K., 1986, Studies on anthesis and duration of pollen and stigma viability in some chilli varieties. *Expt. Genet.*, 2(1-2) : 51-53.
- Basak, R.K., 1967, The pollen grains of solanaceae. *Bull. Bot. Soc. Bengal*, 21 : 49-58.
- *Betlach, J. and Novak, F., 1973, Study of artificial hybridization in vegetable pepper (*Capsicum annum* L.). *Zahradnictvi*, 2/3 : 97-106 (*Plant Breed. Abst* 44 : 6159).
- Berny, M. 1970, Effect of irrigation on flowering and fruit set of red pepper *Acta Agron. Acad. Sci. Hung.*, 19 : 398-401.
- Bertin, R.I., 1989, Effects of pollination intensity in *Campsis radicans*. *Am. J. Bot.*, 76 : 91-92.

- Bertin, R.I., 1990, Effect of pollination intensity in *Campsis radicans*. *Am. J. Bot.*, 77 : 178-187.
- Brink, R.A., 1924, The physiology of pollen II *Amer. J. Bot.* 2 : 283-294.
- *Bozhkhova, Y., 1973, Investigation of the germinability of the progeny produced from seed taken from different parts of the cotton plant. *Restenievdli Nauki*, 8 : 85-91.
- *Cirkova-Gorgievska, M., 1966, Studies on the morphological characteristics of the fruit of some varieties of pepper *Capsicum annuum* (Syn. *Capsicum maxicanum* Hazenb.) with respect to seed production. *Ann. Fac. Agric.*, 19 : 219-254 (*Hort. Abst.*, 38 : 5828)..
- Cochen, S. and Dukas, J., 1990, The optimal number of female flowers and fruits to flower ratio in plants under pollination and resource limitation. *Am. Nat.*, 135 : 218-241.
- *Daskalov, H. and Popova, D., 1962, Studies on flowering biology and pollination of red pepper *Capsicum annuum* L. *Sofija* 13 : 5-18 (*Plant Breed. Abst.*, 33 : 1949.
- *Davis, L.E., Stephenson, A.G. and Winsor, J.A., 1987, Pollen germination improves performance and reproductive output of the common Zucchini squash under field conditions. *J. Am. Soc. Hort. Sci.*, 112(4) : 712-716.
- *Dempsey, A.H., 1966, Effect of storage and stage of flower development on viability of pepper pollen. *Hortscience*, 1 : 56-57.
- Eenink, A.K., 1982, Gametic competition after mixed pollination and double pollinations in witloof chicory (*Chicorium intybus*). *Euphytica*, 31 : 773-786.
- *Farbrother, H.G., 1954, Progress Report. *Expt. Sta. Uganda*. p 15-21.

- Free, J.B., 1975, Pollination of *Capsicum frutescens* L., *Capsicum annuum* L. and *Solanum melongena* L. in Jamaica. *Trop. Agric.*, 52(4) : 353-357.
- Gill, H.S. and Tomar, B.S., 1991, Vegetable statistics at a glance. *PDVR Tech. Bull.*, 4 : 16.
- Gikalov, G.S., 1966, Diverse quality of seeds on sweet pepper plant. *Bull. Appl. Bot. Gen. Pl. Breed.*, 38(1) : 110-123.
- *Gikalov, G.S. and Studenceva, L.I., 1967, The techniques of producing hybrid pepper seed. *Breed. Seed Growing*, 1 : 56.
- Green Leaf, W.H., 1986, Pepper breeding. In : *Breeding Vegetable Crops*. AVI Publishing Company, Baset., M.J., pp 67-134.
- *Guaglitti, L., 1977, Effect of ripening stages of the berries and of the storage within the fruits on viability of seeds in two varieties of pepper. *Eucarpia meeting on Genetics and Breeding Capsicum. Hort. Abst.* 49 : 3467.
- Hill, J.P. and Lord, E.M., 1986, Dynamics of pollen tube growth in wild radish. I. Order of fertilization. *Evolution*, 40 : 1328-1333.
- *Hristov, S. and Gencevo, S., 1965, A study of some problems of the floral biology of pepper (*Capsicum annuum* L.) in relation to heterosis and hybrid seed production. *Sofia*, 2 : 605-615. (*pl. bree. abstr.* 37 : 4698)
- *Il'enko, T.S., 1969, Effect of pistil growth and duration of pollen storage on fruit set in intervarietal crosses of sweet pepper. *Zemledeliya i Ovoshchevodstva* 10(1) : 163-169. (*Pl. breed. abstr.*, 42 : 5900)
- *Kalyagina, L.G. and Pugachev, I.I., 1986, Dynamics of flowering in red pepper in Central Asia. *Vzbekiston Biol. Zurnali*, 4 : 35-37.

- Kato, T. and Tanaka, 1971, Studies on the fruit setting and development of sweet pepper I. fruiting behaviour. *J. Jap. Soc. Hort. Sci.*, 40 : 359-366.
- Khah, E.M. and Passam, H.C., 1992, Flowering, fruitset and development of the fruit and seed of sweet pepper cultivated condition of high ambient temperature. *J. Hort. Sci.*, 67(2) : 251-258.
- Kismova, L., 1968, Some considerations on the use of stored pollen for the production of hybrid seed in vegetables. *Leurar Sti. Inst. Curr. Hort. Vit.*, 10 : 33-45.
- Kiss, A., 1970, Studies of pollen viability in the tapioszele varietal collection of red pepper. *Agron. Botanica*, 12 : 53-60.
- Mazer, S.J., 1987, Parental effects on seed development and seed yield in *Raphanus raphanistrum* - Implications for natural and sexual selection. *Evolution*, 41 : 353-371.
- McDade, L.A., 1983, Pollination intensity and seed set in *Trichanthera gigantea*. *Biostropica*, 15 : 122-126.
- Mulge, R., 1992, Early generation testing in bell pepper (*Capsicum annum* L.) to develop F₁ hybrids resistant to powdery mildew. Ph.D. thesis. University of Agricultural Sciences, Bangalore, India.
- Nair, P.K.K. and Deshpande, S.U., 1968, Pollen studies in successive flowers of *Luffa cylindrica* (Linn.) M.J. Royen. *J. Palynology*, 4 : 98-106.
- Nakamura, R.R., 1986, Maternal investment and fruit abortion in *Phaseolus vulgaris*. *Am. J. Bot.*, 73 : 1049-1057.
- Nandapuri, K.S., Gupta, V.P. and Thakur, P.C., 1970, Correlation studies in chillies. *J. Res. Punjab Agric. Univ.*, 7(3) : 301-303.
- *Petrov Ho, 1965, Studies on heterogeneity of red pepper seeds. *Plovdiv*, 14(2) : 157-167. (*Plant Breed. Abst.*, 36 : 4700)

- Popova, D., 1959, The duration of viability and stigma receptivity in red pepper. *Sofija*, 8 : 215-227.
- *Popova, D., 1963, Utilizing heterosis in the cultivation of peppers in Bulgaria. *Agrobiology*, 871-874.
- *Popova, D. and Mihailov, L., 1968, The influence of some factors on the 1000 seed weight in F₀ heterosis tomatoes. *Genet. Solekc.*, 1 : 279-293.
- *Popova, D. and Mihailov, L., 1972, Effect of some factors on the manifestation of heterosis in sweet pepper. *Priroda* 21(4) : 71-74. (*Pl. Breed. Abst.*, 43 :6172)
- Popova, D. and Mihailov, L., 1978, Biological basis of the hybrid seed production in peppers (*Capsicum annuum* L.). *Acta Hort.*, 83 : 83-87.
- Pyke, G.H., 1982, Fruit set in *Lambertia formosa* sm. *proteaceae*. *Aust. J. Bot.*, 30 : 39-45.
- Raghuvanshi, R.K., 1976, Pollen in *Capsicum* L. *J. Palynol.*, 12(1/2) : 82-86.
- Rylski, I., 1986, Pepper (capsicum). In : *CRC Hand Book of Fruitset and Development*, CRC Press, Florida. pp. 341-348.
- *Saccardo, F. and Ramulu, K., 1977, Cytological investigations in the genus *Capsicum*. *Laboratorio Valorizzazione Colture Industrial del CNEN.*, pp 51-56. (*Pl. breed. Abst.*, 48 : 8896)
- *Samigullina, N.S., 1987, Use of foreign pollen in pollinating tomato. *Referativnyi Zhurnal.*, 9(65) : 252.
- Schichting, C.D., Stephenson, A.G., Davis, L.E. and Winsor, J.A., 1987, Pollen competition and offspring variance. *Plant Cell Incompatibility Newsletter* 19: 79.
- Shivanna, K.R. and Johri, B.M., 1985, *The Angiosperm Pollen Structure and Functions*. Wiley Eastern Ltd., New Delhi. pp 291.

- Singh, D.P., Anand, N. and Deshpande, A.A., 1993, **Improvement of bell pepper.** In : *Advances in Horticulture.* (ed. Chadha, K.L. and Kallo, G.). Malhotra Publishing House, New Delhi, India. pp 87-104.
- Snow, A.A., 1986, Pollination dynamics in *Equilibrium cannum onagraceae* : Consequences for gametophytic selection. *Am. J. Biol.*, 73 : 139-151.
- Ter-Avanesian, D.V., 1959, The effect of the quantity of pollen used in the inheritance of character. *Indian J. Genet.*, 19 : 30-35.
- Ter-Avanesian, D.V., 1978, The effect of varying the number of pollen grains used in fertilization. *Theor. Appl. Genet.*, 52 : 77-79.
- Vasil, I.K., 1960, Studies on pollination germination of certain cucurbitaceae. *Amer. J. Bot.*, 47 : 239-247.
- Vijay, O.P., Singh, D.P. and Yadav, I.S., 1979, Studies on flower development, fruit maturity and floral biology in sweet pepper (*Capsicum annum* L.). *Veg. Sci.*, 6(1) : 5-10.
- Westoby, M. and Rice, B., 1992, Evolution of seed plants and inclusive fitness of plant tissues. *Evolution*, 36 : 713-724.
- Wojciechowski, A., and Andrzejewski, R.P., 1986, Evaluation of crossability in intergeneric crosses of *Lycopersicon esculantum* L. based on the pollen tube growth. *Bull. Polish Acad. Sci. Biol. Sci.*, 34(10-12) : 219-225.
- *Wyatt, R., 1981, The reproductive biology of *Ascelpius tuberosa*. II. Factor determining fruit set. *New Phytol.*, 88 : 375-385.

ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ
ವಿಶ್ವವಿದ್ಯಾನಿಲಯ ಗ್ರಂಥಾಲಯ
ಗಾ.ಕೃ.ವಿ.ಕೆ , ಬೆಂಗಳೂರು-65

29 APR 1994

Th. 3316

ಅನುವೃದ್ಧಿ ಸಂ.....

ಪ. ಸಂ.....