STUDIES ON STANDARDIZATION OF HYBRID SEED PRODUCTION TECHNIQUES UNDER SHADE HOUSE AND OPEN FIELD CONDITIONS IN TOMATO (*Solanum lycopersicum* L.)

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae (also known as the nightshade family) having chromosome number (2n=24). It is believed to be originated from Peruvian and Mexican region. It is one of the most popular self pollinated and widely grown annual vegetable crops. Tomato is cultivated in tropics and subtropics of the world and all over India and it is used as modal plant species to study the physiology and biochemistry of seed development, germination and dormancy (Suhartanto, 2002). It is being cultivated in kitchen gardens, commercial fields and under polyhouse, shade house, net house, poly tunel condition and soil less culture or hydroponic systems.

Tomatoes contribute to a healthy, well-balanced diet and play vital role in rainbow diet type of emerging concepts. They are rich in minerals, vitamins, essential amino acids, sugars and dietary fibers. Tomato contains vitamin B and C, iron and phosphorus. Tomato fruits are consumed fresh in salads or cooked in sauces, soup and meat or fish dishes. They can be processed in to juices and ketchup. Canned and dried tomatoes are economically important processed products, and survey conducted by the University of California at Davis ranked tomatoes as the single most important fruit or vegetable of western diet in terms of overall source of vitamins and minerals (Petro-turza, 1986) and the most important is that the tomato consumption has been shown to reduce the risks of cardiovascular disease and certain types of cancer such as cancers of prostate, lung and stomach (Giovannucci 1999 and Canene Adams *et al*., 2005).

Tomato ranks third in priority after potato and onion in India but ranks second after potato in the world. India ranks second in the area as well as in production of tomato next to China. India ranks second in the world with an area of 865.0 hector, production of 16826 metric tons and productivity of 19.5 mt per ha. Karnataka ranks second next to Andhra Pradesh in production and productivity 1756.7 metric tons and 34.3 mt per ha respectively and area 51.2 ha (Anon., 2011a) and major hybrid seed producing belts in Karnataka are Haveri, Davengare, Belgaum, Dharwad and Bangalore. The Netherland and Chaina are the world leader in intensification of fresh tomato production in greenhouses.

Export of tomatoes has increased from 1, 34,845.15 tons in 2007-08 to 2, 66,986.38 tons in 2011-12. Which accounts to more than 97 percent increase, (Anon., 2011b). India's yields of tomatoes are very low (17.5 tons/ha) compared to many countries like U.S.A., Spain, Italy, Egypt, Brazil etc. In order to be competitive, India must enhance productivity of quality produce. Further, if India has to penetrate Middle East countries effectively, it must enhance quality of tomatoes and bring it to international standards in its produces and though increasing productivity of quality produce of tomato in Indian plains is reduced to a greater extent due to higher temperature which can be explored by Hi-Tech precision modern agricultural systems. The protected cultivation practices can reduce the temperature of tropical regions in north and south Indian plains to get quality produce. As this is the latest practices in Indian agriculture where the plants are grown under controlled or partially controlled environment resulting in higher yields than under open condition (Navale *et al.,* 2003).This technology can also be explored to produce quality tomato hybrid seeds to get quality tomato production and productivity.

Shade house is an important low cost structure for the farmers to minimize biotic and abiotic stress on seed crops, which could be grown round the year, during off-season and also under extreme climatic conditions. It provides a controlled environment inherently free from pest and diseases which help in increasing the fruit and seed yield production and productivity per unit area as compared to open field condition. The shading was effective in reducing light penetration and temperature inside the shade house thereby creating better microclimate for production of higher yield and quality of fruits and seeds (Tiwari *et al*., 2002).

Protected cultivation structures such as shade house and net houses are gaining lot of importance in field of hybrid seed production in the recent decade, due to the increasing demand for quality hybrid seeds of vegetable in domestic and international market. On other side vegetable hybrid seed production in open field condition is facing major and challenging problem of increase in the atmospheric temperature due to global warming which is leading to sudden climatic changes, unseasonal rains and prolong drought, which is leading to lower fruit set %, early fruit maturity, lesser seed yield and higher pest and disease incidence and affecting the high cost hybrid and varietal seed production as well as common agronomic crop production.

The exploitation of heterosis, has led to the development of hybrid, varies in a number of vegetable crops, mainly tomato, chilli and brinjal. The use of hybrid seed has become popular among the commercial vegetable growers and farmers in India recently to meet ever increasing demand for tomato; use of hybrids is one of the means to meet the consumers demand. As hybrids in tomato offer several advantages such as higher productivity, improved quality, resistance to biotic and abiotic stresses and also provide a quick and convenient way of combining desirable characters. In India, Indo-American Hybrid Seed Company took lead to develop and release of first hybrid in 1973 and also taken lead in hybrid seed production under protected condition. It has been realized that hybrids perform better than self pollinated cultivars in respect of uniformity of product, yield, quality, resistance to pest and diseases and adoption to different environmental condition and long storage life. The heterosis in tomato has been exploited for developing hybrids through manual hand emasculation and hand pollination.

In Japan, USA and Holland, seeds of the F_1 hybrids are invariably used for growing tomato chilli and cucumber in glasshouse. It is more profitable to grow the higher yielding and better quality F_1 hybrids than the open pollinated varieties in protected structure, wherein the cost of production is high. Hybrid seed being costly, utmost care and skill must be exercised in raising crop from them therefore; viable hybrid seed production technology for protected cultivation under shade houses type of structure should be developed in order to realize the best potential of hybrid.

One of the main factors affecting crop productivity is plant population which is mainly governed by the plant architecture, soil fertility and time of planting. Maintenance of optimum plant density especially under cover assumes greater importance since it accounts for many fold increase in yield when other factors are non-limiting (Harish *et al.,* 2011).

Pollens are most essential and precious genetic material which transmit the male gametic material in sexual reproduction of all higher plants. Unlike varietal seed production, hybrid seed production involves an effective crossing of emasculated flower with desired pollen or sterile female parent with a selected fertile restorer. So, only desired and viable pollens play a vital role in deciding the success of hybrid seed set on its parent. Kallo (1988) reported that the pollen can be stored for three to four days under ordinary conditions and Jolli (2004) reported that two days old pollen is best to achieve the highest fruits set (%) and seedling vigour index in DTH-1 tomato hybrids female parent line. Further, in hybrid seed production inadequacy of pollens on account of biotic or abiotic factors is very much felt leading to poor seed set. Hence, the protected structures like shade house can play vital role to produces healthy pollens by minimizing biotic and abiotic stress on pollen parent. There is a need to acquire knowledge of pollen viability of the pollen which are produced under shade house and its further application in hybrid seed production to obtain higher quality seed yield.

Optimal receptivity of the style during pollination is of atmost important for efficient hybrid seed production, the desirable hybrid seed production can be obtained from the female parent when there is a perfect coincidence of stigma receptiveness and pollen viability. The stigma receptivity plays a crucial role in hybrid seed production of tomato, Sidhu (1980) reported that the stigma become receptive 16 before anthesis and remain for two to three days after anthesis, Jolli *et al.* (2007) reported that highest fruit set percentage and seedling vigour index were observed when pollination is done three days after emasculation in Arka Alok tomato seed parent. The stigma receptivity largely influenced by the biotic or abiotic factors which can be manipulated by use of protected structures like shade house. Therefore, stigma receptivity after days of emasculation and subsequent pollinations is to be optimized to get increased seed set and yield in female parent of tomato under protected condition as in shade house However, research work pertaining to stigma receptivity is very meagre and inconclusive. With this background, an investigation on hybrid seed production of tomato under shade house condition cv. parental lines of Pusa hybrid-2 during 2012-13 was under taken with the following objectives.

i. To study influences of growing conditions and plant spacing on growth, seed yield and quality of tomato hybrid seed production.

ii. To know the pollen viability of pollen parent (male) and stigma receptivity of seed parent (female) in hybrid seed production of tomato under shade house.

REVIEW OF LITERATURE

The farmers in India involved in vegetable hybrid seed production of different crops, specially tomato is among the most prepared crops by the Indian farmers for profitable hybrid seed production, traditionally farmers practiced the tomato hybrid seed production in open field condition due to which the seed and pollen parental line exposed and face the challenge of harsh sun light, temperature, heavy rain fall and wind speed during their growth period which leads to, low fruit set, higher pest and diseases, lower pollen viability and stigma receptivity, low seed yield and quality or even failure of complete hybrid seed production program. In recent development in seed sciences and technology, the use of protected structure as growing condition for seed crop gaining importance in current decade. Among the different protected structures the low cost with simple components and concept the shade house gaining first choice by farmers to overcome above listed problem of hybrid seed production in open field.

Newly evolved and superior type of hybrids of crops need to be assessed for their optimum density of planting to achieve maximum fruit and seed yield and seed quality both under shade house condition and open field condition and the pollen viability of pollen parent (male) and stigma receptivity of seed parent (female) in (F1) hybrid seed production of tomato under shade house The literature pertaining to hybrid seed production under protected condition and open field , plant population, pollen viability and stigma receptivity with special reference to tomato and other related crop are reviewed and presented in this chapter

2.1 Experiment I : Effect of growing conditions and plant spacing on growth, seed yield and quality of tomato hybrid seed production

2.1.1 Effect of growing condition on growth parameters

Papadopoulos and Ormrod (1990) carried out a experimental in three different season to know the effect of six equidistant spacing’s (23, 30, 38, 45, 53 and 60) by four row planting on growth and developments of green house tomato’s compared to open field and observed that significant increase in growth parameters like plant height (172.0 cm ,199.0 cm and 138.6cm) and inter-nodal length of stem (7.8, 8.1 and 7.9 cm) in different three season respectively under green house due to the closer spacing compared to open field condition plant height (160.9, 189.6, 126.2 cm) and inter-nodal length of stem (7.0, 7.8 and 7.1 cm). And leaf area decreased steadily at all reductions in plant spacing’s (faster in green house then open field condition) among which green house recorded (9295, 11211, 10673 cm^{-2}) in different three season respectively compared to open field condition (9678, 1142, 11566 cm^{-2}). Similarly under same experiment greenhouse conditions recorded significantly higher number of flower clusters and percentage of fruit set were significantly higher compared to open field irrespective of spacings and wider spacing (60 cm) recorded significantly higher number of flower clusters and percentage of fruit set irrespective of growing condition.

Sharma and Tiwari (1993) carried out a experimental study on the effect of shade on growth, growth contributing characters and factors in relation to yield of tomato. Four shade treatments ranging from 1:1(1 row of tomato: 1 row of maize) to 4:1 (4 rows of tomato: 1 row maize) were tried. Plant height, soil temperature and light intensity fruit set, days to harvest, number and weight of fruits per plant, weight and diameter of fruits, fruit juice ratio, seed weight per kg fruit and ripe fruit yield were significantly influenced by shading. Number of primary branches, leaf area, fresh and dry weight of plant was not affected significantly.

Megharaja (2000) recorded significantly higher plant height (94.36 cm), number of branches (31.94) and total number of fruits (12.08) in capsicum under polyhouse condition compared to plants grown under open condition (45.33 cm, 14.25 cm and 5.43 cm. respectively) in capsicum cv. Indira. Higher values with regard to fruit length, fruit breadth, fruit weight and fruit volume (8.54 cm, 6.76 cm, 120.06 g and 255.97 cc, respectively) were recorded with capsicum fruits grown under greenhouse condition as compared to those procured from open field (5.67 cm, 4.40 cm, 56.17 g and 114.42 cc, respectively).

Nagalakshmi *et al.* (2001) noticed that crop are grown under polyhouse showed better plant height tomato cv. S-41(206.8cm), capsicum variety Green Gold (92.3cm) and cauliflower (41.0cm) and number of branches/leaves tomato cv. S-41 (7.8), capsicum variety Green Gold(8.3) and cauliflower (13.0).

When compared to the crop raised under open condition recorded lower plant height tomato cv. S-41 (128.5 cm), capsicum variety Green Gold (51.4cm) and cauliflower (33.0 cm), number of branches/leaves tomato cv. S-41 (4.6), capsicum variety Green Gold(6.4) and cauliflower (10), and earlier in flowering and fruiting were observed in green house when compared to the crop raised under open condition..

Naik (2005) reported that, among the three growing conditions *viz.*, medium cost polyhouse, low cost polyhouse and net house the medium cost polyhouse recorded higher yield. The favourable environmental conditions prevailing in medium cost polyhouse might have helped in better growth of roots and shoots which directly helped in better vegetative growth and finally improving the yield attributing parameters viz., number of fruits per plant (10.29), fruit weight per plant (1.02), pericarp thickness at blossom end (1.23 cm), fruit length (8.49cm) and fruit breadth (7.24) and these finally led to highest total yield of 37.77 t per ha.

Pandey *et al.* (2005) conducted experiment on comparative performance of capsicum lines under glasshouse, polyhouse and open field condition and observed that the plant heights mean values ranged from 77.3 to 65.5 cm in glasshouse 64.0 to 75.3 cm in polyhouse and 64.5 to 52.3 cm in open field condition and fruits per plant (no.) varied from 25 to11 in glasshouse 24 to 9.5 in polyhouse and 20 to 5.9 in open field condition and over all suggested that glasshouse with ventilation in the roof and side windows were found more superior than open field condition and polyhouse for the production of capsicum

Kavitha *et al.* (2008) conducted experiment to elucidate the effect of shade and fertigation on growth, yield and quality of tomato hybrid Ruchi. The experiment was concluded with the results that the shade and fertigation levels and in combination significantly influenced the yield. The highest yield was obtained at 100% water soluble fertilizer and shade followed by 100 % straight fertilizers under shade in all the three seasons.

Thangam and Thamburaj (2008) studied the comparative performance of tomato varieties and hybrids under shade and open condition among which average plant height under shade varied from 307.58 cm to 126 cm and 88.45 to 42.25 in open field number of primary branches per plant under shade was 3.56 were in open field it was 3.50 and the days to first flowering prolonged under shade were mean values ranged from 28.00 to 50.5 compared to open field it mean values varied from 17.00 to 39.50 and the mean no. of fruits per plant varied from 12.35 to 32.4 under shade and 32.55 to 79.00 in open field found that plants grown under shade exhibited better growth and dry matter production compared to those grown in open field.

Zende (2008) conducted an experiment in capsicum cv. Orobelle under two growing environments *viz.*, naturally ventilated polyhouse and shade house and reported that the maximum plant height (144.01 cm) and leaf area (108.34 dm^2) per plant was maximum in naturally ventilated polyhouse than shade house (125.18 cm) shade house (100.20 dm^2). Days to 50 per cent flowering was initiated early under naturally ventilated polyhouse than shade house.

Parvej *et al.* (2010) reported that polyhouse favoured the growth and development of tomato plants through increased plant height, number of branches per plant and leaf area index over the plants grown in open field condition. Flowering in polyhouse plants were advanced two days early compared to the crop raised in open field condition.

Sharma *et al*. (2010) conducted an experiment on the performance of capsicum genotypes in polytunnel vis-à-vis in open field conditions and found that plant grown under shade exhibited better growth in terms of plant height compared to those in open field. Capsicum cv. California Wonder reported the highest plant height (67.25 cm) among the nine genotypes under shade house.

Harish (2011) reported that naturally ventilated polyhouse condition registered higher plant height (37.63 cm,71.88 cm and 85.72 cm), number of branches (3.25,8.10 and9.87) at 30,60 and 90 days after transplanting , leaf area (15.47 dm^2, 77.38 dm^2 and 120.49 dm^2) and leaf area index (4.51,22.32 and 34.62) 30,60 and 90 days after transplanting respectively compared to open condition leaf area (11.51 dm^2,41.55 dm^2 and 75.56 dm^2) leaf area index (3.33,11.99 and 21.78) 30,60 and 90 days after transplanting respectively

Kengar (2011) reported that STH-801 tomato hybrid plant were significantly taller with mean height of (309.03 cm), produced maximum number of branches (8.71/ plant) and larger leaves (79.22 cm^{-2}).

2.1.2 Effect of growing condition on fruit and seed yield parameters

The protected structures like shade house provides favorable condition leading to maximum fruit and seed yield compared to open field condition, due to adverse climatic condition, seed plant will be in harry to complete the life cycle as soon as possible and response very weekly to inputs and genetic character of plant, with special reference to tomato and other related crop are reviewed and presented below;

An alternative high and low humidity during day and night in case of greenhouse grown sweet pepper gave more fruit set (65.1%) number of fruits (10.9) and increased seed number (119.2) as compared to continuously high or low humidity (Bakker, 1989).

Ochigbu and Harris (1989) conducted research under polyethylene greenhouse condition from 1989-90 to 1990-91 and concluded that maximum yield of ripe tomato fruits (8.6 kg/ m^2) and total yield (9.4 kg/ m^2) were obtained under greenhouses as compared to open conditions (6.6 kg/ m^2 and 7.35 kg/ m^2, respectively) .

Higher fruit yield of sweet pepper (4.62 kg/m^2) was obtained under plastic cover as compared to open (3.40 kg/m^2) and harvesting was early under plastic cover as compared to open field (Buczkowska, 1990).

Bhatnagar *et al.* (1990) observed that tomato gave maximum yields (507 q/ha) inside the greenhouse as compared to no yields under open field condition, because all the plants were killed due to severe frost during winter in hilly region of Uttar Pradesh.

More *et al*. (1990) reported that cucumber variety 'Poinset' gave a higher yield (1.70 kg/plant) under polyhouse as compared to lower yield (0.75kg/plant) in open conditions, during winter months under North Indian conditions due to low temperature.

Nimje *et al.* (1990) observed that sweet pepper cv. California Wonder was found to be best suited for greenhouse cultivation. Among the three varieties California Wonder yielded 445 qha^{-1} under greenhouse as against only 164 qha^{-1} under field condition. Further, in the sequence of cropping, two crops of sweet pepper and one crop of ladies finger, ladies finger produced maximum yield (1053q/ha/year) under greenhouse as compared to 385q/ha/year under normal field condition.

Choudhury and Bhuyan (1992) observed that plants grown under 0, 30 and 73 per cent shade produced yields of 28.40, 20.24 and 11.71 t/ha respectively. The yield significantly decreased with increase in intensity of shading. The plants grown under 0, 40 and 73 per cent shade produced 27.17, 13.42 and 7.41 fruits *i.e.* the number of fruits per plant sharply decreased with increase in the percentage of shading. The number of fruits per kilogram also decreased with increasing shading implying that the average fruit size was higher in shade than at the open.

Jeevansab (2000) Reported that the fruit yield of capsicum differed significantly with the growing environments. The highest fresh fruit yield (30.50 t/ha) was obtained under polyhouse followed by open condition (12.00 t/ha)

Nagalakshmi *et al.* (2001) reported that tomato, S-1 and capsicum variety Green Gold grown under polyhouse recorded more number of fruits per plant were tomato, S-1 (56.8) and capsicum variety Green Gold (13.6) , fruit weight in tomato S-1 (120.4) and capsicum variety Green Gold (60.3), fruit yield per plant in tomato S-1 (1.83kg) and capsicum variety Green Gold (1.63kg) and per hectare tomato S-1 (98.5kg) and capsicum variety Green Gold (80 kg) when compared to the crop raised under open condition number of fruits per plant (30.4 and 5.3), fruit weight (50.5 and76.4 g), fruit yield per plant (1.02 and 0.404) in plant tomato, S-1 and capsicum variety Green Gold respectively

Prasad (2001) reported that the maximum total yield (82.31 t/ha) of bell pepper was recorded under greenhouse compared to that of open field condition (19.89 t/ha).

Basavaraja *et al*. (2003) opined that the higher yields obtained from the polyhouse was due to the favourable air temperature, optimum relative humidity and light intensity present in the structure, which had helped in getting good vegetative and reproductive characters in capsicum.

Singh *et al.* (2003) observed that the higher productivity of tomato (93.20 t/ha) and capsicum (76.40 t/ha) inside greenhouse which was mainly due to higher temperature (4 – 9^0C) than the outside during the month of December to February and high rate of utilization of carbon-dioxide inside greenhouse. Microclimate inside greenhouse during winter months was mainly responsible for better yield due to their beneficial effects on flowering and fruiting.

Naik (2005) reported that, among the three growing conditions namely, medium cost polyhouse, low cost polyhouse and net house, the medium cost polyhouse recorded higher yield attributing parameters *viz*., number of fruits per plant (10.29), fruit weight per plant (1.02 kg) and highest total fruit yield of 37.77 tonnes ha^{-1}.

Pandey *et al.* (2005) reported that higher number of fruits per plant and fruit yield per plant in capsicum lines were observed in Glasshouse with ventilation (25.0 and 2.50 kg) compared to polyhouse (24 and 2.4 1kg) and open field condition (20 and 1.51 kg) respectively

Singh *et al.* (2007) conducted a study in the polyhouse to assess the yield performance of capsicum cv. California Wonder transplanted in first week of March and recorded higher average fruit weight (54 g), number of fruits per plant (16.3) and yield per m^2 (6.5 kg/m^{-2}). As compared there was no fruit yield when capsicum was grown in open field condition.

Kavitha *et al.* (2008) conducted an experiment in three seasons to elucidate the effect of shade and fertigation on growth, yield and quality of tomato hybrid Ruchi. The experiment was concluded with the results that the shade and fertigation levels singly and in combination significantly influenced the yield. Among which highest yield was obtained at 100% water soluble fertilizer and shade followed by 100 % straight fertilizers under shade.

Zende (2008) conducted an experiment in capsicum cv. Orobelle under two growing environments *viz*., naturally ventilated polyhouse and shade house and reported that number of fruits per plant (23.44), fruit weight 125.48 g/fruit), yield per plant (2.09 kg/plant) and total yield ha^{-1} (64.91 t/ha) were higher under naturally ventilated polyhouseas compared to shade house (19.27 fruits/plant, 116.96 g/fruit, 1.63 kg/plant and 50.65 t/ha) respectively

Harish (2011) reported that naturally ventilated polyhouse condition registered higher number of fruits per plant (44.46), fruit yield per plant (2.78kg) and per hectare (79.66t/ha) as compared to open condition (22.46, 1.92kg and 59.31t/ha) respectively

Kengar (2011) reported that STH-801 tomato hybrid plant recorded significantly higher number of clusters per plant (12.15), number of fruits per cluster (7.75) and percent fruit set (93.17%).

2.1.3 Effect of spacing on growth parameters

To achieve superior tomato hybrid seed production there is a need to investigate for optimum planting density to attend maximum fruit and seed yield and seed quality both under shade house and open field condition. Especially under shade house for effective use of limited ground area to get more cost effective hybrid seed production and affective use of resource, like water and light. The spacing plays the dominant role in seed plant life cycle so review on effect of spacing on growth parameters special reference to tomato and other related crop are reviewed and presented below.

Rajeshwar *et al.* (1981) studied the effect of spacing and reported that the tomato plants which were spaced closer (45 x 30 cm) grew taller (80.08 cm) lower plant height (66.69 cm) in wider spacing (60 x 60 cm) , whereas wider spaced (60 x 60 cm) plants produced significantly more leaves (68.76), branches (12.00) and dry matter per plant (117.22) compared to (45 x 30 cm) produced lesser (64.40) (11.52) (84.45) respectively.

Papadopoulos and Ormrod (1988) studied the effect of six equidistant spacings under greenhouse (23, 30, 38, 45, 53 and 60 cm) on interception of photosynthetically active radiation (PAR) by four row planting of greenhouse tomato cv. Jumbo and Ohio CR-6. The proportion of available PAR intercepted increased with the closer plant spacing. Increased PAR penetration and improved distribution was observed with increase in plant spacing.

Singh and Singh (1992a) observed the significantly higher plant height (mean value of two years observation) (76.735 cm) in closer spacing level of 60 x 45 cm compared to wider spacing level 75 x 60 cm (71.52 cm) and 60 x 60 cm (74.135 cm) and obtained the maximum seed content g/kg of fruit in medium spacing level 60 x 60 cm (5.47g/kg) compared to that of other spacings levels 60 x45 cm (5.34g/kg) and 75 x 60 cm (5.39g/kg).

Maximum plant height, number of branches, fruit volume, fruit girth, fresh weight of green fruit (128.0 g) and fresh weight of fruits (637.5 g/plant) were recorded in sweet pepper at a fertility level of 250:200:200 kg NPK per ha with a spacing of 60 cm x 40 cm (Shrivastava *et al.,* 1993).

Sharma and Peshin (1994) conducted an experiment on the studies on sweet pepper and noticed (mean data of two year) that the days to 50 per cent flowering and plant height was not significant. However, an increasing trend was seen with the closer spacing 30 x 45 cm (53.26 and 64.48 cm) and significantly maximum number of branches (6.97), no. of fruits per plants (13.46) seed yield per plant (13.52g), 1000 seed weight (7.18g) and germination percentage (92.16%) was recorded at the wider plant spacing (60 cm x 45 cm) (all data's are mean of two years observation 1989 and 1990).

Singh *et al.* (1997) conducted an experiment on plant density on growth in brinjal hybrids and observed the lowest plant height (68.21 cm) and highest dry matter accumulation (66.58q/ha) in 45 x 45 cm compared to other spacing's 60 x 45 cm (72.50 cm and 56.72 q/ha), 75 x45 cm (75.83 cm and 50.31 q/ha) and 90 x 45 cm (77.83 cm and 43 q/ha) 105 x 45 cm (80.66 cm and 38.74q/ha) respectively.

Ravinder *et al.* (1998) studied the effect of plant geometry on growth parameters in tomato and found that the closer spacing of 75 cm x 20 cm both side seeding produced the highest (mean value of two years) plant height (52.94 cm), maximum yield (442.63 q/ha) and cost benefit ratio (1:3.68) compared to wider spacing of 90 cm x 40 cm recorded lower (48.3 cm) (347.765) and (1:0.89) respectively.

Srinivasan *et al.* (1999) observed that the closer spacing of 80 cm x 30 cm recorded taller mean plants height of two seasons (108.9 cm) while the wider spacing of 80 cm x 60 cm produced shorter tomato plants (87.6 cm) and the wider spacing of 80 cm x 60 cm recorded higher no. of fruits / plant (71.2) and medium spacing 80 x 45 cm recorded higher fruit yield (407.7q/ha).

Kanthaswamy *et al.* (2000) conducted an experiment on a study on effect of spacing in cucumber under polyhouse and revealed that the plant height was higher at wider spacing (90 cm x 60 cm).

Prasad (2001) reported that plant height, number of branches and leaf area were recorded highest in capsicum under greenhouse condition. Plant height was higher in closer spacing of 30 cm x 30 cm and number of branches and leaf area were more in wider spacing of 30 cm x 60 cm under greenhouse condition compared to that of open condition.

Balaraj *et al.* (2002) conducted spacing trails on chilli varieties for two years and reported that the plant height at harvest was maximum (98.18 cm) at closer spacing 60 cm x 60 cm.

Zende (2008) conducted an experiment to study the effect of planting geometry in capsicum cv. Orobelle under two growing environments *viz.*, naturally ventilated polyhouseand shade house and reported that the closer spacing of 45 x 30 cm recorded maximum plant height (148.97 cm) compared to wider spacing 45 x 60 cm recorded lower plant height (124.83 cm) and highest number of leaves per plant and leaf area recorded in wider spacing 45 x 60 cm (107.77 and 120.14 $dm^{-2)}$ and minimum (85.61 and 89.60 dm^{2}) number of leaves per plant and leaf area was observed under spacing 45 x 30 cm..

Harish (2011) reported that naturally ventilated polyhouse condition registered higher number of fruits per plant (44.46), fruit yield per plant (2.78kg) and per hectare (79.66t/ha) as compared to open condition (22.46, 1.92kg and 59.31t/ha) respectively.

2.1.4 Effect of spacing on fruit and seed yield parameters

Satyanarayana (1984) studied the influence of plant density on yield parameters of brinjal cv. Bhagyamathi and found that a plant spacing 60 × 60 cm (27,778 plants/ha) was the optimum for production of brinjal.

Mangal and Jasim (1987) studied the performance of varieties of tomato under plastic house with three spacing (20 cm, 30 cm and 40 cm) and observed significant reduction in total yield/plastic house (975-0a) under closer spacing Compared to wider spacing (40cm) (848-7ab).

Dharmatti and Kulkarni (1988) conducted studies on spacing trials in bell pepper and reported that number of fruits per plant, fruit yield per plant, number of seeds per fruit and total seed yield ha^{-1} was higher (3.05, 66.58 gm, 216.26 and 80.91 kg, respectively) with 60 x 45 cm spacing. Fruit yield per hectare was maximum (35.64 q) at wider spacing of 60 x 60 cm.

Dimir and Gulshan Lal (1988) stated that. Widest spacing of 60 x 60 cm recorded highest fruits per plant (36.4) yield /plant (2.108kg) and fruit weight (56.69g) but lowest yield per hectare (347 q/ha).

Srinivasa *et al.* (1988) observed that wider row spacing of 90 cm x 50 cm and 90 cm x 41.6 cm gave significantly more fruit yield (70 and 68 t/ha, respectively) than narrow spacing of 75 cm x 60 cm (47.4 t/ha) and 75 x 50cm (46.1 t/ha) in tomato cultivars Pusa Ruby and NTDr-1 in red sandy soils.

Savic *et al.* (1990) reported the higher yield of tomato fruits under the higher crop density in variety Kampbell (47.60 t/ha) and the least yield (19.86 t/ha) under the lowest crop density.

Singh and Naik (1990) obtained maximum number of fruits per plant and fruit yield per plant with wider spacing. Increased plant spacing from 30 cm to 50 cm had no significant effect on fruit yield. However, the higher fruit yield was recorded with closer spacing.

Savic and Llic (1992) studied the effect of spacing on capsicum yield and found that closer spacing of 60 cm x 15 cm produced higher fruit yield (514.3 kg/ha) with lower yield per plant (0.46 kg) and widest spacing produced least yield (351.6 kg/ha) with higher fruit yield per plant (1.05kg/plant).

Singh and Singh, (1992b) conducted the studies on effect of spacing on fruit yield in two tomato cultivars and reported that the fruit yield of tomato was found maximum when HS-110 and Pusa Ruby varieties planted at 60 x 45 cm and 60 x 60 cm spacings, respectively.

Arora *et al.* (1995) conducted the studies in tomato cv. Hisar Arun plants spaced at 90 x 45cm with one seedling per hill planted on both sides of the beds resulted in higher seed content (5.5 g/kg fruit), seed yield (4.77 g/plant) and total seed yield (212 kg/ha).

Pandey *et al.* (1996) studied the effect of spacing on yield parameters of tomato hybrids and found that adopting a spacing of 60 x 45 cm resulted in higher yield (199.07 q/ha).

Singh and Sharma (1996) studied the effect of spacing on tomato cultivars and found that the wider spacing (60 x 60 cm) produced the highest fruit yield per plant (2.19 kg) and fruit weight (97.68 gm) compared to that of closer spacing (60 x 45 cm) produced the lowest yield per plant (1.97 kg) and fruit weight (83.14 gm) and

Streck *et al.* (1996) studied the performance of indeterminate tomato cultivar Montecarlo under plastic greenhouse at densities equivalent to 20,000, 30,000, 40,000 and 50,000 plants per ha. Fruit yield was higher with a planting density of 50,000 plants ha^{-1} when seedlings were transplanted in July as compared in February.

Pawar and Karale (1997) reported that among the various spacings tried in tomato, the spacing of 90 cm x 40 cm gave the highest no. fruits per plant (21.1) compared to other spacings 75 x 30 cm (18.2), 90 X30 cm (18.1) and 75 x 40 cm (19.3).

Tomato cv. Recento cultivated hydroponically under greenhouse with different plant densities (3.1, 2.1 or 1.6 plants/m^2) showed that low plant densities of 2.1 and 1.6 plants per m^2 did not significantly increase the number of flowers per truss and fruit set, as compared with high planting density (3.1 plants/m^2). The number of large fruits (>150g) greatly increased at low planting density (Yeongcheol *et al.,* 1997).

Streck *et al.* (1998) evaluated tomato cv. Montecarlo at different plant densities (20,000, 40,000, 80,000 or 1,00,000 plants/ha) and found that plant densities of 80,000 plants $ha^{-1}$and 1,00,000 plants ha^{-1} gave the highest fruit yield under greenhouse condition.

Maya *et al.* (1999) reported the highest days to 50% flowering (71.2) at a spacing of 60 x 45 cm with moderate plant population compared to 60 x 30 cm (68.9) and 60 x 60 cm (69.9) and number of fruits per plant highest in spacing level of 60 x 60 cm (5.55) compared to 60 x 45 cm (4.66) and 60 x 45 cm (4.27) fruit weight highest in spacing level of 60 x 30 cm (68.6g) compared to 60 x 45 cm (67.8g) and 60 x 60 cm (64.6g).

Sharanabasava (2000) conducted the studies in tomato and noticed that fruit yield per plant reduced significantly under closer plant spacing of 60 cm x 20 cm and increase in fruit yield per plant as increase in row spacing was observed under cover.

Yield of paprika pepper increased as plant density increased. Fruit number and fruit weight per plant was decreased with increasing plant populations and weight per fruit decreased slightly (Cavero *et al.,* 2001).

Prasad (2001) observed that number of fruits per plant, average fruit weight, and yield per plot and per hectare was higher in capsicum under greenhouse condition than that of open condition. Number of fruits per plant and average fruit weight was higher with wider spacing of 30 x 60 cm. Fruit yield per plot and per hectare was recorded higher in closer spacing of 30 x 30 cm.

Sharma *et al.* (2001) observed that the closer spacing level 60 x 30 cm (70.8 days) took lesser days to maturity compared to other spacing 60 x 45 cm (76.1 days) and 60 x 60 cm (78.5 days) and obtained the highest fruit and seed yield of tomato (431.7 q/ha and 107.1 kg/ha, respectively) in medium spacing of 60 cm x 45cm than the wider spacing of 60 x 60 cm (361.9 q/ha and 94.29 kg/ha) and narrow spacing of 60 x 30cm (390.9 q/ha and 89.92 kg /ha).

Balaraj *et al.* (2002) conducted the spacing trials on chilli varieties and reported that the number of fruits per plant (100) was higher at wider spacing of 90 x 90 cm. fruit yield and seed yield was maximum (1200 kg/ha and 586 kg/ha, respectively) in closer spacing of 60 x 60 cm.

Dasgan and Abak (2003) reported that the average no of fruit per plant (78.7) and total yield per plant (2.77 kg) was more with wider spacing of 80 x 45 cm/4 shoots in bell pepper under glasshouse condition.

Singh *et al.* (2004) conducted study on three capsicum varieties (California wonder, bharat and pusa deepti) under green house condition for three season and noticed that higher number of fruits per plant (45.20, 40.20 and 38.30), average fruit weight (68.55, 63.43 and 53.46 g) and fruit yield per plant (3.09, 2.55 and 2.05 kg) was seen in wider spacing of 60 cm x 30 cm as compared to all other spacing 50 x 40 cm, 45 x 45 cm and 40 x 30 cm.

Mantur *et al.* (2007a) conducted a study on effect of plant geometry on yield of capsicum under shade house during summer and kharif season and revealed that the number of fruits per plant, fruit weight, fruit yield per plant and fruit yield per m^2 was maximum (8.94, 88.50 g, 760.50 g and 3.06 kg, respectively) in 4.4 plant per m^2 plant geometry during summer. Number of fruits per plant and fruit yield per plant was maximum (10.07 and 931.60 g, respectively) in 3.7 plant per m^2 plant geometry during kharif. Fruit weight and fruit yield per m^2 was maximum (93.20 g and 3.94 kg, respectively) in 4.4 plant per m^2 plant geometry during *kharif*.

Mantur *et al.* (2007b) conducted a study on influence of spacing on yield of tomato grown under shade house in summer 05-06 and kharif 06 and reported that wider spacing of 60 x 60 cm gave the significantly highest mean fruit yield per plant in two seasons (4.31 kg and 4.01 kg, respectively) and narrow spacing of 60 cm x 45 cm gave the higher mean fruit yield per m^2 in two season (8.67 kg/m^{-2}) which is with 60 x 30 cm (8.64 kg/m^{-2}) by using indeterminate tomato variety Himsona in shade house.

Mantur and Patil (2008) conducted a study on effect of spacing on yield of tomato variety Himsona under 50 per cent shade house during kharif and summer season and revealed that average fruit weight was significantly more (73.64 g and 71.36 g, during summer and kharif) respectively, fruit yield per plant was significantly more (4.27 kg and 3.07 kg, during summer and kharif respectively) in 60 x 60 cm spacing and fruit yield per m^2 was higher (10.11 kg and 7.22 kg during summer and kharif respectively) in 60 x 45 cm spacing.

Zende (2008) conducted an experiment to study the effect of planting geometry in capsicum cv. Orobelle under two growing environments *viz.*, naturally ventilated polyhouse and shade house and reported that the wider spacing of 45 x 60 cm has recorded the higher number of fruits per plant (22.96), fruit weight (127.22 g) and yield per plant (2.15 kg) irrespective of growing condition, were as closer spacing 45 x 30 cm recorded lower number of fruits per plant (19.27 fruits) fruit weight (115.17 g/fruit) and yield per plant (1.66 kg/plant). Total yield ha^{-1} was higher in closer spacing of 45 cm x 30 cm under both naturally ventilated polyhouse and shade house.

Harish (2011) noticed that spacing level 60 X 60 cm registered higher number of seeds per plant (163.38), seed weight per fruit (0.44g) and seed yield per plant (16.75g) as Compared to other spacing levels 60 X45 cm and 60 x75 cm in tomato.

2.1.5 Effect of spacing on seed quality parameters

Jarmillov and Marin (1978) obtained 90 per cent germination when seeds were produced from the plants spaced at 80 cm x 60 cm (20,833 plants/ha) as compared to 80 cm x 45 cm (27,777 plants/ha) in tomato cv. Roma.

Kalappa (1982) reported that 1000 seed weight recorded a decreased trend (6.29 to 6.25 g) as plant population increased from 40,000 to 60,000. Root length and shoot length were higher (5.44 cm and 2.87 cm, respectively) at wider spacing and seedling vigour index was significantly more at 50,000 plants ha^{-1}.

Dharmatti and Kulkarni (1988) conducted studies affect spacing on seed quality parameters in bell pepper, reported that 1000 seed weight, germination per cent, root length, shoot length and seedling vigour index were highest (4.20 g, 55.87 %, 4.26 cm, 5.16 cm and 646, respectively) at the spacing of 60 cm x 45 cm and seedling dry weight (0.135 g) was maximum at 60 cm x 60 cm spacing.

Arya *et al.* (1997) noticed that 1000 seed weight was higher in optimum spacing combination of 75 cm x 30 cm and higher seed germination percentage was observed in closer spacing of 75 cm x 30 cm in tomato.

Jayaraj *et al*. (1999) observed that germination per cent was highest at a spacing of 60 cm x 45 cm. Seedling root length, shoot length and vigour index were recorded highest in wider spacing of 75 cm x 60 cm in chilli cv. PLR1.

Balaraj *et al.* (2002) conducted the spacing trials on chilli varieties and reported that 1000 seed weight, germination per cent and vigour index were maximum (5.11 g, 78.03 % and 1236, respectively) at wider spacing of 90 cm x 90 cm.

Harish (2011) observed that spacing level 60 X 60 cm registered significantly higher germination per cent(88.04 %), root length(3.81 cm), shoot length(9.6 cm), dry weight of seedlings(14.96 mg) and vigour index (1160) compared to other spacing levels 60 X45 cm and 60 X75 cm in tomato.

2.2 Experiment II: Studies on pollen viability of pollen parent and stigma receptivity of seed parent in (F_1) hybrid seed production of tomato under shade house

2.2.1 Pollen viability of pollen parent

Temperature, sunlight and RH plays an important role in maintenance of pollen viability. In most systems, low temperature and low humidity prolong pollen viability (Stanley and Linskens), Pollen forms the transportable hereditary unit and its preservation is considered as one of the methods for long term storage of plant germplasms. Storage of pollen and its use in artificial pollination are in use since antiquity. This technique becomes more relevant when varieties bloom at different times or pollens of the same cultivar has to be used frequently in crossing programme (Saunders, 1908) the knowledge of pollen viability and its storage is important in tomato hybrid seed production where hand pollination is involved this will help the hybrid seed producer for affective use of pollen and pollination. The pollen quality can be increased if the pollen parent is grown in the optimum environment. This can be provided by adoption of protected cultivation in field of hybrid seed production. Shade house type of structure is gaining importance to proved optimum environment to pollen parent growth and pollen production, keeping in importance of all this, the study is conducted and review were listed below.

The quality of donor pollens depositing on stigma of female parent is the most important criterion in hybrid seed programme to get maximum F1 hybrid seed set and yield. The most reliable method of assessing pollen viability is placing the pollens on stigmas of the emasculated flowers of the female parent and counting the seed numbers of the fruits that are set after pollination (Mc Guire, 1952).

According to Dempsey and Yamaguchi (1960), pollens were remained viable for only few hours after anther dehiscence depending upon the temperature and humidity in many vegetable crops. However, under ordinary conditions at low temperature and moisture content pollens could be stored for 4 to 5 days; for six months at 50^oC in dessicator for five to six days at room temperature and 70 per cent relative humidity for two days on the flower itself in brinjal and for 8-10 days at 20-22^0C and 50-55 per cent relative humidity.

Dorosiev (1962) accomplished artificial pollination by direct transfer of pollens from flower of the pollen donor to stigma with or without the aid of transfer tools. Direct transfer was more time consuming and required a large number of pollens donating flowers than the previously extracted pollens by pollen collecting device.

The results of pollen viability studies conducted by Prasad and Batham (1975) on 20 varieties of tomato at Kanpur revealed that the maximum pollen viability ranged from 93.35 to 98..60 per cent in 5193 strain and Pusa Ruby variety is observed in December month, at that time temperature was 15 + 20^{o}C and relative humidity of 82.5 + 0.5 per cent.

While, it was 88.10 and 95.00 per cent in November month in 5442 strains and Kalyanpur and Angurlata varieties, respectively where temperature was 19.5 + 2^{0}C and relative humidity of 82.5 + 0.5 per cent. In a study conducted by Srivastava and Bajpai (1977) noticed in brinjal to test the viability of freshly dehisced pollen grains of the hybrids and their parents in acetocarmine, 95-98 per cent pollen viability in parents and 85 to 86.5 per cent in hybrids.

Petrova *et al*. (1981) reported that duration of pollen viability did not last for more than four days in eggplant. However, pollination of flowers should not be delayed beyond two to three days after emasculation.

Kaloo (1986) stated that tomato flowers collected in the afternoon hours could be stored for certain period depending upon temperature and humidity under ordinary conditions whereas, their pollens could be stored for three to four days. A flower that is stored for one day at normal temperature exhibited better seed set and yield.

Devadas *et al*. (1992) reported that self pollination resulted in a higher seed number per fruit and individual seed weight. However, percentage of field emergence and seedling vigour were significantly higher in the seeds obtained by cross pollination in bittergourd cv. CO-1.

The results of trial carried out over a two consecutive years Sarkar *et al*. (1998) revealed that at anthesis, and pollen germination was 66 per cent which dropped to one per cent after 42 hours of anthesis. Stigma attained receptivity 4 hours before flower opening. Only 5 per cent fruit set was observed at 36 hours after flower pollinated in the pointed gourd (*Trichosanthus dioica* Ruxb.)

According to Yogeesha *et al*. (1999), the pollens of tomato Pusa Gaurav and Chikoo male parental line of Pusa hybrid-2 and Pusa hybrid-1 respectively stored under room conditions (Mean maximum temperature of 26^{0}C and RH of 47%) retained higher viability even after five days of storage

Nascimento *et al*. (2000) stated that in brinjal, manual pollination could be done in the morning hours by using pollens of freshly opened flowers on the same day. Pollens were collected from male line flowers by using a vibrator, further stored in expender of micro tubes kept in aluminium container with silica gel under 5^{0}C 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 F_1 hybrid seed set and better seed quality.

Hazra *et al*. (2003) reported that emasculated flowers of the six parental line of brinjal were pollinated with mixed pollens at four stages *viz.*, one day before anthesis, during anthesis, one and two day after anthesis. And observed the stigma receptiveness was peak during anthesis by registering the highest percentage of fruit set.

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

Chen-youYuan *et al.* (2003) reported that, seed yield and quality of netted melon (*Cucumis melo reticulates*) was the highest when the crop was pollinated right after collection of fresh pollen during the big bud stage.

Patil (2005) reported that. Pollination of emasculated female flowers with fresh male pollen was found to be superior by registering higher F_1 hybrid seed yield and quality compared to one day, two day and three day old pollens in tomato

Jolli (2008) reported that two days old pollens recorded significantly higher per cent of fruit set (55.69), fruit yield of 1846.40 g per plant and seed yield of 11.46 g per plant compared to one day old pollen (48.80%) (1439.99 g) and (8.35 g) respectively followed by three days old pollens (51.69), (1644.65 g) and (10.39 g) respectively , used for pollination.

Kivadasannavar *et al*. (2008) reported that the use of fresh pollen recorded significantly higher fruit set (33.06%), seed yield per plant (6.95g), 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).

Bellad (2012) conducted experiment in watermelon and reported that pooled data show Significant gradual decline from fresh pollens to the two day old pollen over the pollination was observed for various fruiting and seed yield components under study. In general, fruit girth, fruit length, fruit weight, fruit yield per vine, number of seeds per fruit, percentage of filled seeds, seed weight, seed yield per vine and hectare were significantly higher (23.86 cm, 28.17 cm, 7.75 kg, 38.17 kg, 57.11, 87.21%, 4.87 g, 24.67 g and 80.52 kg in fresh pollens, respectively) as against two days stored old pollens. Pollination time, the period of pollen storage also exhibited the similar significant reduction trend from fresh pollens (P_1) to the two-day-old pollens (P_3) for various seed quality parameters like 100 seed (7.82 g), germination (85.83%), shoot length (13.15 cm), root length (9.80 cm), seedling vigour index (1968) and seedling dry weight (20.90 mg) respectively.

2.2.2 Stigma receptivity of seed parent

The knowledge of Stigma Receptivity of seed parent in hybrid seed production is very important particularly crop like tomato where the manual emasculation and pollination are involved. In search of new growing condition to achieve higher fruit set percentage, seed yield and quality. The shade house is the better option and mostly liked by the Indian farmer due to its simplicity and cost affective investigation in Stigma Receptivity of seed parent will enable the seed producer to know when to emasculate and how long pollination can be continued under shade house, Keeping the importance of hybrid tomato in mind this study was conducted and special reference to tomato and other related crop are reviewed and studies on this aspect were listed below.

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 to18 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.

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 to12.00.

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 that the maximum stigma receptivity on four days after emasculation of flower as exhibited by higher values of fruit set (80.55), number of seed per fruit (146.1), seed to fruit ratio (0.0046), in S-120 (tomato Pusa hybrid-2 female parental line)

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). 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 over other treatments pollination two day after emasculation, pollination one day after emasculation and pollination to fresh emasculation stigma.

Kivadasannavar *et al*. (2009) reported that higher number of crossed fruits retained per plant, fruit set, fruit weight, number of seeds per fruit seed weight per fruit, seed yield per plant, germination and seedling vigour index (34.81, 49.37%, 56.54 g, 52.75, 6.28 g, 3.80 g, 88.20% and 1534, respectively) were observed when pollination was done one day after emasculation in chili.

Singh *et al*. (2009) conducted investigation on stigma receptivity in hybrid seed production of bhendi and reported that the pollination on the day of emasculation recorded higher fruit set (32.91%), seed yield per plant (28.65g), field emergence (83.75%) and seedling vigour index (3312) as compared to delayed pollination.

MATERIAL AND METHODS

The investigations were carried out to study the effect of growing condition and plant spacing on growth, seed yield and quality of tomato hybrid seed production cv. female parental line of Pusa hybrid-2. The field experiment was carried out in shade houses and in open field of Hi-Tech Horticulture Unit, Saidapur Farm main agriculture research station, UAS Dharwad. The laboratory studies were carried out at Seed Quality and Research Laboratory, National Seed Project, UAS, Dharwad. The investigation was done on pollen viability of pollen parent (male) and stigma receptivity of seed parent (female) in parental line of Pusa Hybrid-2 tomato under shade house. The details materials used and the methods adopted during the course of investigation are given below.

3.1 General description

3.1.1 Location of the experiment

The field experiment was carried out in shade houses and in open field of Hi-Tech Horticulture Unit, Saidapur Farm, MARS UAS Dharwad. The seed quality parameters were studied at seed quality and research laboratory National seed project University of Agricultural Sciences, Dharwad. The Dharwad is situated in Northern Transitional Zone (8) of Karnataka at 15^{0}-26' N latitude and 75^{0}-7' East longitude at an altitude of 678 m above mean sea level.

3.1.2 Climatic condition

The monthly meteorological data pertaining to temperature, rain fall, relative humidity and wind speed for the crop growth period at MARS Dharwad and are presented in Table 1 and depicted in Fig. 1 and average monthly meteorological data of 61 years (1950-2011) are presented in Table 1a.

3.1.3 Soil characteristics of experimental site

The experimental site consisted of black clay soil and was neutral in reaction. The composite soil samples of the experimental plots was collected from 0-30 cm depth before the start of the experiment and analyzed for different physical and chemical characters by following the standard procedures. The results are presented in Table 2.

3.2 Design and layout

The field experiment was laid out in randomized block design with factorial concept having three replications and eight treatments combination, the size of the gross plot was 1.50 X 1.00 m and net plot was 14 X 1.00 m (Fig. 2).

3.3 Seed source

The Foundation seeds of S-120 (female) x Gavrou (male) parents were obtained from the Senior Breeder (tomato), IARI, New Delhi.

3.4 Isolation

Tomato is highly self-pollinated crop, however an out crossing about 5 percentage is observed due to insects. Hence it requires more isolation distance compared to other self-pollinated crops. An isolation distance of 100 m as recommended by the seed certification agency has been maintained between experimental crop and other contaminating tomato varieties in the field and in case of hybrid seed production 5 m isolation distances between the male and female parental line.

3.5 Description of tomato cultivar

Pusa hybrid-2 (S-120 x Gavrou) developed at IARI, New Delhi. The female line S-120 developed at IARI which have semi determinate spreading type plant, fruit are uniform red in colour, flattish round smooth in shape, medium to large in size, mild in acidity and resistance against nematodes and Gavrou male parental line developed at IARI which have determinate growth, fruit colour is yellowish red at maturity, oblong in shape and uniform ripening good for processing and transport and Pusa hybrid-2 which have determinate type of growth habit, fruits are round and medium size have field resistant to nematodes, yield up to 550 quintals per ha and suitable for long distance transportation available for march end to may end.

Table 1: Monthly Meteorological data during the investigation period from August 20012 to February 2013 at MARS, Dharwad

Month	Shade house condition					Open field condition				
	Mean Temperature (^oC)		Relative humidity (%)	Rainfall (mm)	Wind speed (Km/hr)	Mean Temperature (^oC)		Relative humidity (%)	Rainfall (mm)	Wind speed (Km/hr)
	Max. (^oC)	Min. (^oC)				Max. (^oC)	Min. (^oC)			
August (2012)	29	23.7	88	90.0	7.56	27	20.5	85	90.0	10.96
September(2012)	29.6	22.1	83	89.6	6.25	28.2	19.7	80	89.6	9.48
October (2012)	30.6	21.8	69	89.2	4.37	29.7	18.2	65	89.2	7.41
November(2012)	30.3	20.4	67	35.7	3.2	29.2	17	63	35.7	5.5
December (2012)	31.2	17.9	61	19.6	3.4	30	14.4	58	19.6	5.6
January (2013)	32.1	18.2	49	2.2	2.3	31.2	14.5	47	2.2	4.6
February (2013)	33.1	19.5	54	4.2	4.2	32.6	16.8	51	4.2	6.3

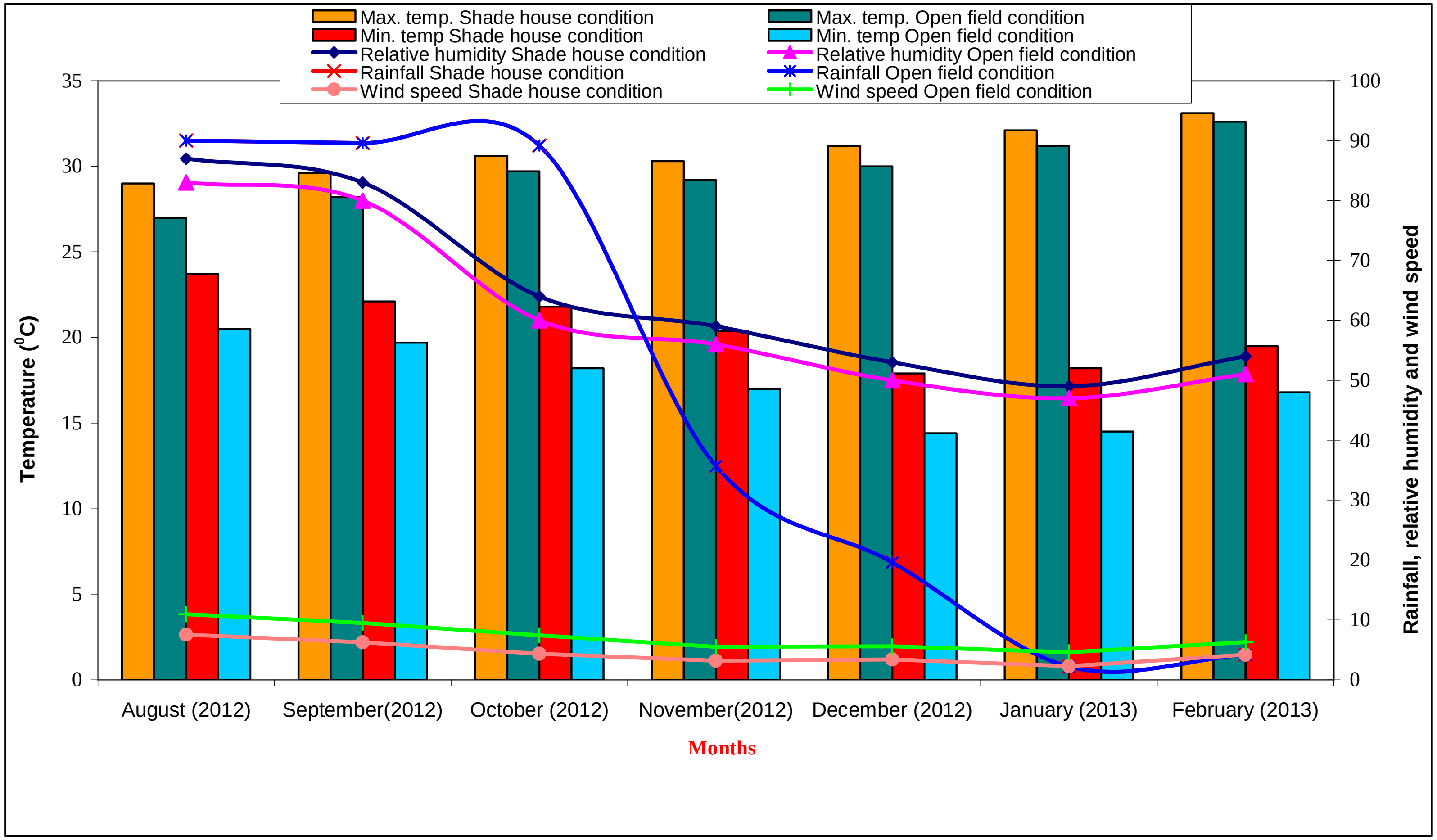

Fig. 1: Monthly Meteorological data during the investigation period from August 2012 to February 2013 at MARS, Dharwad

Table 1a: Average monthly meteorological data of 61 years (1950-2011) at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Months	Rainfall (mm)	Mean Temperature (^oC)		Relative humidity (%)
	1950-2011	Maximum	Minimum	1950-2011
		1950-2011	1950-2011	
January	0.8	28.7	14.07	64.81
February	11.5	31.6	16.56	54.41
March	1.5	34.9	19.71	64.24
April	48.6	36.6	20.11	78.05
May	20.0	35.2	20.95	75.78
June	106.4	30.2	21.68	86.29
July	153.8	27.3	20.85	89.18
August	101.0	27.2	20.16	88.6
September	107.5	27.9	19.96	86.68
October	125.9	29.5	18.65	79.4
November	32.0	28.9	15.93	73.62
December	4.9	27.8	13.20	69.12
Total	**713.8**	**-**	**-**	**-**

Table 2: Physical and chemical properties of the soil of the experimental sites at Hi-Tech Horticulture Unit Saidapur Farm, Main Agricultural Research Station, UAS, Dharwad

Particulars	Value	Method employed
1. Physical properties		
Coarse sand (%)	7.20	International pipette method (Piper, 1966)
Fine sand (%)	16.31	
Silt (%)	19.40	
Clay (%)	21.80	
Textural class	Clay	
Bulk density (Mg/m^3)	1.39	Core method (Black (1967)
2. Chemical properties		
Organic carbon (%)	0.85	Walkey and Black wet oxidation method (Jackson 1973)
Available N (kg/ha)	230.10	Alkaline permanganate method (Subbiah and Asija (1956)
Available P_2O_5 (kg/ha)	120.0	Olsen's method. (Jackson, 1973)
Available K_2O (kg/ha)	275.41	Flame photometer (Jackson, 1973)
Electrical conductivity (dS/m)	0.5	Conductivity bridge (Jackson, 1967)
Soil pH (1:2.5) Soil: water solution	6.80	pH meter (Jackson, 1967)

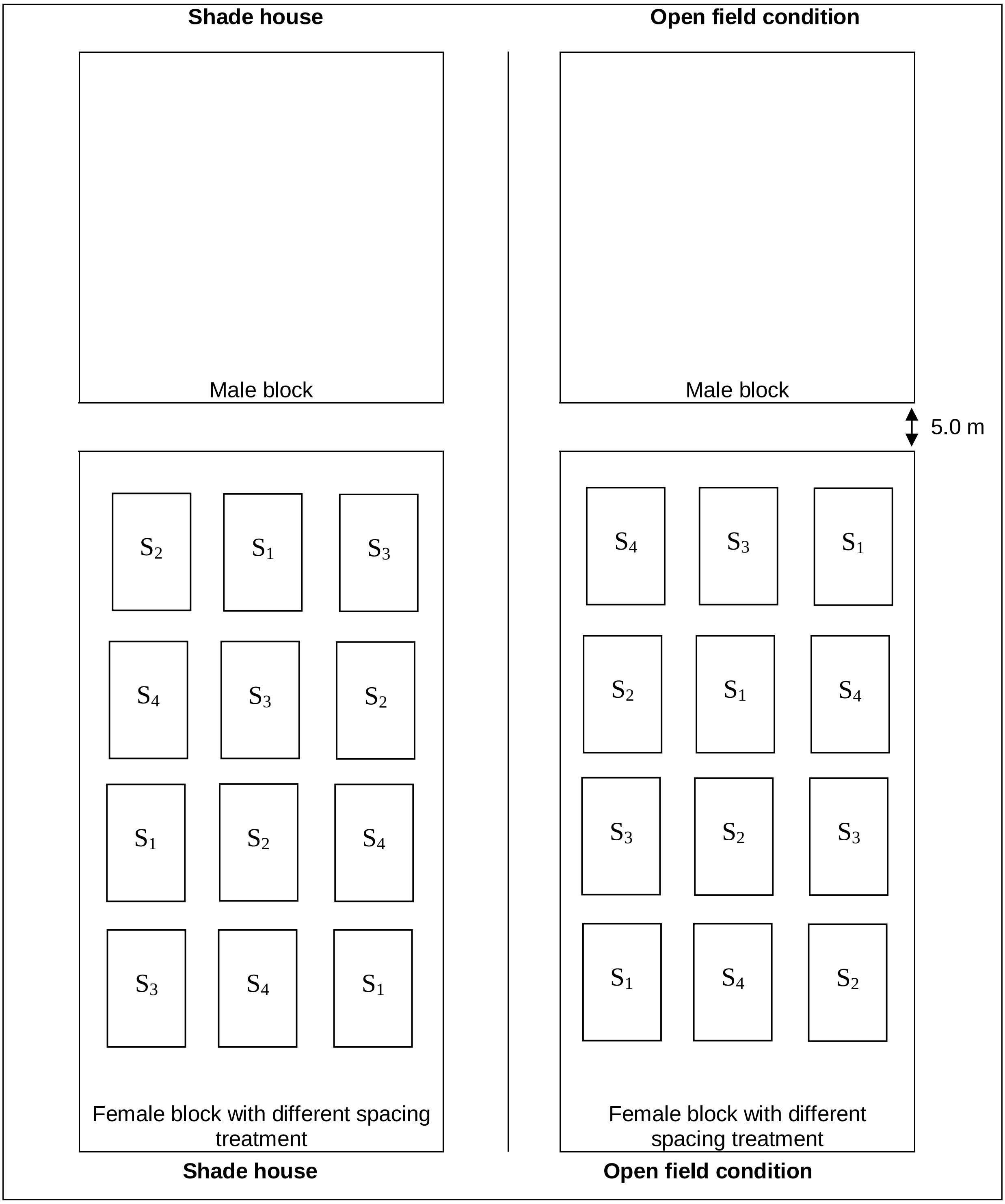

Fig. 2 : Plan of layout of the experiment-I

3.6 Experimental methods

3.6.1 Emasculation

The removal of androecium (stamens) from bisexual flowers is called as emasculation. The buds to be opened next day were selected in female parental line and removed the androecium (anther cone) along with the corolla during emasculation. These emasculated buds were covered with butter paper pockets to avoid cross-pollination by insect or wind and also for easy identification of emasculated flowers. The emasculation was carried out daily from 4:00 pm to 6:00 pm. The care was taken to remove the unemasculated flowers found during emasculation to avoid genetic contamination (Plate 2).

3.6.2 Pollen collection

Fully opened male parent flower are pinched and collected in a brown paper pockets during early hours of the day and anther cones are separated from sepals and petioles were spread on a thin muslin cloth and exposed to sun for two to three hours dried anthers were kept in a steel cup covered with muslin cloth and putting one more steel cup in an inverted position and were agitated rigorously. The pollen were separated from the anther cone and filtered through muslin cloth in another cup and the pollens were transferred to pollen ring and used for pollinating emasculated flowers (Plate 2).

3.6.3 Pollen storage

Pollen collected by above method were transferred to plastic cup containers with the help of a camel brush and the cups were stored under ambient condition to release the pollens and such stored pollen were used for pollinating emasculated flowers (Plate 1).

3.6.4 Pollination

The transfer of pollen from male parent to female parent is called as pollination, pollen collected from the above method were loaded in pollen ring and used for pollinating the emasculated flower by deeping the stigma in rings to effect pollination 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 fruits in the seed parent (Plate 2).

3.6.5 *In vitro* determination of pollen viability through Acetocarmine stain

To find out the pollen viability, the pollen grains randomly collected at anthesis from male block and stored as per treatments then different days old pollens as per treatments used for determination of pollen viability through acetocarmine stain by taken pollens in cavity slides and stained with one per cent acetocarmine solution. The viable pollen stained immediately as dark red and the non viable pollen grains were counted using stereomicroscope the viability percentage was calculated from the mean of five microscopic field count.

3.7 Cultural operations

3.7.1 Details of shade house (35 % shading net)

The experiment was carried out in open field and a shade house covered by using 35 per cent green colour shading net. The size of the shade house constructed was 1280 m^2 (40 $\times$ 32 m) having 3.50 m height by using galvanized iron pipes. To protect the structure from high winds casuarinas trees were planted 10 m away from shade house as wind breaks (Plate 1).

3.7.2 Seedling raising in protrays

The well sterilized coco peat media was used for raising seedlings in protrays of 98 cells and before that protrays were drenched with 0.3 % copper oxychloride solution. Seeds treated with thiram (0.3g/100g seeds) were sown one seed per cell, to a depth of 0.50 cm. Seeds were covered with the thin layer of vermicompost, watered lightly, then trays were covered with polythene sheet for four to five days without watering. After 4-6 days Seeds will germinated and the emerge seedlings then in protrays were drenched with 0.3 % of 19:19:19 complex fertilizer one time and general spray of insecticide and fungicide were given to control pest and diseases. Thus seedling were ready for transplanting 25 days after sowing.

1. Crossing Kit **2. Plastic cup used for pollen storage**

3. Different color woolen threads used for easy identification of Crossed bud as per treatment

Outer view of shade house (35% shading)

Plate 1: Crossing and outer view of shade house

Plate 2. Crossing operation

3.7.3 Preparation of experimental plot

The land was deep ploughed once and was brought to fine tilth by repeated harrowing and leveling. Then FYM was applied at the rate of 25 t ha^{-1} and mixed well in soil and layout was made as per the plan given in Fig.1. All the cultural operations were followed as per the package of practices.

3.7.4 Bed preparation

Land was brought to fine tilth in both in shade house and open field condition. The residues of previous crop, weeds, stubbles and stones were completely removed from the experimental area and incorporated well decomposed farmyard manure, sand, and coir pith in the ratio 2:1:1, diamonium phosphate (20 kg) and urea (5 kg) was also applied as basal dose for area per 1000 meter square. the experimental area was irrigated three to four times and brought to a fine tilth. Raised bed of 30 cm height and 100 cm width to a length of 35 m were prepared with the walking space of 50 cm between beds.

3.7.5 Transplanting

The transplanting was done by planting uniform length, healthy, vigourous seedling, from protrays as per the treatments in shade house and open field. Plants were watered with hose pipe with rose head can immediately after transplanting and every day until the plants established and then with drip irrigation.

3.7.6 Application of fertilizer

The recommended dose of fertilizers at the rate of 115: 100: 60 NPK kg per hector was applied in two splits in the form of urea S.S.P and murate of potash. Half of the nitrogen and entire quantity of phosphorus and potash were applied as basal dose and the remaining half quantity of nitrogen was applied 30 days after transplanting (DAT).

3.7.7 Gap filling

In order to maintain recommended plant population as per treatments, gap filling was taken up after seven days of transplanting.

3.7.8 After care and plant protection

The experimental plot was free from weeds by regular hand weeding. Depending upon the requirement and climatic conditions, protective irrigation was given during the cropping period and necessary plant protection measures were taken as and when required to control pest and diseases.

3.7.9 Training of tomato plants

The training in open field condition was done by tying plants stems along the plastic twine using GI wire for latterly of tying the erected bamboos sticks of 2.5 m height. In shade house plastic twine were twined alone with plant to latterly running GI wire over the roof of shade house. Tying of plants to the plastic twine started from fourth week after transplanting and tying was done at weekly intervals.

3.7.10 Harvesting

Harvesting is done in both the growing conditions as per the treatments after the fruits were fully matured and turned to red in colour. The fruits were kept separately as per treatments to extract the seed

3.7.11 Seed extraction

The fruits were harvested separately according to the treatment in both growing conditions and the harvested fruits were kept for fermentation up to 2 days and fruits were crushed without causing damage to the seed. The seeds were separated manually by repeated hand washing of the pulp then the seeds collected on the sieve were separated and dried in the shade till the seeds reached about 7 per cent moisture content, the weight of seeds from each treatment was recorded using electronic balance.

3.8 Experimental details

3.8.1 Experiment – I: Effect of growing conditions and plant spacing on growth, seed yield and quality of tomato (F1) hybrid seed production

Treatment details

Factor-I: Growing Condition (G) - Two

G_1- Shade house
G_2- Open field condition

Factor-II: Spacing Levels (S) – Four
S_1- 75cmX60 cm
S_2- 50cmX45 cm
S_3- 60cmX45 cm
S_4- 60cmX60 cm

Treatment combinations (GXS) -- Eight

T_1 - G_1S_1	T_5 – G_2S_1
T_2 - G_1S_2	T_6 – G_2S_2
T_3 - G_1S_3	T_7 – G_2S_3
T_4 - G_1S_4	T_8 – G_2S_4

3.8.2 Collection of experimental data

Five plants were randomly selected in female parental line and tagged in net plot area as per the treatments in both the growing conditions (Plate 3).

3.8.2.1 Growth parameters

3.8.2.1.1 Plant height (cm)

The Plant height of the five randomly selected plants were measured from base of plant to the terminal growth point of main stem at 30, 60 and 90 DAT. the average height was work out and expressed in centimeters

3.8.2.1.2 Number of leaves per plant

Total numbers of leaves on primary and secondary branches of five randomly selected and tagged plants were counted at 30, 60, and 90 DAT and average was calculated and expressed as number of leaves per plant.

3.8.2.1.3 Leaf Area ($dm^2 plant^{-1}$)

The leaves from five randomly selected plants from each treatment were used for the estimation of leaf area. Leaf area was computed at 30, 60, and 90 DAT by using disc method (Stickler *et al.,* 1961) and expressed as dm^2 $plant^{-1}$.

3.8.2.1.4 Leaf Area Index (LAI)

The leaf area index was measured and calculated at 30, 60, and 90 DAT by dividing the leaf area per plant by the land area occupied by the plant (Sestak *et al.,* 1971).

$$LAI = \frac{\text{Leaf area } (dm^2)}{\text{Land area } (dm^2)}$$

3.8.2.1.5 Days to 50 percent flowering

Daily observation was made on the five randomly selected and tagged plants for flowering. The day on which 50 per cent of plant showed flower initiation was considered as 50 per cent flowering. the number of days taken from the date of transplanting to flowering was calculated and expressed in number as days taken for 50 per cent flowering

3.8.2.1.6 Days to fruit maturity

The change of the fruit colour from green to bold red colour is the indication of fruit maturity. The days to fruit maturity was calculated from the date of transplanting to the maturity and expressed in days to maturity

3.8.2.2 Fruit yield parameters

3.8.2.2.1 Fruit set (%) per plant

This observation was recorded at 12 days after crossing on female parent. The fruit set percentage was calculated based on total number of floral buds crossed and number of fruit retained on each plant were counted and it was expressed as fruit set percentage by using the formula as below.

$$\text{Fruit set (\%) per plant} = \frac{\text{Total number of crossed fruits retained per plant}}{\text{Total number of female buds crossed per plant}} \times 100$$

General view of female parental line under shade house with different level of spacings

General view of female parental line under open field condition with different level of spacings

Plate 3: General view of experiment number I

3.8.2.2.2 Number of fruits per plant

The number of mature fruits that were harvested from the tagged plants in each picking was recorded till the final harvest and the mean values expressed as whole number of fruit.

3.8.2.2.3 Fruit weight (g)

The matured fruit harvested from five randomly selected and tagged plants were weighed as per the treatments and expressed fruit weight in grams.

3.8.2.3 Seed yield parameters

3.8.2.3.1 Number of seeds per fruit

The seeds extracted from five randomly selected plant and tagged plants in each treatment and number of seed were counted manually and worked out as number of seeds per fruit.

3.8.2.3.2 Seed weight per fruit (g)

The seed extracted from five randomly selected and tagged plant from each treatment was dried the around 7 per cent moisture. The seed weight per fruit was calculated and expressed in grams.

3.8.2.3.3 Seed yield per plant (g)

The seeds were extracted from matured fruits from five randomly selected and tagged plants and dried under shade for six to eight days until seed moisture reaches 7.0 per cent. The total seed weight was recorded and expressed as seed weight per plant in grams.

3.8.2.3.4 Seed yield per plot (g)

The seed yield five randomly selected and tagged plant was added to the yield of net plot area for calculation of seed yield and was recorded as seed yield per plot

3.8.2.3.5 Seed yield per hectare (kg)

The seed yield five randomly selected and tagged plant was added to the yield of net plot area for calculation of seed yield and was recorded as seed yield per hectare

3.8.2.3.6 Seed recovery (%)

Seed recovery per cent was calculated by dividing the seed yield per fruit with average fruit weight and multiplied by hundred

$$\text{Seed recovery in per cent} = \frac{\text{Seed yield per fruit (g)}}{\text{Fruit weight (g)}} \times 100$$

3.8.2.4 Seed quality parameters (after harvest)

3.8.2.4.1 Germination (%)

Germination test was conducted using four replicates of 100 seeds each by adopting "Top of paper method" as described by ISTA (Anon., 2007a). The germination cabinet was maintained at 25 ± 1^0C temperature and 90 ± 2 per cent relative humidity. At the end of 14th day of germination test, the number of normal seedlings in each replication was counted and the germination was calculated and expressed in percentage.

3.8.2.4.2 Root length (cm)

From the germination test, ten normal seedlings were selected randomly in each treatment from all the replications on 14^{th} day. The root length was measured from the tip of the primary root to base of hypocotyl and mean root length was expressed in centimeters.

3.8.2.4.3 Shoot length (cm)

Ten normal seedlings used for root length measurement were also used for the measurement of shoot length. The shoot length was measured from the base of the primary leaf to the base of the hypocotyl and mean shoot length was expressed in centimeters.

3.8.2.4.4 Seedling vigour index

The seedling vigour index was computed using the formula as suggested by Abdul-Baki and Anderson (1973) and expressed as whole number.

Seedling vigour index = Germination (%) × Mean length of seedlings (cm)

3.8.2.4.5 Dry weight of seedlings (mg-^{10})

Ten normal seedlings used for measuring root and shoot length were kept in butter paper and dried in a hot-air oven maintained at 75 ± 1^{0}C temperature for24 hours. Then the seedlings were removed and allowed to cool in a desiccator for 30 minutes for cooling before weighing in an electronic balance. The average weight was calculated and expressed as dry weight of seedlings in milligrams (Anon., 2007a).

3.8.2.4.6 Hundred seed weight (g)

Hundred seeds were drawn at random from each treatment and replication and the seed weight was recorded and expressed in grams

3.8.2.4.7 Total Dehydrogenase Activity (TDH)

The total dehydrogenase activity was determined by the method described by Perl *et al.* (1978) with slight modifications. Twenty five seeds were selected randomly and pre conditioned by imbibing the seeds for 24 hours. After piercing the seed coat a little with the help of a needle, the cotyledons, and the embryonic axis were soaked in 0.5 per cent Tetrazolium solution at 30^{0} ± 1^{0}C for a period of m 16-24 hours. Then they were washed thoroughly with distilled water. The red colour (formazan) was eluted from the stained embryos by soaking in 5 ml of 2-methoxy ethanol for 6 to 8 hours in airtight vials. The extract was decanted and the colour intensity was measured at 480 nm using spectro UV-VIS double beam pc scanning spectrophotometer (UVD-2950). The total dehydrogenase activity was expressed in terms of absorbance at 480nm.

3.8.3 Experiment – **II**: Studies on pollen viability of pollen parent and stigma receptivity of seed parent in (F1) hybrid seed production of tomato under shade house.

Treatment details

Factor-**I** Pollen viability of pollen parent (P) - four

P_0: Pollination immediately after collection (fresh pollen)

P_1: One day stored Pollen

P_2: Two days stored Pollen

P_3: Three days stored Pollen

Factor-**II** Stigma receptivity of seed parent (R) - five

R_0 : Pollination on the same day of emasculation

R_1 : Pollination one day after emasculation

R_2 : Pollination two days after emasculation

R_3 : Pollination three days after emasculation

R_4 : Pollination four days after emasculation

Treatment combinations -Twenty

T_1 – P_0R_0	T_{11} – P_2R_0
T_2 - P_0R_1	T_{12} – P_2R_1
T_3 - P_0R_2	T_{13} – P_2R_2
T_4 - P_0R_3	T_{14} – P_2R_3
T_5 - P_0R_4	T_{15} – P_2R_4
T_6 – P_1R_0	T_{16} – P_3R_0
T_7 – P_1R_1	T_{17} – P_3R_1
T_8 – P_1R_2	T_{18} – P_3R_2
T_9 – P_1R_3	T_{19} – P_3R_3
T_{10} – P_1R_4	T_{20} – P_3R_4

3.8.3.1 Design of experiment

The shade house experiment was laid out in female and male block system among which the 5 x 18 m^2 is female block size in which 250 number of female parental plant were transplanted to get sufficient flower buds.

In complete experiment the totally 1200 flower buds were crossed, among which 20 number of flower buds were crossed with respect to each treatment in each replication and different colour threads were tied to the pedicel of the crossed buds as per the treatments for easy identification (Fig. 3 and Plate 4).

3.8.4 Collection of experimental data

3.7.4.1 In vitro determination of pollen viability through Acetocarmine stain

a. Percentage of dark stained pollens (viable)

b. Percentage of unstained pollens (unviable)

After pollen stained the viable pollen become immediately dark red and the non viable pollen grains were counted using stereomicroscope the viability percentage was calculated from the mean of five microscopic field counts.

3.8.4.2 Fruit and seed yield parameters (after harvest)

3.8.4.2.1 Fruit set percentage

This observation was recorded at 12 days after crossing on female parent. The fruit set percentage was calculated based on total number of floral buds crossed and number of fruit retained in each treatment was counted and it was expressed as fruit set percentage by using the formula as below.

$$\text{Fruit set (\%)} = \frac{\text{Total number of crossed fruits retained per treatment}}{\text{Total number of female buds crossed per treatment}} \times 100$$

3.8.4.2.2 Fruit weight (g)

The fruit weight was measured as per the procedure furnished in 3.8.2.2.3.

3.8.4.2.3 Number of seeds per fruit

The numbers of seeds per fruit were counted as per the procedure furnished in 3.8.2.3.1

3.8.4.2.4 Seed weight per fruit (g)

The seed weight per fruit was recorded as per the procedure furnished in 3.8.2.3.2.

3.8.4.2.5 Seed weight per plant (g)

The seed weight per plant was recorded as per the procedure furnished in 3.8.2.3.3.

3.8.4.2.6 Seed recovery percentage

The seed recovery percentage was calculated as per the procedure furnished in 3.8.2.3.6.

3.8.4.3 Seed quality parameters (after harvest)

3.8.4.3.1 Germination (%)

Seed germination percentage was recorded as per earlier mentioned procedure in section 3.8.2.4.1.

3.8.4.3.2 Root length (cm)

Root length was measured as per the procedure stated in 3.8.2.4.2.

3.7.4.3.3 Shoot length (cm)

The Shoot length was measured as per the procedure stated in 3.8.2.4.3.

3.8.4.3.4 Seedling vigour index

Seedling vigour index was recorded as per the procedure furnished in 3.8.2.4.4.

3.8.4.3.5 Dry weight of seedling (mg^{-10})

Seedling vigour index was recorded as per the procedure furnished in 3.8.2.4.5

3.9 Statistical analysis

The data collected in respect to various parameters on growth, yield and quality attributes were analyzed statistically as described by Gomez and Gomez (1984). The critical difference (CD) values were calculated at 5 per cent (P=0.05) probability level where ‘F’ test was significant. The data on percentage of germination and seed recovery percentage were transformed in to arcsine square root percentage values and transferred data was used for statistical analysis (Snedecor and Cochran, 1967).

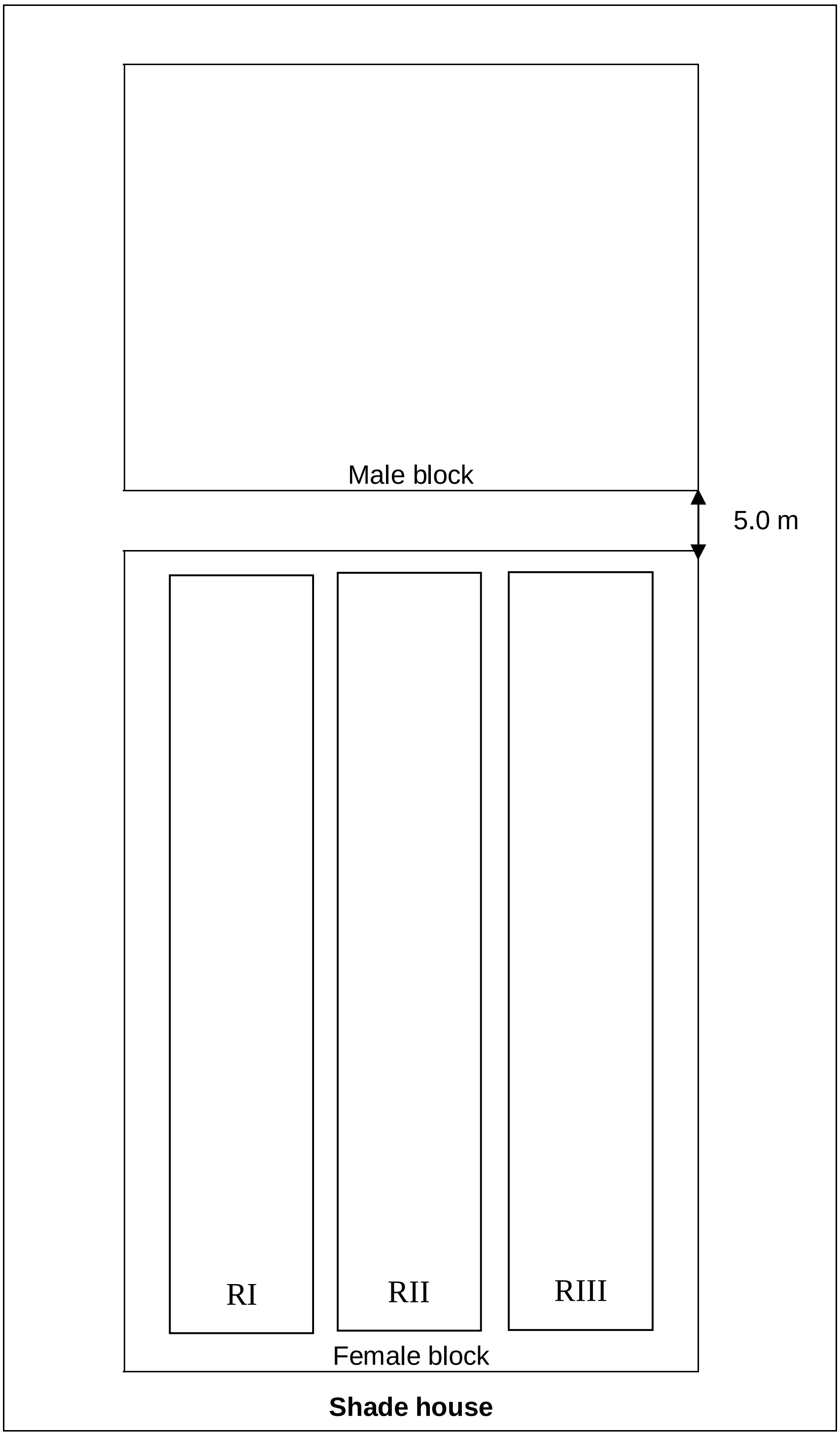

Fig. 3 : Plan of layout of the experiment-II

General view male parental line (male block)

General view of female parental line (female block)

Plate 4: General view of experiment number II

EXPERIMENTAL RESULTS

The results of experiment conducted to study the effect of growing conditions and plant spacing on growth, seed yield and quality of tomato (F_1) hybrid seed production and to know the pollen viability of pollen parent (Gaurav) and stigma receptivity of seed parent (S-120) in hybrid seed production of tomato under shade house in tomato Pusa Hybrid-2 parental lines are presented in this chapter

4.1 Experiment-I : Effect of growing conditions and plant spacing on growth, seed yield and quality of tomato hybrid seed production

4.1.1 Growth parameters

4.1.1.1 Plant height (cm) at 30 days after transplanting (DAT)

The data on plant height at 30 DAT as influenced by growing conditions, spacing on growth and their interaction effects are presented in Table 3.

The plants height at 30 DAT was significantly influenced by growing conditions irrespective of spacing, significantly higher plant height (70.58 cm) at 30 DAT was noticed under G_1 (shade house condition) compared to that of G_2 (open field condition) (57.34 cm).

The plants height at 30 DAT was influenced significantly by spacing irrespective of growing conditions; significantly higher plant height (69.37 cm) at 30 DAT was noticed in spacing at S_2 (50 x 45 cm) which was on par with S_3 (60 x45 cm) (64.73 cm) and lower plant height at 30 DAT observed in S_1 (75 x 60 cm) (59.53 cm).

The interaction effects between growing condition and spacing were found to be non-significant for plant height at 30 DAT however the numerically higher plant height (76.47) was observed in treatment combination of G_1S_2 (shade house at 50 x 45 cm) followed by G_1S_3 (shade house at 60 x 45 cm) (71.07 cm) and the lowest plant height was observed in treatment combination G_2S_1 (open field condition at 75 x 45 cm spacing level) (52.97 cm).

4.1.1.2 Plant height (cm) at 60 days after transplanting (DAT)

The data on Plant height at 60 DAT influenced by the growing condition, spacing's and their interaction effects are presented in the Table 3.

Plant height at 60 DAT was influenced significantly by growing conditions. Among them, growing conditions G_1 (shade houses) produced significantly higher Plant height (140.38 cm) at 60 DAT compared to that of G_2 (open field condition) (84.40 cm).

Plant height at 60 DAT was influenced significantly by spacing's irrespective of growing conditions. Among them, spacing level S_2 (50 x 45 cm) produced significantly higher Plant height (122.03 cm) at 60 DAT followed by S_3 (60 x 45 cm) (114.62 cm) and the lowest Plant height (102.93cm) was observed in S_1 (75 x 60 cm).

The interaction effects between growing condition and spacing were found to be significant for plant height at 60 DAT among the treatment combinations, G_1S_2 (shade house at 50 x 45 cm) closer spacing level recorded significantly higher Plant height (155.97 cm) at 60 DAT which was on par with G_1S_3 (shade house at 60 x 45 cm) (143.13 cm) and the lowest recorded in G_2S_1 open field condition at S_1 (75 x 60 cm) spacing level (80.07 cm).

4.1.1.3 Plant height (cm) at 90 days after transplanting (DAT)

The observations on plant height at 90 days after transplanting (DAT) influenced by the growing condition, spacing and their interaction effects are presented in the Table 3 and depicted in Fig. 4.

The growing condition had significantly affect on Plant height at 90 DAT among them G_1 shade houses recorded the highest plant height (186.54 cm) at 90 DAT compared to that of open field condition (119.26 cm).

The Spacing levels has influenced significantly on the Plant height at 90 DAT, among the treatments the closer spacing level S_2 (50 x 45cm) has recorded the highest plant height (164.21 cm) at 90 DAT and followed by S_3 (60 x 45 cm) (155.90 cm) and S_1 (75 x 60 cm) recorded the lowest plant height (140.07 cm) at 90 DAT .

Table 3. Effect of growing condition and plant spacing on plant height and number of leaves per plant at different growth stages in tomato hybrid seed production

Treatments	Plant height (cm)			Number of leaves per plant		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Growing condition (G)						
G_1- Shade house	70.58	140.38	186.54	23.59	41.70	74.87
G_2- Open field condition	57.34	84.40	119.26	20.91	32.34	41.39
S. Em ±	1.40	1.74	1.90	0.57	0.57	0.75
CD at 5%	4.24	5.29	5.75	1.74	1.72	2.27
Spacing (S)						
S_1- 75 cm x 60 cm	59.53	102.93	140.07	21.62	36.25	57.30
S_2- 50 cm x 45 cm	69.37	122.03	164.21	18.68	32.78	51.83
S_3- 60 cm x 45 cm	64.73	114.62	155.90	23.07	37.42	58.63
S_4- 60 cm x 60 cm	62.22	109.97	151.43	25.63	41.63	64.75
S. Em ±	1.98	2.46	2.68	0.81	0.80	1.06
CD at 5%	6.00	7.48	8.14	2.46	2.44	3.20
Interaction (GxS)						
G_1S_1	66.10	125.80	166.33	21.33	38.53	71.70
G_1S_2	76.47	155.97	200.47	19.80	36.80	67.83
G_1S_3	71.07	143.13	193.17	25.43	43.30	77.63
G_1S_4	68.70	136.60	186.20	27.80	48.17	82.30
G_2S_1	52.97	80.07	113.80	21.90	33.97	42.90
G_2S_2	62.27	88.10	127.95	17.57	28.77	35.83
G_2S_3	58.40	86.10	118.63	20.70	31.53	39.63
G_2S_4	55.73	83.33	116.67	23.47	35.10	47.20
S. Em ±	2.80	3.49	3.79	1.15	1.14	1.49
CD at 5%	NS	10.57	11.51	NS	3.45	4.53

NS – Non significant DAT - Days after transplanting

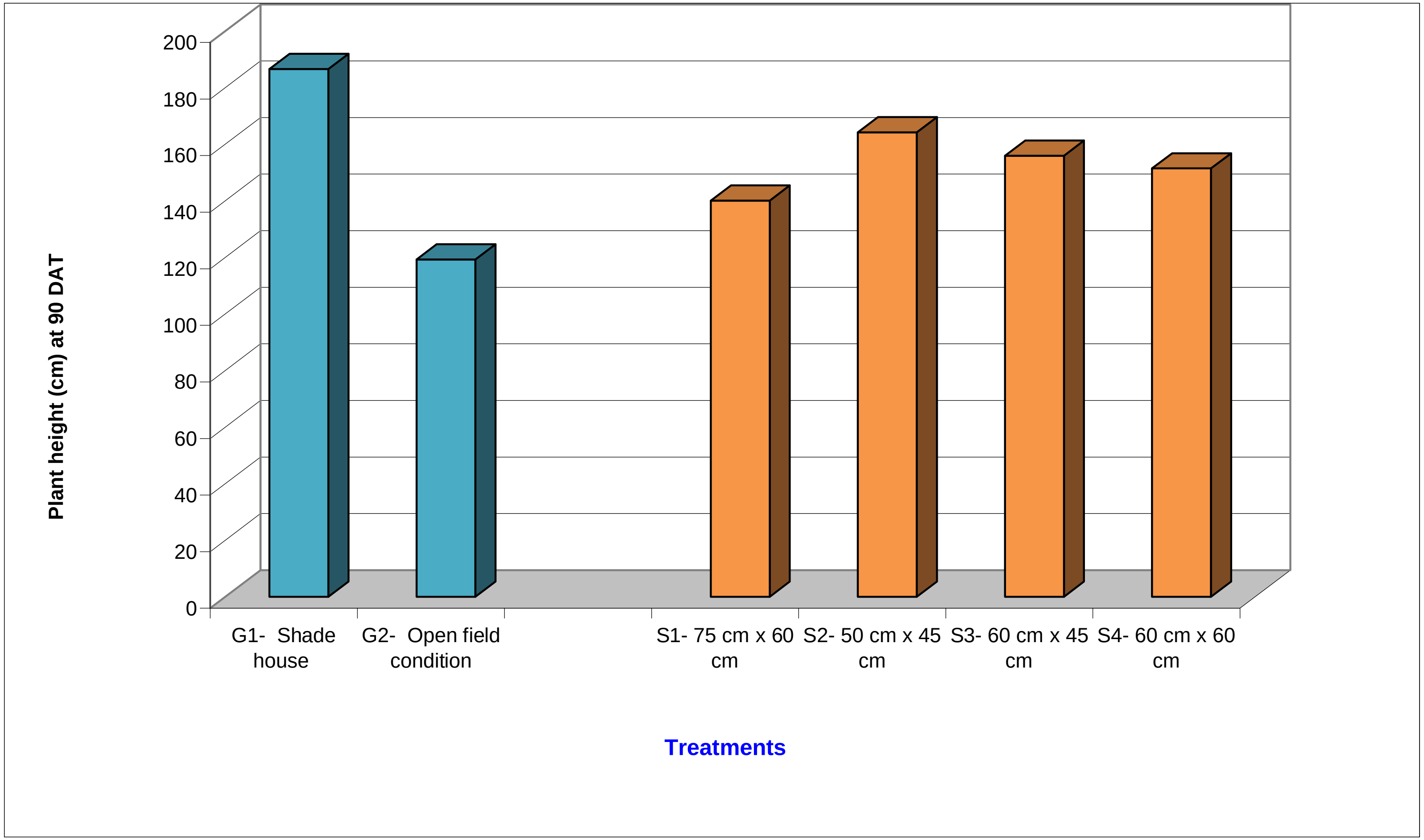

Fig. 4 : Effect of growing condition and plant spacing on plant height (cm) at 90 DAT in tomato hybrid seed production

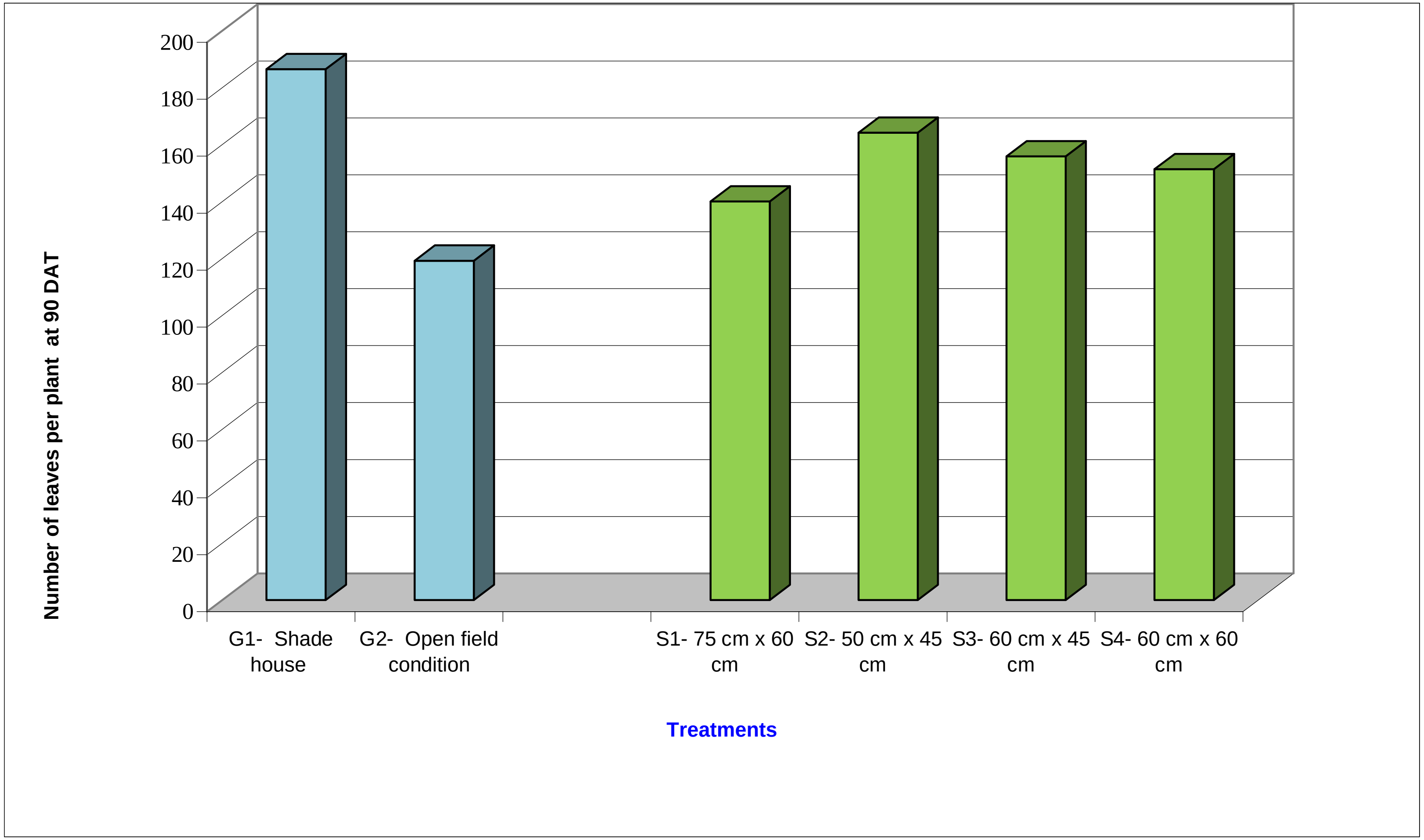

Fig. 5 : Effect of growing condition and plant spacing on number of leaves per plant at 90 DAT in tomato hybrid seed production

The interaction effects between growing condition and spacing were found to be significant for plant height at 90 DAT, Among the treatments combination, the G_1S_2 shade house at S_2 (50 x 45 cm) closer spacing level recorded significantly higher plant height (200.47cm) at 90 DAT which was on par with G_1S_3 (shade house with 60 x 45 cm) (193.17 cm) and the lowest recorded in combination of G_2S_1 (open field condition with 75 x 60 cm) spacing level (80.07 cm).

4.1.1.4 Number of leaves per plant at 30 days after transplanting (DAT)

The data on Number of leaves per plant at 30 days after transplanting (DAT) as influenced by the growing condition, spacing, and their interaction effects are presented in Table 3.

The number of leaves per plant at 30 DAT differed significantly due to growing condition, irrespective of spacing. Among them, the significantly higher number of leaves per plant at 30 DAT under shade house condition (23.59) compared to that of open field condition (20.91).

Irrespective of growing condition the spacing was found to influence significantly on number of leaves per plant at 30 DAT. Among them, significantly higher leaves (25.63) per plant at 30 DAT were noticed at a spacing of S_4 (60 x 60 cm) which was on par with S_3 (60 cm x 45 cm) (23.07). While, the lowest number of leaves (18.68) per plant at 30 DAT was noticed at a spacing of S_2 (50 cm x 45 cm).

The interaction effects between growing condition and spacing were found to be non-significant for number of leaves per plant at 30 days after transplanting DAT among the treatment combination the G_1S_4 (shade house with 60 x 60 cm) recorded numaricaly higher leaves per plant (27.80) at 30 DAT followed by combination G_1S_3 (shade house with 60 x 45 cm) (25.43) and the lowest (17.57) recorded in G_2S_2 (open field condition with 50 x 45 cm) spacing level.

4.1.1.5 Number of leaves per plant at 60 days after transplanting (DAT)

The data on number of branches per plant at 60 days after transplanting (DAT) as influenced by growing condition, spacing, and their interaction effects are presented in Table 3.

Number of branches per plant at 60 DAT was affected significantly by growing condition. Among them, shade house produced significantly higher number of branches (41.70) per plant at 60 days after transplanting compared to that of open field condition (32.34).

Spacing level had shown significant affect on number of branches per plant at 60 DAT, significantly higher number of branches per plant (41.63) were observed in spacing level of S_4 (60X60 cm) and followed by S_3 (60 x 45 cm) (37.42) and the spacing level S_2 (50 x 45cm) recorded lest number of branches per plant (32.78) at 60 days after transplanting.

The interaction effects between growing condition and spacing were found to be significant for number of leaves per plant at 60 days after transplanting. Among the treatment combinations, the G_1S_4 (shade house with 60 x 60 cm) recorded significantly higher number leaves (48.17) per plant at 30 DAT followed by G_1S_3 (shade house with 60 x 45 cm spacing level) (43.30) and the lowest was recorded in G_2S_2 (open field condition with 50 x 45 cm spacing level (28.77).

4.1.1.6 Number of branches per plant at 90 days after transplanting (DAT)

The data on Number of leaves per plant at 90 days after transplanting (DAT) as influenced by the growing condition, spacing and their interaction effects are presented in the Table 3 and depicted in Fig. 5.

The number of leaves per plant at 90 DAT differed significantly due to growing condition, irrespective of spacing. It was significantly higher under shade house condition (74.70) compared to that of open field condition (41.39).

Irrespective of growing condition, the spacing was found to influence number of leaves per plant at 90 DAT significantly. Significantly higher leaves per plant at 90 DAT was noticed at a spacing of S_4 (60 cm x 60 cm) (64.75) and was followed by spacing of S_3 (60 cm x 45 cm) (58.63). While, the lowest leaves per plant at 90 DAT was noticed at a spacing level of S_2 (50 cm x 45 cm) (51.83).

The interaction effects between growing condition and spacing were found to be significant for number of leaves per plant at 90 DAT among the treatment combinations, the G_1S_4 (shade house with 60 x 60 cm) recorded significantly higher leaves per plant (82.30) at 90 DAT followed by G_1S_3 (shade house with 60 x 45 cm spacing level) (77.63) and the lowest recorded in G_2S_2 (open field condition at 50 x 45 cm) spacing level (35.83).

4.1.1.7 Leaf area (dm^2 $plant^{-1}$) at 30 days after transplanting (DAT)

The data on leaf area (dm^2 $plant^{-1}$) at 30 days after transplanting as influenced by growing condition, spacing, and their interaction effects are presented in Table 4.

Leaf area at 30 DAT were affected significantly by growing condition. Among them, shade house produced significantly higher leaf area (15.35 dm^2 $plant^{-1}$) at 30 DATcompared to that of open field condition (11.35 dm^2 $plant^{-1}$).

Spacing level had shown significant affect on Leaf area at 30 DAT significantly higher Leaf area (15.67 dm^2 $plant^{-1}$) are observed in spacing level of S_4 (60X60 cm) followed by S_3 (60 x 45 cm) (13.15 dm^2 $plant^{-1}$) and spacing level S_2 (50 x 45cm) recorded lest Leaf area (11.71 dm^2 $plant^{-1}$) at 30 DAT.

The interaction effects between growing condition and spacing were found to be significant for Leaf area at 30 days among the treatment combinations, the G_1S_4 shade house with 60 x 60 cm) recorded significantly higher on Leaf area (18.32 dm^2 $plant^{-1}$) at 30 days and followed by G_1S_3 (shade house with 60x45 cm) (15.50 dm^2 $plant^{-1}$) and the lowest recorded in G_2S_2 open field condition with 50 x 45 cm) spacing level (9.91 dm^2 $plant^{-1}$).

4.1.1.8 Leaf area (dm^2 $plant^{-1}$) at 60 days after transplanting (DAT)

The data on Leaf area (dm^2 $plant^{-1}$) at 60 days after transplanting as influenced by growing condition, spacing and their interaction effects are presented in Table 4.

Leaf area at 60 DAT was affected significantly by growing condition. Among the treatments, shade house produced significantly higher leaf area (78.37 dm^2 $plant^{-1}$) at 60 DAT compared to that of open field condition (32.37dm^2).

Spacing level had shown significant effect on Leaf area at 60 DAT significantly higher Leaf area (60.39 dm^2 $plant^{-1}$) were observed at spacing level of S_4 (60 x 60 cm) followed by S_3 (60 x 45 cm) (54.99 dm^2 $plant^{-1}$) and spacing level S_2 (50 x45 cm) had recorded lest leaf area (53.68 dm^2 $plant^{-1}$) at 60 days after transplanting DAT .

The interaction effects between growing condition and spacing were found to be significant for on leaf area at 60 days among the treatment combinations, the G_1S_4 (shade house with 60 x 60 cm) spacing level recorded significantly higher leaf area (85.90dm^2 $plant^{-1}$) at 60 days followed by G_1S_3 (78.79dm^2 $plant^{-1}$) and the lowest recorded in G_2S_2 (open field condition with 50x 45 cm) spacing level (30.94dm^2 $plant^{-1}$).

4.1.1.9 Leaf area (dm^2 $plant^{-1}$) at 90 days after transplanting (DAT)

The data on leaf area (dm^2 $plant^{-1}$) at 90 days after transplanting (DAT) as influenced by growing condition, spacing, and their interaction effects are presented in Table 4.

Leaf area at 90 DAT was affected significantly by growing condition. Among them, shade house produced significantly leaf area (131.75 dm^2 $plant^{-1}$) at 90 DAT compared to that of open field condition (69.92 dm^2 $plant^{-1}$).

Spacing level had shown significant affect on leaf area (dm^2 $plant^{-1}$) at 90 DAT significantly larger leaf area (104.74 dm^2 $plant^{-1}$) were observed at spacing level of S_4 (60X60 cm) followed by S_3 (60 x 45 cm) (100.98) and level S_2 (50 x 45cm) recorded lest leaf area (97.84 dm^2 $plant^{-1}$) at 90 DAT.

The interaction effects between growing condition and spacing were found to be significant for on leaf area at 90 days among the treatment combinations, the G_1S_4 (shade house with 60 x 60 cm) recorded significantly higher on leaf area (137.87 dm^2 $plant^{-1}$) at 60 which was on par with G_1S_3 (shade house with 60 x45 cm) (132.93 dm^2 $plant^{-1}$) and the lowest recorded in G_2S_2 (open field condition with 50 x 45 cm) spacing level (68.19 dm^2 $plant^{-1}$).

4.1.1.10 Leaf area index at 30 days after transplanting (DAT)

The data on leaf area index at 30 days after transplanting (DAT) as influenced by growing condition, spacing, and their interaction effects are presented in Table 4.

Leaf area index at 30 days after transplanting were affected significantly by growing condition. Among them, shade house produced significantly higher leaf area index (0.50) at 30 DAT compared to that of open field condition (0.37).

Table 4. Effect of growing condition and plant spacing on leaf area and leaf area index per plant at different growth stages in tomato hybrid seed production

Treatments	Leaf area (dm^2 / $plant^{-1}$)			Leaf area index		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
Growing condition (G)						
G_1- Shade house	15.35	78.37	131.75	0.50	2.56	4.32
G_2- Open field condition	11.35	32.37	69.92	0.37	1.06	2.29
S. Em ±	0.24	0.77	0.64	0.01	0.03	0.02
CD at 5%	0.71	2.33	1.95	0.03	0.08	0.06
Spacing (S)						
S_1- 75 cm x 60 cm	12.87	53.68	99.78	0.29	1.19	2.22
S_2- 50 cm x 45 cm	11.71	52.43	97.84	0.52	2.33	4.35
S_3- 60 cm x 45 cm	13.15	54.99	100.98	0.49	2.04	3.74
S_4- 60 cm x 60 cm	15.67	60.39	104.74	0.44	1.68	2.91
S. Em ±	0.33	1.09	0.91	0.01	0.04	0.03
CD at 5%	1.01	3.29	2.75	0.04	0.11	0.09
Interaction (GxS)						
G_1S_1	14.06	74.87	128.70	0.31	1.66	2.86
G_1S_2	13.51	73.91	127.48	0.60	3.29	5.67
G_1S_3	15.50	78.79	132.93	0.57	2.92	4.92
G_1S_4	18.32	85.90	137.87	0.51	2.39	3.83
G_2S_1	11.68	32.49	70.86	0.26	0.72	1.57
G_2S_2	9.91	30.94	68.19	0.44	1.38	3.03
G_2S_3	10.79	31.18	69.02	0.40	1.15	2.56
G_2S_4	13.01	34.89	71.62	0.36	0.97	1.99
S. Em ±	0.47	1.54	1.28	0.02	0.05	0.04
CD at 5%	1.43	4.66	3.89	0.05	0.15	0.12

DAT - Days after transplanting

Spacing level had shown significant effect on leaf area index at 30 DAT significantly higher leaf area index (0.52) were observed in spacing level of S_2 (50 x 45 cm) on par with S_3 (60 x 45 cm) (0.49) and spacing level S_1 (75 x 60 cm) recorded lest leaf area index (0.29) at 30 DAT .

The interaction effects between growing condition and spacing were found to be significant for leaf area index at 30 days, among the treatment combinations, the G_1S_2 (shade house with 50 x 45 cm) recorded significantly higher on leaf area index (0.60) at 30 days followed by G_1S_3 (shade house with 60 x 45 cm) (0.57) and the lowest recorded in G_2S_1 (open field condition at S_1 75 x 60 cm) spacing level (0.26).

4.1.1.11 Leaf area index (dm^2 $plant^{-1}$) at 60 days after transplanting (DAT)

The data on leaf area index at 60 days after transplanting (DAT) as influenced by growing condition, spacing's, and their interaction effects are presented in Table 4.

Leaf area index at 60 DAT were effected significantly by growing condition. Among them, shade house produced significantly higher leaf area index (2.56) at 60 days after transplanting compared to that of open field condition (1.06).

Spacing level had shown significant affect on leaf area index at 60 DAT significantly higher leaf area index (2.33) were observed in spacing level of S_2 (50 x 45 cm) followed by S_3 (60 x 45 cm) (2.04) and spacing level S_1 (75 x 60 cm) recorded lest Leaf area index (1.19) at 60 DAT .

The interaction effects between growing condition and spacing were found to be significant for leaf area index at 60 days among the treatment combinations, the G_1S_2 (shade house with 50 x 45 cm) recorded significantly higher on leaf area index (3.29) at 30 days followed by S_3 60 x 45 cm (2.92) and the lowest recorded in G_2S_1 open field condition with 75 x 60 cm) spacing level (0.72).

4.1.1.12 Leaf area index (dm^2 $plant^{-1}$) at 90 days after transplanting (DAT)

The data on leaf area index at 90 days after transplanting (DAT) as influenced by growing condition, spacing, and their interaction effects are presented in Table 4.

Leaf area index at 90 DAT were affected significantly by growing condition. Among them, shade house produced significantly higher leaf area index (4.32) at 90 DAT compared to that of open field condition (2.92).

Spacing level had shown significant affect on leaf area index at 60 DAT significantly higher leaf area index (4.35) was observed in spacing level of S_2 (50 x 45cm) followed by S_3 (60 x 45 cm) (3.74) and spacing level S_1 (75 x 60 cm) recorded lest Leaf area index (2.22) at 90 DAT .

The interaction effects between growing condition and spacing were found to be significant for on leaf area index at 90 days among the treatment combinations, G_1S_2 (shade house with 50 x 45 cm) recorded significantly higher on leaf area index (5.67) at 90 days followed by G_1S_3 (Shade house with 60 x 45 cm) (4.92) and the lowest was recorded in G_2S_1 (open field condition with 75 x 60 cm) spacing level (1.57).

4.1.1.13 Days after transplanting (DAT) to 50% flowering

The observation on days to 50 (%) flowering as influenced by growing condition, spacing's , and their interaction effects are presented in the Table 5.

The days to 50 per cent flowering differ significantly due to growing condition where less number (31.83) of days required to 50 per cent of flowering in open field condition compared with shade houses growing condition were flowering dialed (36.00 days)

Spacing influenced significantly on days to 50 (%) flowering irrespective of growing condition. Significantly less number (31.17) of days were taken by closer spacing S_2 (50 x 45 cm) followed by S_3 (60 x 45 cm) (33.50) days and more number of days taken by S_4 (60 x 60 cm) (36.33) days.

The two way interaction effects between growing condition and spacing (GxS) were found to be non-significant for 50% flowering DAT as numerically lesser days to 50 (%) flowering was observed in treatment combination of G_2S_2 (open field condition with 50 x 45 cm) (28.00) followed by G_2S_3 (open field with 60 x 45 cm) (30.33) and the highest was observed in combination G_1S_4 (Shade house with 60 x 60 cm) (37.67)

4.1.1.14 Days after transplanting (DAT) to fruit maturity

The observations on Days after transplanting (DAT) fruit maturity as influenced by growing condition, spacing and their interaction effects are presented in Table 5.

The DAT to fruit maturity influenced significantly due to growing condition, irrespective of spacings. Significantly lesser number of DAT taken to fruit maturity (91.42) had observed with open field condition compared to that of shade house condition (79.17 days)

The fruit maturity DAT differed significantly due to spacing, irrespective of growing condition. Significantly lowest DAT for fruit maturity was recorded in S_2 (50 x 45 cm) (81.00) followed by S_3 (60 x 45 cm) (86.17) and highest DAT fruit maturity was recorded in S_4 (60 x 60 cm) (88.50),

The two way interaction effects between growing condition and spacing (GxS) showed non-significant differences on fruit maturity DAT. However, the fruit maturity DAT was comparatively lesser in G_2S_2 (open field condition at 50 x 45 cm) (75) followed by G_2S_3 (open field condition with 60 x 45 cm) (78.67) and more days were taken by G_1S_4 (shade house with 60 x 60 cm spacing level) (94.67).

4.1.2 Fruit and seed yield parameters

4.1.2.1 Fruit set (%)

The data recorded on fruit set (%) as influenced due to growing condition, spacing and their interaction effects are presented in the Table 6 and depicted in Fig. 6

The fruit set influenced significantly by growing condition, irrespective of spacing. Significantly higher fruit set (67.6%) was observed with shade house condition compared to that of open field condition (61.2 %)..

Fruit set (%) differed significantly due to spacing, irrespective of growing condition. Significantly higher fruit set (71.1%) was recorded in S_4 (60 x60 cm), followed by S_3 (60 x 45 cm) (65.54 %) and the lowest fruit set (56.7 %) was recorded in S_2 (50 X45 cm).

The two way interactions between growing condition and spacing (GxS) showed marked differences on fruit set (%). Significantly higher fruit set (74.6%) was recorded in G_1S_4 (shade house with 60 x 60 cm) combination followed by G_1G_3 (shade house with 60 x 45 cm) (69.9%) and the lower was observed in G_1S_2 (open filed condition with 50 x 45 cm) (51.9%).

4.1.2.2 Number of fruits per plant

The data on number of fruits per plant as influenced by due to growing condition, spacing and their interaction effects are presented in the Table 6 and depicted in Fig. 6.

Number of fruits per plant differed significantly due to growing condition the growing condition shade houses recorded highest number of fruits (18) per plant in compared with open field condition (14).

Irrespective of growing condition, spacing's was found to be significant affect on number of fruit. Significantly higher number of fruits (19) per plant was observed in S_4 (60 x 60 cm) followed by S_3 (60 x 45 cm) (16). While, the lowest number of fruits per plant (13) was noticed in S_2 (50 x 45 cm).

The two way interactions between growing condition and spacing (GxS) are found to be significant. The number of fruits per plant was significantly higher in treatment combination G_1S_4 (shade house condition at spacing of 60 cm x 60 cm) (22) followed by G_1S_3 (shade house with 60 x 45 cm) (19). The lowest was observed in G_2S_2 (open field condition at spacing 50 cm x 45 cm) (13).

4.1.2.3 Fruit weight (g)

The data on fruit weight (g) as influenced by growing condition, spacing and their interaction effects are present in Table 6.

The fruit weight differed significantly with respect to growing condition. Among them open field condition recorded significantly higher fruit weight (91.8g) as compared with shade house condition (80.1g).

Significantly higher individual fruit weight was noticed with respect of different spacing levels irrespective of growing condition, among the treatment combinations, spacing level S_4 (60X60 cm) recorded the highest fruit weight (91.1g) on par with S_1 (75 x 60 cm) with (86.6) fruit weight and the lowest (81.5) was recorded at S_2 (50 x 45cm) spacing level

Table 5. Effect of growing condition and plant spacing on days to 50% flowering and days to fruit maturity in tomato hybrid seed production

Treatments	Days to 50 % flowering	Days to maturity
Growing condition (G)		
G_1- Shade house	36.00	91.42
G_2- Open field condition	31.83	79.17
S. Em ±	0.47	0.59
CD at 5%	1.41	1.79
Spacing (S)		
S_1- 75 cm x 60 cm	34.67	85.17
S_2- 50 cm x 45 cm	31.17	81.33
S_3- 60 cm x 45 cm	33.50	86.17
S_4- 60 cm x 60 cm	36.33	88.50
S. Em ±	0.66	0.83
CD at 5%	2.00	2.53
Interaction (GxS)		
G_1S_1	35.67	89.67
G_1S_2	34.00	87.67
G_1S_3	36.67	93.67
G_1S_4	37.67	94.67
G_2S_1	33.67	80.67
G_2S_2	28.33	75.00
G_2S_3	30.33	78.67
G_2S_4	35.00	82.33
S. Em ±	0.93	1.18
CD at 5%	NS	NS

NS – Non significant

Table 6. Effect of growing condition and plant spacing on fruit set percentage, number of fruits per plant and fruit weight (g) in tomato hybrid seed production

Treatments	Fruit set (%)	Number of fruits per plant *	fruit weight(g)
Growing condition (G)			
G_1- Shade house	67.6	18	80.1
G_2- Open field condition	61.2	14	91.8
S. Em ±	0.8	0.3	0.9
CD at 5%	2.5	0.9	2.6
Spacing (S)			
S_1- 75 cm x 60 cm	64.3	15	86.6
S_2- 50 cm x 45 cm	56.7	13	81.5
S_3- 60 cm x 45 cm	65.5	16	84.7
S_4- 60 cm x 60 cm	71.1	19	91.1
S. Em ±	1.1	0.4	1.2
CD at 5%	3.5	1.2	3.7
Interaction (GxS)			
G_1S_1	64.2	17	78.9
G_1S_2	61.5	15	76.7
G_1S_3	69.9	19	81.1
G_1S_4	74.6	22	83.9
G_2S_1	64.4	14	94.3
G_2S_2	51.9	11	86.3
G_2S_3	61.1	13	88.3
G_2S_4	67.5	16	98.3
S. Em ±	1.6	0.6	1.7
CD at 5%	4.9	1.7	NS

NS – Non significant

* Only 25 days (from flowering) crossing had done

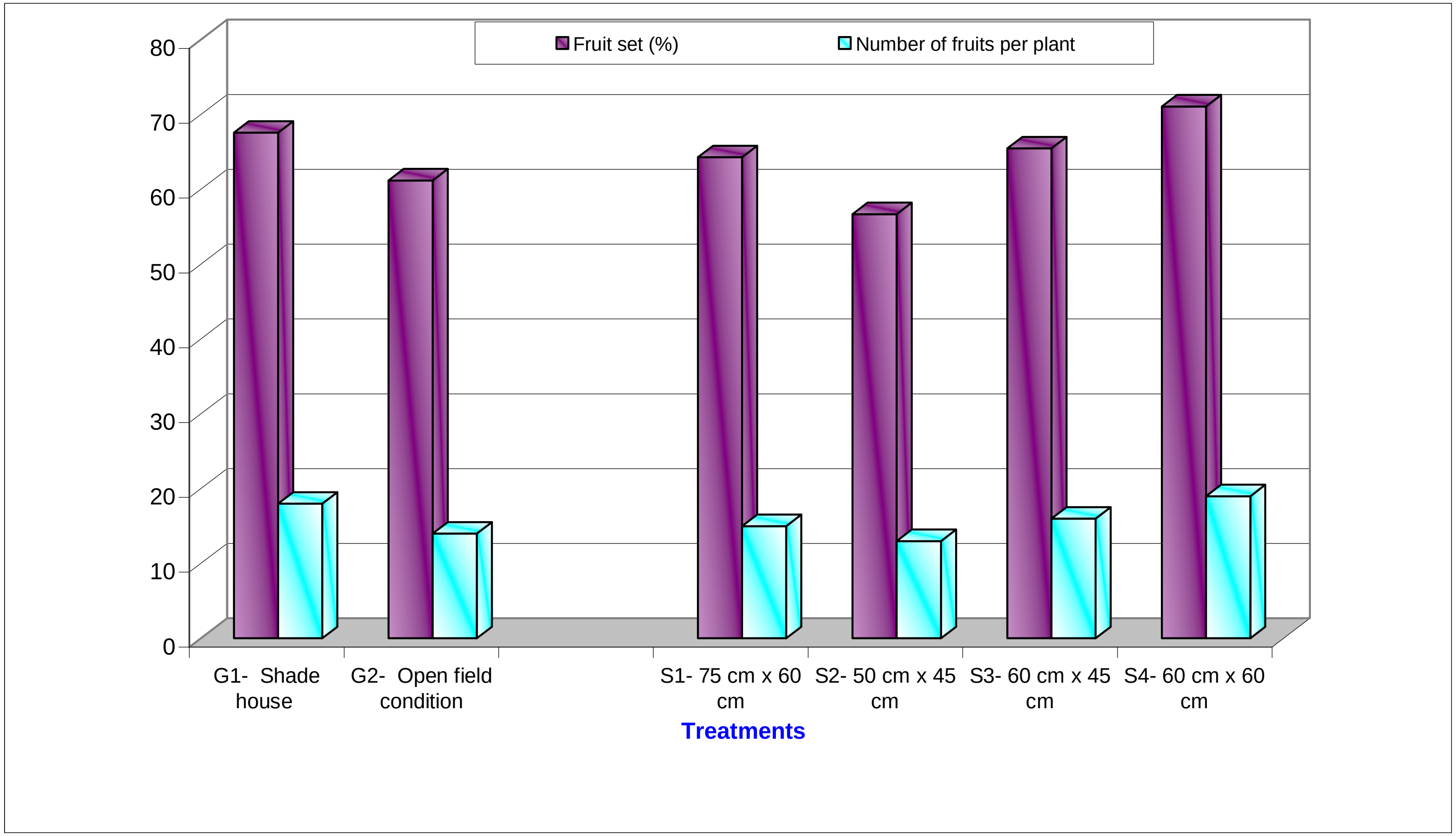

Fig. 6 : Effect of growing condition and plant spacing on fruit set percentage and number of fruits per plant in tomato hybridseed production

Table 7. Effect of growing condition and plant spacing on number of seeds per fruit, seed weight per fruit and seed recovery (%) in tomato hybrid seed production

Treatments	Number of seeds per fruit	Seed weight per fruit(g)	Seed recovery (%)
Growing condition (G)			
G_1- Shade house	139	0.323	0.402(3.633)
G_2- Open field condition	105	0.238	0.259(2.916)
S. Em ±	1	0.004	0.006(0.030)
CD at 5%	4	0.011	0.018(0.090)
Spacing (S)			
S_1- 75 cm x 60 cm	122	0.280	0.329(3.271)
S_2- 50 cm x 45 cm	111	0.248	0.309(3.165)
S_3- 60 cm x 45 cm	121	0.280	0.334(3.292)
S_4- 60 cm x 60 cm	134	0.313	0.351(3.370)
S. Em ±	2	0.005	0.009(0.042)
CD at 5%	6	0.016	0.026(0.127)
Interaction (GxS)			
G_1S_1	134	0.310	0.393(3.592)
G_1S_2	127	0.287	0.374(3.504)
G_1S_3	139	0.330	0.408(3.660)
G_1S_4	155	0.363	0.434(3.949)
G_2S_1	110	0.250	0.265(2.949)
G_2S_2	95	0.210	0.243(2.826)
G_2S_3	104	0.230	0.260(2.924)
G_2S_4	114	0.263	0.268(2.965)
S.Em ±	3	0.007	0.012(0.057)
CD at 5%	8	0.023	NS

NS – Non significant

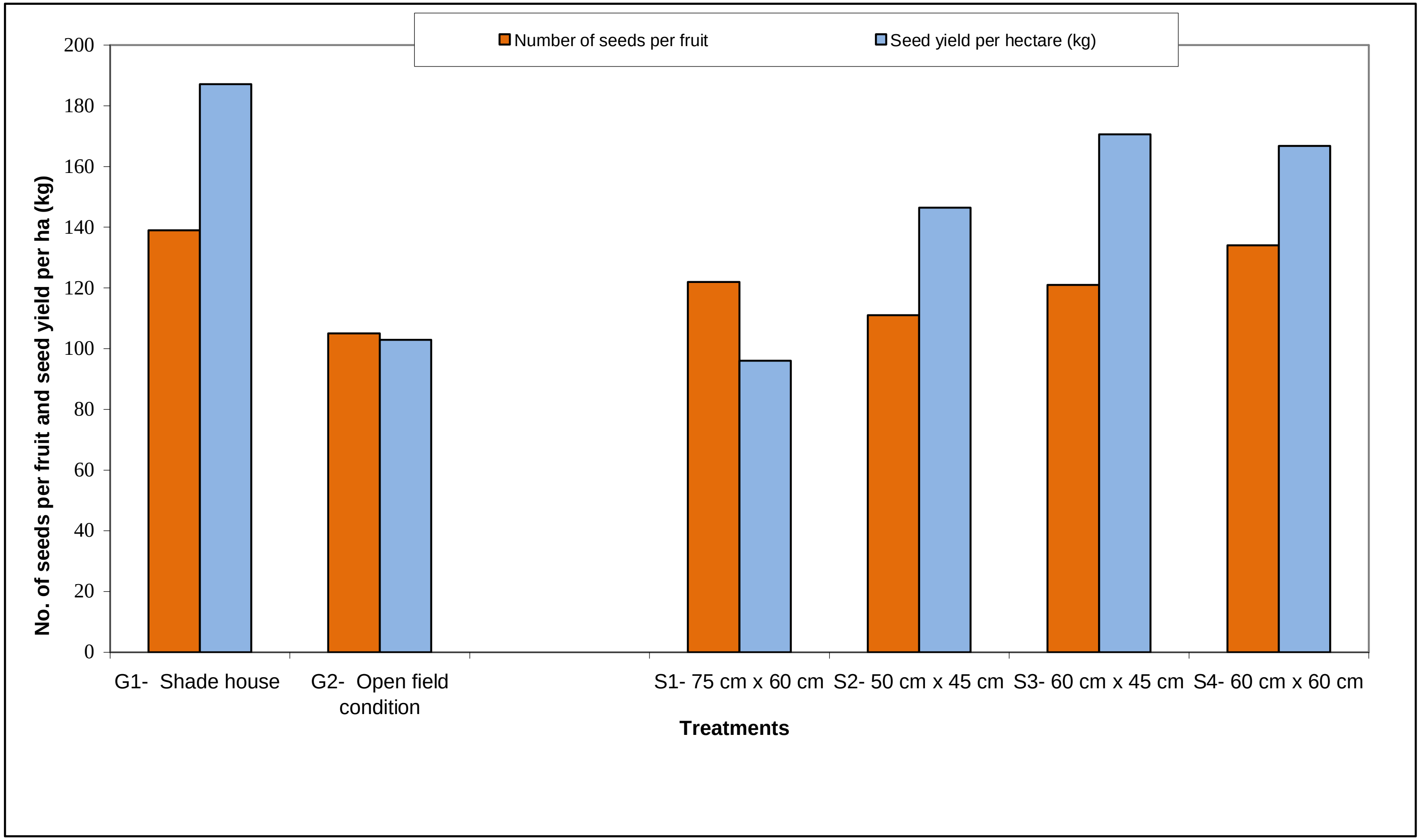

Fig. 7 : Effect of growing condition and plant spacing on number of seeds per fruit and seed yield per hectare in tomato hybrid seed production

Table 8. Effect of growing condition and plant spacing on seed yield per plant (g), seed yield plot (g) and seed yield per ha (kg) in tomato hybrid seed production

Treatments	Seed yield per plant (g)	Seed yield per plot (g)	Seed yield per hectare (kg)
Growing condition (G)			
G_1- Shade house	5.8	280.7	187.1
G_2- Open field condition	3.3	154.3	102.9
S. Em ±	0.1	4.1	2.7
CD at 5%	0.3	12.3	8.2
Spacing (S)			
S_1- 75 cm x 60 cm	4.3	144.0	96.0
S_2- 50 cm x 45 cm	3.3	219.7	146.4
S_3- 60 cm x 45 cm	4.6	256.0	170.6
S_4- 60 cm x 60 cm	6.0	250.2	166.8
S. Em ±	0.1	5.8	3.8
CD at 5%	0.4	17.5	11.6
Interaction (GxS)			
G_1S_1	5.1	171.6	114.4
G_1S_2	4.2	280.9	187.3
G_1S_3	6.2	342.0	228.0
G_1S_4	7.9	328.1	218.7
G_2S_1	3.5	116.4	77.6
G_2S_2	2.4	158.4	105.6
G_2S_3	3.1	169.9	113.3
G_2S_4	4.1	172.3	114.9
S. Em ±	0.2	8.1	5.4
CD at 5%	0.5	24.7	16.5

The two way interactions between growing condition and spacing (GxS) were found to be non-significantly with respect to fruit weight .among which the numerically highest fruit weight observed in G_2S_4 (open field condition with spacing level 60 x 60 cm) (98.3g) on par with G_2S_1 (94.3g) and lower fruit weight (76.7) was observed in G_1S_2 (shade house at a spacing of 50 cm x 45 cm) these data.

4.1.2.4 Number of seeds per fruit

The results on number of seeds per fruit as influenced by growing condition, spacing, and their interaction effects are presented in the Table 7 and depicted in Fig. 7.

The number of seeds per fruit varied significantly due to growing condition, irrespective of spacing. The number of seeds (138.67) per fruit was higher shade house compared to that open field condition (105.38).

A significant difference on number of seeds per fruit was noticed among the four spacing, irrespective of growing condition. Number of seeds (134.17) per fruit was significantly higher in S_4 (60 x 60 cm) followed by S_3 (60 x 45 cm) (121.17) and the lowest number of seeds (110.58) per fruit was observed in S_2 (50 x 45 cm)

The interaction of growing condition, spacing were found to be significant with respect of number of seed per plant, the treatment combination G_1S_4 (shade house condition at spacing of 60 x 60 cm) recorded higher number of seeds (154.67) per fruit followed by G_1S_3 (shade house condition at spacing of 60 x 45 cm) (138.67). The G_2S_2 (open field at 50X 45 cm) recorded the lowest number of seeds (94.50) per fruit

4.1.2.5 Seed weight per fruit (g)

The data on days Seed weight per fruit (g) as influenced by growing condition, spacing and their interaction effects are present in Table 7.

Seed weight per fruit recorded significantly higher in shade houses growing condition (0.323 g) as compared to that open field condition (0.238 g).

Spacing also had influenced significantly the seed weight per fruit irrespective of growing condition where the spacing level S_4 (60 x 60 cm) recorded highest Seed weight (0.313g) per fruit followed by S_3 (60 x 45 cm) (0.280g) and the lowest seed weight (0.248 g) per fruit was noticed in spacing level S_2 (50 x 45 cm).

The two way interactions between growing condition and spacing (GxS) .had shown significant difference on seed weight per fruit and the seed weight (0.363g) per fruit was significantly higher in treatment combination of G_1S_4 (shade house with 60 x 60 cm) spacing followed by G_1S_3 (0.330) (shade house with 60 x 45 cm) and lowest was observed in G_2S_2 (open field condition at a spacing level of 50 cm x 45cm) (0.230 g).

4.1.2.6 Seed recovery (%)

The data on Individual Seed recovery (%) as influenced by growing condition, spacing and their interaction effects are present in Table 7.

The Seed recovery (%) differed significantly with respect to growing condition. Among them shade condition recorded significantly higher Seed recovery (0.402%) as compared with open field condition (0.259 %).

The significant difference in Seed recovery (%) was observed due to the spacing levels irrespective of growing condition. significantly higher Seed recovery (0.351%) was noticed with respect of S_4 (60 x 60 cm) spacing levels which was on par with spacing level S_3 (60 x 45cm) (0.334%) and the lowest Seed recovery (0.309%) was recorded in S_2 (50 x 45 cm).

The interaction between growing condition and spacing had non-significant affect on seed recovery (%) however the higher seed recovery (%) had seen in G_1S_4 (.434%) followed by G_1S_3 (0.408 %) and the lowest in G_2S_2 (0.243%).

4.1.2.7 Seed yield per plant (g)

The results on Seed yield per plant (g) as influenced by growing condition, spacing and their interaction are presented in Table 8.

The growing condition shade houses showed significantly influence on the seed yield per plant. Significantly higher seed yield per plant (5.8g) was obtained in shade houses as compared with open field condition (3.3g).

The spacing level had significantly influence on seed yield per plant. The highest seed yield per plant (6.0g) was recorded in the spacing level at S_4 (60 x 60 cm) followed by S_3 (60 x 45 cm) (4.6 g) the lowest seed yield per plant (3.3 g) value was noticed in spacing at S_1 (50 x 45cm).

The interaction involving two growing condition and four spacing levels and the treatment combination were found to be significant. Higher seed yield per plant (7.9g) was noticed G_1S_4 (shade house at 60 x 60 cm) followed by the combination G_1S_3 (shade house with 60 x 45 cm) (6.2g) and the minimum seed yield per plant (2.4g) recorded in G_2S_2 (shade house with 50 x 45 cm).

4.1.2.8 Seed yield per plot (g)

The observations on Seed yield per plot as influenced by growing condition, spacing and their interaction effects are presented in Table 8..

The Seed yield per plot influenced significantly due to growing condition, irrespective of spacing. Significantly higher seed yield per plot (280.7 g) was observed under shade house condition compared to that of open field condition (154.3g).

Seed yield per plot differed significantly due to spacing, irrespective of growing condition. Significantly higher seed yield per plot (256.0g) was recorded in S_3 (60 x 45 cm), which was on par with S_4 (60 x 60 cm) with (250.2.1g) and the lowest Seed yield per plot (144.0g) was recorded in S_1 (75 x 45 cm).

The two way interaction effects between growing condition and spacing (GxS) showed significant differences on seed yield per plot, among the treatment combination the significant higher seed yield per plot (342.0g) was observed G_1S_3 (shade house with 60 x 45 cm) which was on par with G_1S_4 (shade house with 60 x 60 cm) (328.1g) and the lowest (172.3 g) in $G_2S_{1\,(}$(shade house with 75 x 60 cm).

4.1.2.9 Seed yield per hectare (kg)

The data on seed yield per hectare (kg) as influenced by due to growing condition, spacing and their interaction effects are presented in the Table 8 and depicted in Fig. 7.

Seed yield per hectare differed significantly due to growing condition, the growing condition G_1 shade houses recorded highest seed yield per hectare (187.1 kg) in compared with open field condition (102.9 kg).

Irrespective of growing condition, seed yield per hectare had affect by spacing was found to be significant between different four spacing levels. Significantly higher seed yield per hectare (170.6kg) was observed in S_3 (60 X45 cm) which was on par with S_2 (60 x 60 cm) (166.8 kg). While the lowest seed yield per hectare (96.0 kg) was noticed at S_1 (75 x 60 cm) (96.0kg).

The two way interactions between growing condition and spacing (GxS) are found to be significant with respect to seed yield per hectare. The seed yield per hectare was significantly higher in treatment combination G_1S_3 (shade house condition 60 cm x 45 cm) (228.0kg) which was on par with G_2S_4 (shade house with 60 x 60 cm) (228.0kg) and the lowest was observed in G_2S_1 (open field condition with 75 cm x 60 cm) (77.6 kg).

4.1.3 Seed Quality parameters

4.1.3.1 100 seed weight (g)

The results on 100 seed weight (g) as influenced by growing condition, spacing and their interaction effects are present in Table 10 and depicted in Fig. 8.

The 100 seed weight differs significantly due to growing condition. Among which growing condition shade house recorded higher 100 seed weight (0.307g) compared with open field condition (0.228g).

Spacings had significant difference for 100 seed weigh. Among the treatments the higher 100 seed weight (0.322g) was observed in spacing level of S_4 (60 x 60 cm) followed by S_3 (0.264 g) and lower 100 seed weight (0.227 g) recorded in spacing level at S_2 (50 x 45cm).

The interactions between growing condition and spacing showed non significant differences for 100 seed weight However numerically higher value (0.369) was noticed in G_1S_4 (shade house with 60 x 60 cm) followed by G_1S_3 (shade house with 60 x 45 cm)(0.315) and the lowest 100 seed weight (0.263g) with G_2S_2 (shade house with 50 x 45 cm).

4.1.3.2 Seed germination (%)

The data recorded on germination percentage as influenced due to growing condition, spacing and their interaction effects are presented in the Table 9 and depicted in Fig. 9.

The germination percentage influenced significantly due to growing condition, irrespective of spacing. Significantly higher germination percentage was observed under shade house condition (92.5 %) compared to that of open field condition (86.7 %).

Germination percentage differed significantly due to spacing, irrespective of growing condition. Significantly higher germination percentage was recorded in S_4 (60 x 60 cm) (92.3 %), followed by S_3 (60 x 45 cm) (89.7 %) S_1 (75 x 45 cm) (89.5%) and the lowest germination (86.8%) percentage was recorded in S_2 (50 x 45 cm)

The two way interactions between growing condition and spacing (GxS) did not show marked differences on germination percentage. Numerically, higher germination (95.7%) was recorded in G_1S_4 (shade house at 60 x 60 cm) followed by G_1G_3 (shade house at 60 x 45 cm) (93.0%) and the lower germination (84.0%) was observed in G_2S_2 (open field at 50 x 45 cm).

4.1.3.3 Seedling vigour index

The effect of growing condition, spacing and their interaction effects are presented in Table 9 and depicted in Fig. 10.

The recorded Data indicated that Seedling vigour index differed significantly due to growing condition irrespective of spacing. Significantly higher seedling vigour index (1766) was observed under shade house condition compared to that of open field condition (1469).

Seedling vigour index differed significantly due to spacing, irrespective of growing condition. Significantly higher seedling vigour index (1815) was recorded in S_4 (60 x 60 cm), followed by S_3 (60 x 45 cm) (1605) and the lowest Seedling vigour index (1477) was recorded in S_2 (50 x 45 cm).

The two way interaction effects between growing condition and spacing (GxS) showed significant differences on seedling vigour index. Were significantly higher seedling vigour index (2041) observed in treatment combination of G_1S_4 (shade house at 60 x 60 cm) and followed by G_1S_3 (shade house at 60 x 45 cm) (1774) and the lowest in G_2S_2 (open field at 50 x 45 cm) (1370) which was on par with G_2G_3 (1437).

4.1.3.4 Root length (cm)

Data pertaining to root length as due to the effect of growing condition, spacing, and their interaction effects are presented in Table 9.

The root length differs significantly due to growing condition and irrespective of spacing's. Significantly higher root length (10.9 cm) was recorded in G_1 shade house condition compared to G_2 open field condition (9.6 cm).

Root length was differed significantly due to spacing irrespective of growing condition. Significantly higher root length (11.3 cm) was recorded in S_4 (60 x 60 cm) which was on par with S_3 (60 x 45 cm) (10.2 cm) and lower root length (9.6 cm) was recorded in treatment S_2 (50 cm x 45 cm)

The two way interaction effects between growing condition and spacing (GxS) showed non-significant differences on root length. However numerically, the root length (12.6 cm) was comparatively more in G_2S_4 (shade house at 60 x 60 cm) followed by G_1S_3 (10.9 cm) and the lowest (9.2 cm) in G_2S_2 (open field at 50 x 45 cm).

4.1.3.5 Shoot length (cm)

The observations on Shoot length (cm) as influenced by growing condition, spacing and their interaction effects are presented in Table 9.

The shoot length influenced significantly due to growing condition, irrespective of spacing. Significantly higher Shoot length was observed with shade house condition (8.2 cm) compared to that of open field condition (7.3 cm).

Table 9. Effect of growing condition and plant spacing on 100 seed weight, seed germination (%) and seedling vigour index in tomato hybrid seed

Treatments	100 seed weight (g)	Germination (%)	Seedling vigour index
Growing condition (G)			
G_1- Shed house	0.307	92.5 (74.3)*	1766
G_2- Open field condition	0.228	86.7 (68.6)	1469
S. Em ±	0.008	0.4 (0.3)	23
CD at 5%	0.023	1.1 (0.9)	71
Spacing (S)			
S_1- 75 cm x 60 cm	0.258	89.5 (71.2)	1572
S_2- 50 cm x 45 cm	0.227	86.8 (68.8)	1477
S_3- 60 cm x 45 cm	0.263	89.7 (71.5)	1605
S_4- 60 cm x 60 cm	0.322	92.3 (74.3)	1815
S. Em ±	0.011	0.5 (74.3)	33
CD at 5%	0.032	1.5 (1.3)	101
Interaction (GxS)			
G_1S_1	0.280	91.7 (73.2)	1664
G_1S_2	0.263	89.7 (71.2)	1585
G_1S_3	0.315	93.0 (74.7)	1774
G_1S_4	0.369	95.7(78.0)	2041
G_2S_1	0.236	87.3 (69.4)	1479
G_2S_2	0.190	84.0 (66.4)	1370
G_2S_3	0.211	86.3 (68.3)	1437
G_2S_4	0.275	89.0 (70.6)	1589
S. Em ±	0.015	0.7 (0.6)	47
CD at 5%	NS	NS	142

NS – Non significant

* Figures in the parenthesis are arcsine transformed values

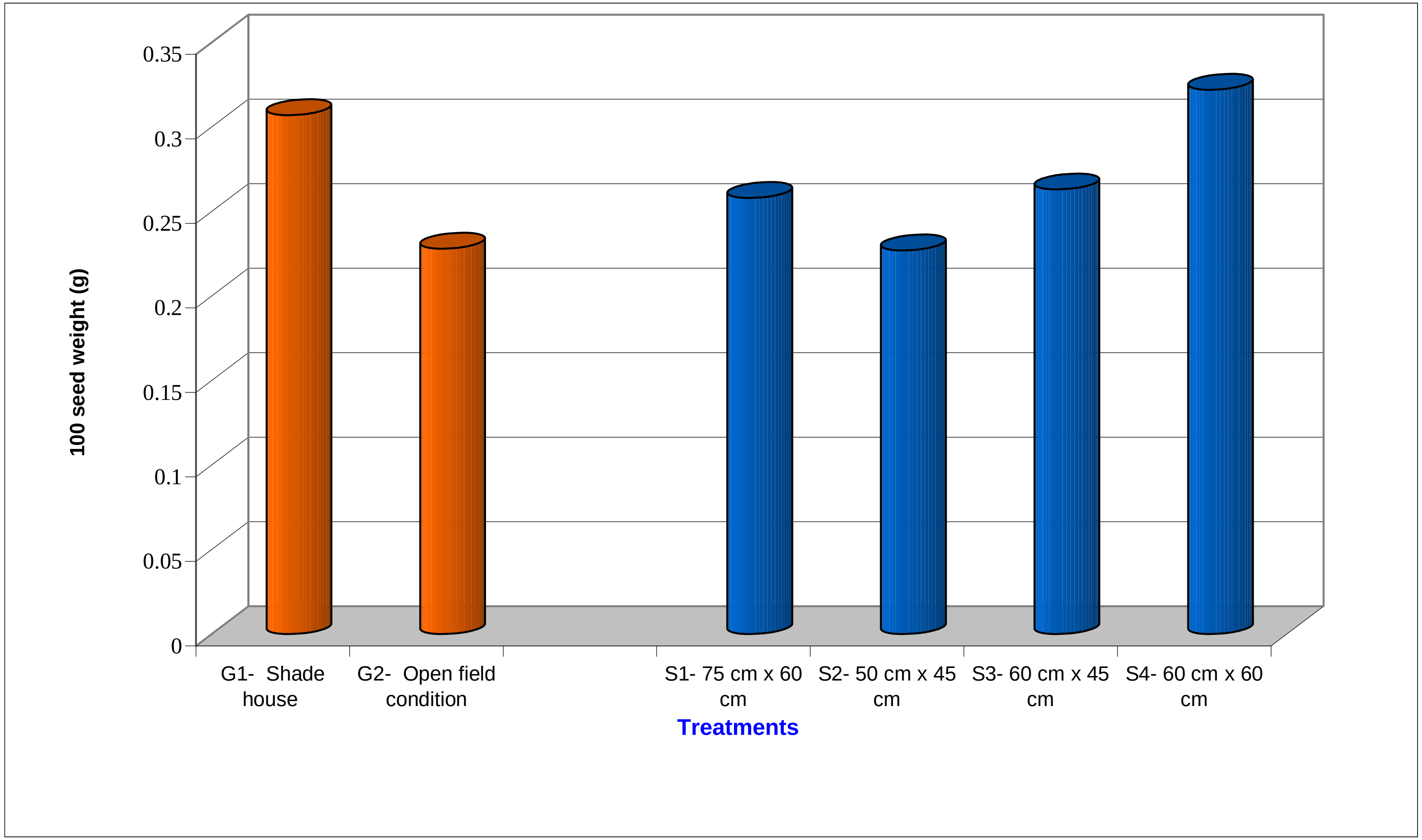

Fig. 8: Effect of growing condition and plant spacing on 100-seed weight (g) in tomato hybrid seed production

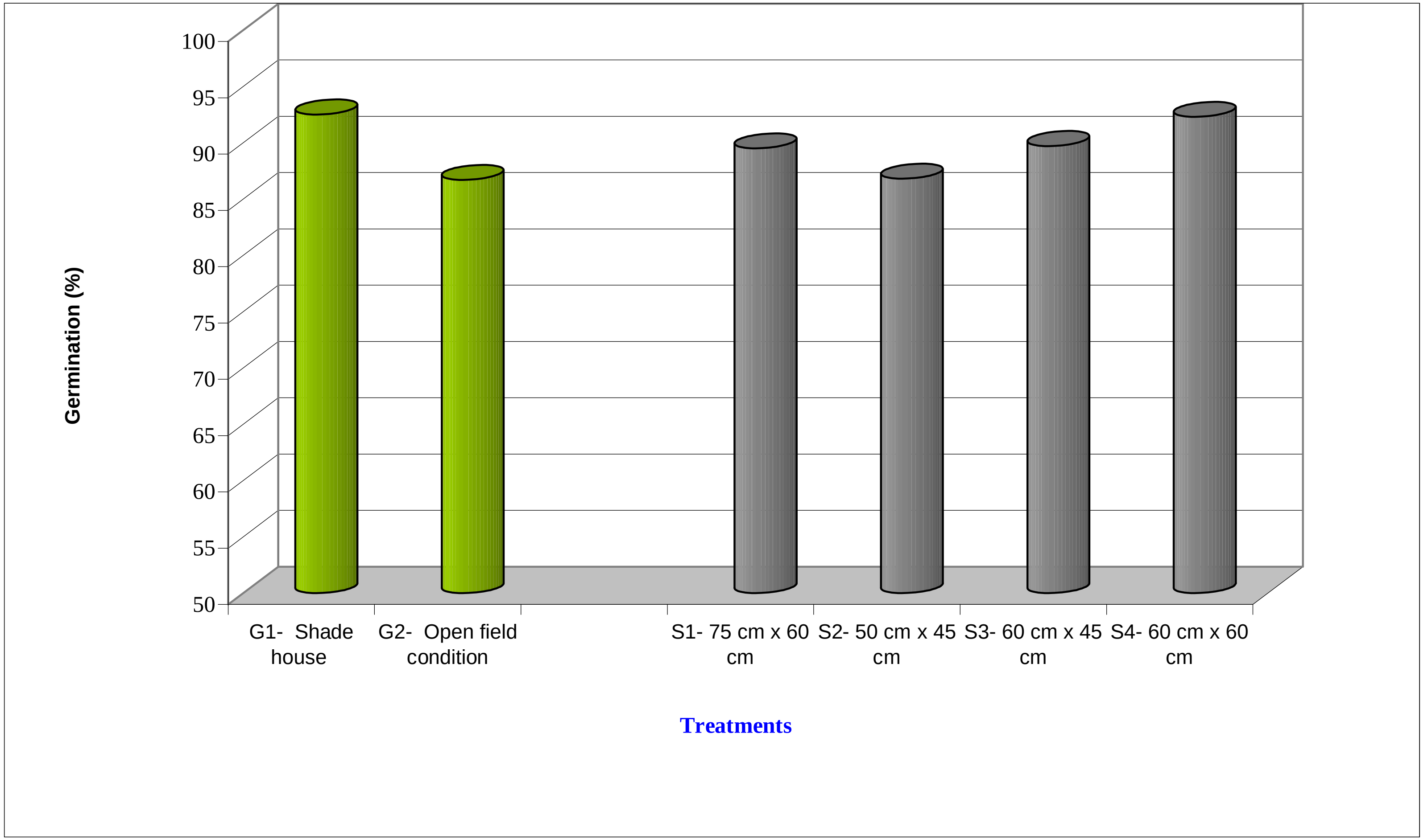

Fig. 9 : Effect of growing condition and plant spacing on germination percentage in tomato hybrid seed productiona

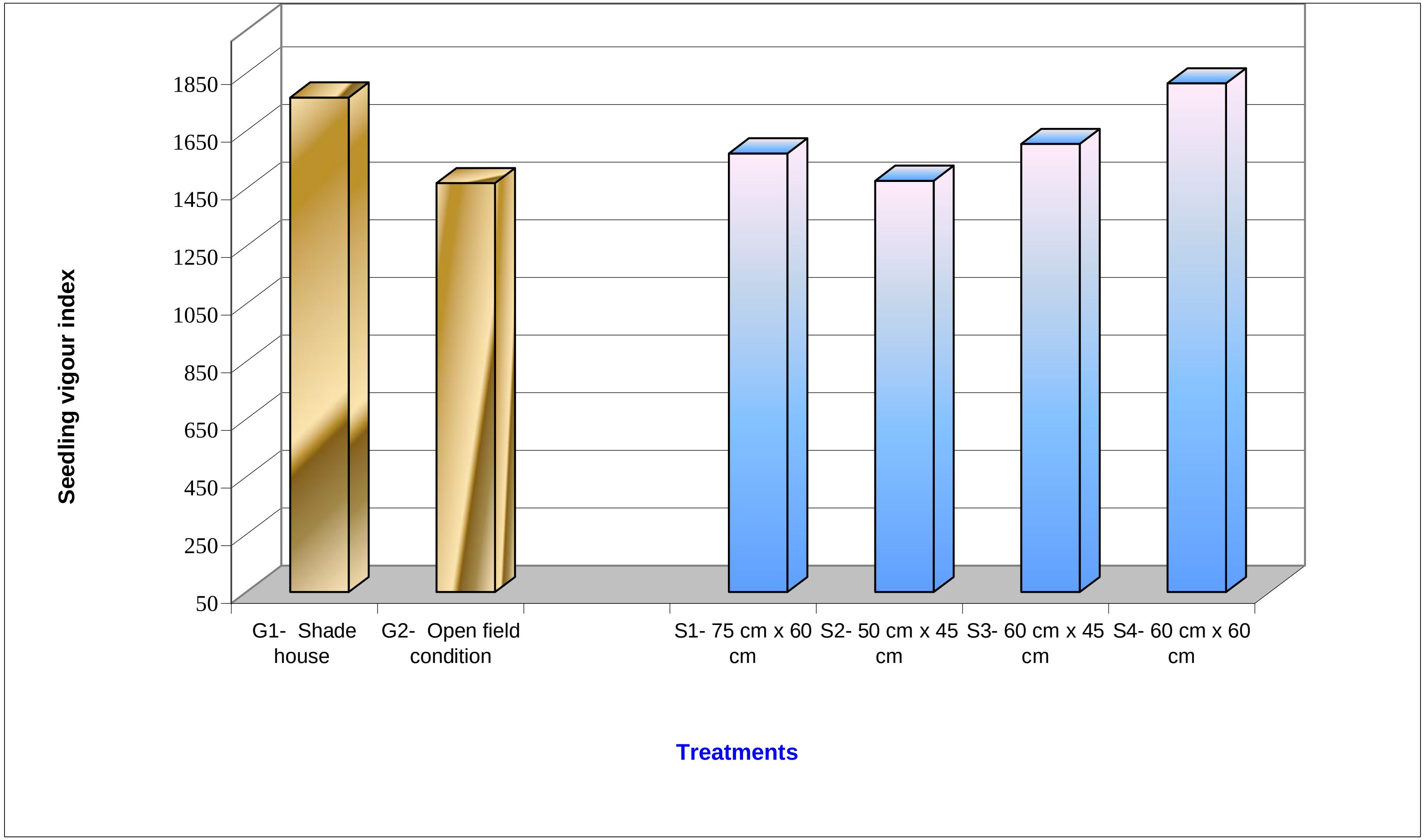

Fig. 10 : Effect of growing condition and plant spacing on seedling vigour index in tomato hybrid seed production

Shoot length differed significantly due to spacing, irrespective of growing condition. Significantly higher Shoot length (8.3 cm) was recorded in S_4 (60 x 60 cm), followed by S_3 (60x45 cm) (7.7 cm) and the lowest Shoot length (7.4 cm) was recorded in S_2 (50 x 45 cm).

The two way interaction effects between growing condition and spacing (GxS) showed non-significant differences on shoot length. However, the shoot length was comparatively more in treatment combination of G_1S_4 (shade house at 60 x 60 cm) (8.8 cm) and less in G_2S_2 (7.1 cm) (open field at 50 x 45 cm)..

4.1.3.6 Seedling dry weight (mg^{-10} seedlings)

The data presented in table on seedling dry weight (mg^{-10} seedlings) as influenced by growing condition, spacing and their interaction effects are listed in Table 10.

Data recorded on seedling dry weight differed significantly due to growing condition irrespective of spacing. Significantly higher seedling dry weight (6.84 mg^{-10} seedlings) was observed in G_1 (shade house) compared to that of G_2 (open field condition) (5.62 mg^{-10} seedlings).

Significant differences were noticed in seedling dry weight due to four levels of spacing. Significantly higher seedling dry weight (7.08 mg^{-10} seedlings) was recorded at S_4 (60 cm x 60 cm) which was on par with S_3 (6.33 mg^{-10} seedlings) and the lowest dry weight of seedlings was observed at a spacing of S_2 (50 cm x 45 cm) (5.35 mg^{-10} seedlings)

The two way interaction effects between growing condition and spacing (GxS) showed non-significant differences on seedling dry weight. However numerically the seedling dry weight (8.00 mg^{-10}seedlings) was comparatively more in G_1S_4 (shade house with 60 x 60 cm) followed by G_1S_3 (shade house with 60 x 45 cm) (7.16 mg^{-10}seedlings) and less in G_2S_2 (open field condition with 60 x 45 cm) (4.90 mg^{-10} seedlings).

4.1.3.7 Total Dehydrogenase Activity (TDH)

Influences of growing condition, spacing and their interaction on Total Dehydrogenase Activity (TDH) activity are presented in Table 10.

Data indicated that significant difference in TDH activity with respect of different growing condition, irrespective of spacing. Significantly higher TDH activity (1.93) was observed in G_1 (shade house) compared to that of G_2 (open field condition) (1.64).

The TDH activity was not significant differ due to four levels of spacing but numerically higher TDH activity was noticed in S_4 (1.78) followed by S_3 (60 x 45 cm) (1.78) and the lowest in S_2 (1.76)

The two way interaction effects between growing condition and spacing (GxS) showed non-significant differences on TDH activity. However, numerically higher TDH activity was comparatively more in G_1S_4 (shade house with 60 x 60 cm) (1.95) and less in G_2S_2 (open field condition with 50 x 45 cm) (1.61).

4.2 Experiment II: Studies on pollen viability of pollen parent and stigma receptivity of seed parent in hybrid seed production of tomato under shade house

4.2.1 In vitro determination of pollen viability through Acetocarmine stain method

The observed data on In vitro determination of pollen viability pollen parent (p), through acetocarmine stain are presented in Table 11.

The microscopic observational count indicated that there was significant differences in pollen viability in pollen parent, as per the pollen storage duration treatment where the treatment P_0: Immediately after collection and pollination (Fresh pollen) had significantly higher percentage of dark stained pollens (viable) (92%) followed by P_1: One day stored pollen (85%), P_2: Two day stored pollen and P_3: Three day pollen stored recorded least percentage of unstained pollens (unviable) (67%)

4.2.2 Fruits set percentage

The data on fruit set percentage as influenced by pollen viability of pollen parent (P), stigma receptivity of seed parent (R) and their interaction affect results are presented in Table 12 and depicted in Fig. 11.

The analysis indicated that the significant differences for fruit set percentage with respect to pollen viability of pollen parent, irrespective of receptivity of seed parent, the significantly highest fruits set (66.6).

Table 10. Effect of growing condition and plant spacing on root length shoot length, seedling dry weight (mg^{-10} seedlings) and TDH activity in tomato hybrid seed

Treatments	Root length (cm)	Shoot length (cm)	Dry weight of seedlings (mg)	TDH Activity
Growing condition (G)				
G_1- Shed house	10.9	8.2	6.84	1.93
G_2- Open field condition	9.6	7.3	5.62	1.64
S. Em ±	0.2	0.1	0.19	0.01
CD at 5%	0.7	0.3	0.59	0.03
Spacing (S)				
S_1- 75 cm x 60 cm	9.9	7.6	6.15	1.79
S_2- 50 cm x 45 cm	9.6	7.4	5.35	1.76
S_3- 60 cm x 45 cm	10.2	7.7	6.33	1.78
S_4- 60 cm x 60 cm	11.3	8.3	7.08	1.80
S. Em ±	0.3	0.1	0.27	0.01
CD at 5%	1.0	0.4	0.83	NS
Interaction (GxS)				
G_1S_1	10.2	8.0	6.40	1.92
G_1S_2	10.0	7.7	5.80	1.91
G_1S_3	10.9	8.2	7.16	1.93
G_1S_4	12.6	8.8	8.00	1.95
G_2S_1	9.7	7.3	5.90	1.65
G_2S_2	9.2	7.1	4.90	1.61
G_2S_3	9.5	7.2	5.50	1.63
G_2S_4	10.1	7.7	6.17	1.66
S. Em ±	0.5	0.2	0.39	0.02
CD at 5%	NS	NS	NS	NS

NS – Non significant

Table 11. In vitro determination of pollen viability through Acetocarmine stain

	Percentage of dark stained pollens (viable)	Percentage of unstained pollens (unviable)
P_0	92	08
P_1	85	15
P_2	78	22
P_3	67	33
SEm±	1.2	0.6
CD	2.6	1.3

$\mathbf{P_0}$: Immediately after collection and pollination
$\mathbf{P_1}$: One day stored Pollen
$\mathbf{P_2}$: Two day Stored Pollen
$\mathbf{P_3}$: Three day Stored Pollen

Percentage was recorded in P_2 (Two day stored pollen) followed by fruit set (61.9) percentage in P_1 (One day stored pollen) and the lowest fruit set (51.0) percentage was noticed in P_0 [pollination immediately after collection (fresh pollen)].

The stigma receptivity of seed parent had significant affect on fruit set percentage irrespective of pollen viability of pollen parent, among which R_2 (Pollination two days after emasculation) had observed higher Fruits set (67.7) percentage followed by R_3 (Pollination three day after emasculation) (65.1%) and the lowest Fruits set (43.1) percentage was noticed in stigma treatment of R_0 (Pollination on the same day of emasculation).

In the interaction effect between stigma receptivity of seed parent and pollen viability of pollen parent significant differences were observed with respect to fruit set percentage. Among the treatment combinations, the highest fruit set (75.2) percentage was observed in P_2R_2 (P_2: Two day stored pollen with R_2 Pollination two days after emasculation) followed by combination of P_2R_3 (Two day stored pollen used for pollination three days after emasculation at) (72. 2%) and significantly lowest fruit set (32.4%) was observed in P_0R_0 (P_0: Pollination immediately after collection [fresh pollen)] with R_0 : Pollination on the same day of emasculation).

4.2.3 Fruit weight (g)

The data on fruit weight (g) at different four treatments on pollen viability of pollen parent (P), and five treatments on stigma receptivity of seed parent (R) and their interaction affect results are presented in Table 12.

The fruit weight of tomato differed significantly due to pollen viability of pollen parent , irrespective of stigma receptivity of seed parent, among the treatments significantly highest fruit weight (92.47g) was recorded in P_2 (Two day stored pollen) and followed by P_1(One day stored pollen) (89.01g) and the lowest Fruit weight (83.75) was noticed in P_0 [pollination immediately after collection (fresh pollen)].

The Stigma receptivity of seed parent had significant affect on fruit weight irrespective of pollen viability of pollen parent among which R_2 Pollination two days after emasculation had observed higher fruit weight (95.7g) followed by R_3 (Pollination three days after emasculation) (93.3g) and the lowest fruit weight (80.0g) was noticed in stigma treatment of R_0 (Pollination on the same day of emasculation).

In the interaction effect between pollen viability of pollen parent and stigma receptivity of seed parent differences significantly with respect of fruit weight, among the treatment combinations, the highest fruit weight (98.87g) was observed in P_2R_2 (P_2: Two day stored pollen with R_2 Pollination two days after emasculation) followed by combination of P_2R_3 (two days stored pollen used to pollination three days after emasculation) at (72.2%) and significantly lowest individual fruit weight (73.7g) was observed in P_0R_0 [P_0: Pollination immediately after collection (fresh pollen)] with R_0 Pollination on the same day of emasculation).

4.2.4 Number of seeds per fruit

The observation on Number of seeds per fruit as influenced by pollen viability of pollen parent (P), Stigma receptivity of seed parent (R) and their interaction results are presented in Table 12 and depicted in Fig. 11.

The analysis indicated that the significant differences for number of seeds per fruit with respect to pollen viability of pollen parent, irrespective of receptivity of seed parent Significantly the highest number of seeds per fruit (106.47) was recorded in P_2 (Two day stored pollen) followed by P_1 (One day stored pollen) (97.13) and the lowest number of seeds per fruit (84.07) was noticed in P_0: [Pollination immediately after collection (fresh pollen)].

The stigma receptivity of seed parent had significant affect on number of seeds per fruit irrespective of pollen viability of pollen parent among which R_2 Pollination two days after emasculation had observed higher number of seeds per fruit (114.83) followed by R_3 pollination three day after emasculation (106.33) and the lowest number of seeds per fruit (71.42) was noticed in treatment of R_0 Pollination on the same day of emasculation.

The two way interaction effects between pollen viability of pollen parent and stigma receptivity of seed parent showed significant differences on number of seeds per fruit were significantly higher number of seeds per fruit (129.00) observed in P_2R_2 (Two day stored pollen used for pollination two days after emasculation).

Table 12. Effect of pollen viability of pollen parent and stigma receptivity of seed parent on fruits set percentage, fruit weight and number of seeds per fruit in hybrid seed production of tomato under shade house

Treatments	Fruits set percentage	Fruit weight (g)	Number of seeds per fruit
Pollen viability of pollen parent (P)			
P_0	51.0	83.75	84.07
P_1	61.9	89.01	97.13
P_2	66.6	92.47	106.47
P_3	56.5	84.76	91.15
mean	59.0	88.75	94.70
SEm±	0.4	0.46	0.65
CD	1.3	1.31	1.87
Stigma receptivity of seed parent (R)			
R_0	43.1	77.03	71.42
R_1	61.2	89.96	96.33
R_2	67.7	95.13	114.83
R_3	65.1	93.60	106.33
R_4	58.0	88.02	84.60
Mean	59.0	88.75	94.70
SEm±	0.5	0.51	0.73
CD	1.4	1.46	2.09
Interaction (PxR)			
P_0 x R_0	32.4	71.70	59.33
P_0 x R_1	52.1	91.13	87.00
P_0 x R_2	62.3	95.30	103.67
P_0 x R_3	58.8	94.93	94.67
P_0 x R_4	49.6	90.67	75.67
P_1 x R_0	46.7	79.57	74.33
P_1 x R_1	65.3	89.00	100.33
P_1 x R_2	68.2	95.57	116.00
P_1 x R_3	66.7	93.83	109.33
P_1 x R_4	62.4	87.07	85.67
P_2 x R_0	51.4	82.63	82.33
P_2 x R_1	69.0	93.30	104.67
P_2 x R_2	75.2	98.87	129.00
P_2 x R_3	72.2	96.37	121.00
P_2 x R_4	65.3	91.20	95.33
P_3 x R_0	41.7	74.23	69.67
P_3 x R_1	58.6	86.40	93.33
P_3 x R_2	65.0	90.77	110.67
P_3 x R_3	62.8	89.27	100.33
P_3 x R_4	54.6	83.13	81.73
Mean	59.0	88.75	94.70
SEm±	1.0	1.02	1.46
CD	2.9	2.93	4.19

P_0: Immediately after collection and pollination
P_1: One day stored Pollen
P_2: Two day Stored Pollen
P_3: Three day Stored Pollen

R_0 : Pollination on the same day of emasculation
R_1 : Pollination one day after emasculation.
R_2 : Pollination two days after emasculation.
R_3 : Pollination three days after emasculation
R_4 : Pollination four days after emasculation

LEGEND

Pollen viability of pollen parent (P)

P_0: Immediately after collection and pollination

P_1: One day stored Pollen

P_2: Two day Stored Pollen

P_3: Three day Stored Pollen

Stigma receptivity of seed parent (R)

R_0 : Pollination on the same day of emasculation

R_1 : Pollination one day after emasculation.

R_2 : Pollination two days after emasculation.

R_3 : Pollination three days after emasculation

R_4 : Pollination four days after emasculation

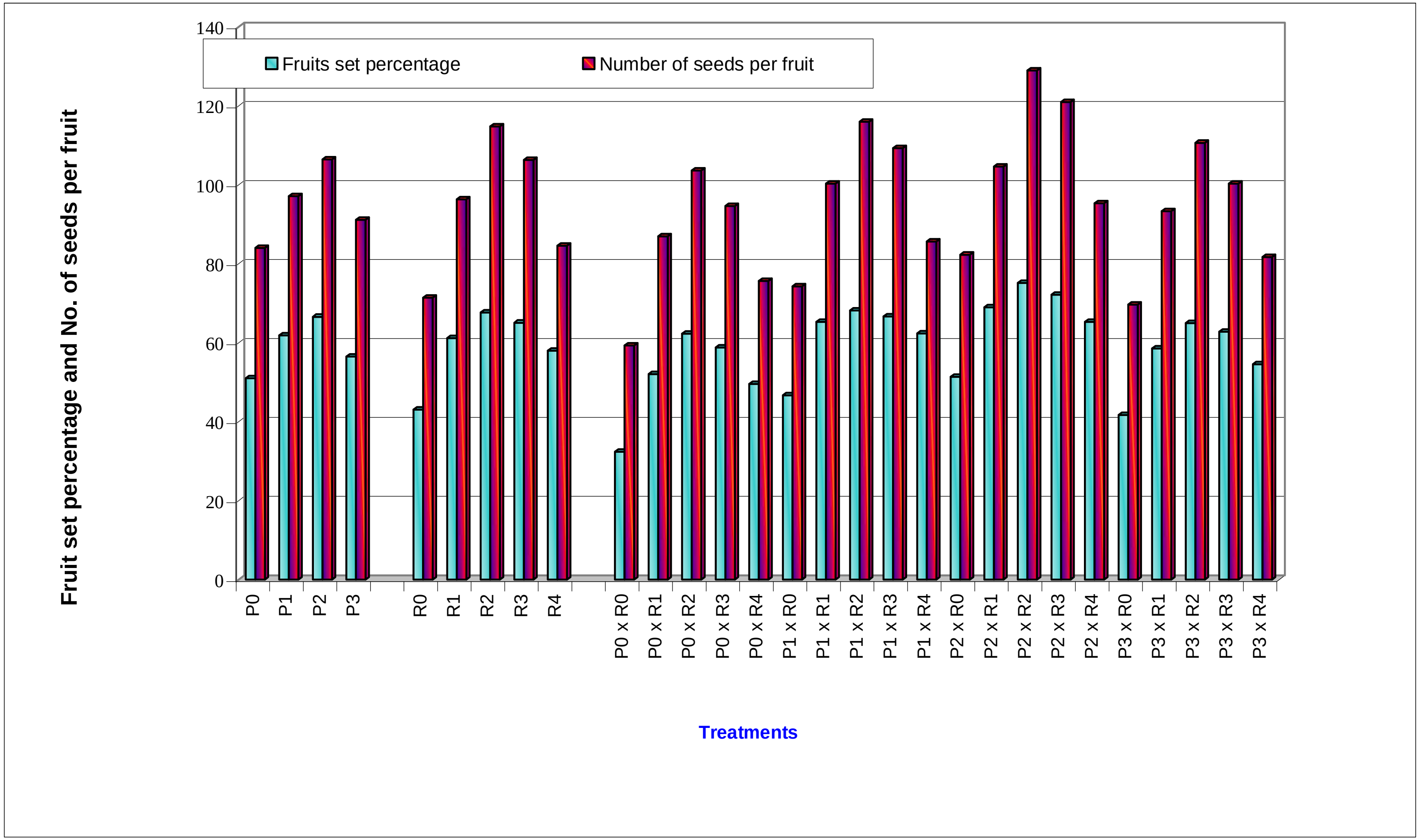

Fig. 11 : Effect of pollen viability of pollen parent and stigma receptivity of seed parent on fruits set percentage and number of seeds per fruit in hybrid seed production of tomato under shade house

Which was on par with P_2R_3 (two day stored pollen used for Pollination three days after emasculation) (121.00) and the lowest number of seeds per fruit (59.33) recorded in P_0R_0 [P_0: Pollination immediately after collection (fresh pollen)] with R_0 : Pollination on the same day of emasculation).

4.2.5 Seed weight per fruit (g)

The data pertaining to seed weight per fruit (g) as it was influenced by pollen viability of pollen parent (P), stigma receptivity of seed parent (R) and their interaction affect results are presented in Table 13 and depicted in Fig. 12.

The marked variations in seed weight per fruit indicated with respect to pollen viability of pollen parent, irrespective of stigma receptivity of seed parent significantly, the highest seed weight per fruit (0.36g) was recorded in P_2 (Two day stored pollen), followed by P_1 (one day stored pollen) (0.32g) and the lowest to seed weight per fruit (0.25g) was noticed in P_0: pollination immediately after collection (fresh pollen).

The stigma receptivity of seed parent had significant affect on to seed weight per fruit (g) irrespective of pollen viability of pollen parent among which R_2 (Pollination two days after emasculation) had observed higher to seed weight per fruit (0.38g) followed by R_3 (Pollination three days after emasculation) (0.35g) and the lowest to seed weight per fruit (0.21 g) was noticed in treatment of R_0 (Pollination on the same day of emasculation).

The two way interaction effects between pollen viability of pollen parent and stigma receptivity of seed parent showed significant differences on Seed weight per fruit and were significantly higher Seed weight per fruit (0.46g) observed in P_2R_2 (Two day stored pollen used for Pollination two days after emasculation) followed by (0.42g) P_2R_3 (two day stored pollen used for pollination three days after emasculation) and the lowest Seed weight per fruit (0.16 g) recorded in P_0R_0 [P_0: Pollination immediately after collection (fresh pollen)] with R_0 : Pollination on the same day of emasculation).

4.2.6 Seed weight per plant (g)

A glance of the results on seed weight per plant as it was influenced by pollen viability of pollen parent (P), stigma receptivity of seed parent (R) and their interaction are presented in Table 13.

The data on seed weight per plant indicated that the significant differences for seed weight per plant with respect to pollen viability of pollen parent, irrespective of stigma receptivity of seed parent, The significantly higher seed weight per plant (7.02g) was recorded in P_2 (Two day stored pollen) followed by P_1 (One day stored pollen) (6.26g) and the lowest Seed weight per plant (4.89g) was noticed in P_0: [Pollination immediately after collection (fresh pollen)].

The stigma receptivity of seed parent had significant affect on seed weight per plant irrespective of pollen viability of pollen parent among which R_2 (Pollination two days after emasculation) had observed higher seed weight per plant (7.44g) followed by R_3 (Pollination three days after emasculation) and the lowest Seed weight per plant (6.80g) was noticed in treatment of R_0 (Pollination on the same day of emasculation)

The interaction between pollen viability of pollen parent and stigma receptivity of seed parent were found to be significant. The P_2R_2 (Two day stored pollen used for pollination two days after emasculation) recorded higher seed weight per plant (8.94g) followed by P_2R_3 (two day stored pollen used for pollination three days after emasculation) (8.23g). The P_0R_0 (P_0: Pollination immediately after collection (fresh pollen) with R_0 : pollination on the same day of emasculation) produced the lowest seed weight per plant (3.11g).

4.2.7 Seed recovery percentage

The marked variations on seed recovery percentage as influenced by pollen viability of pollen parent (P), stigma receptivity of seed parent (R) and their interaction affect results are presented in Table 13 and depicted in Fig. 12

The recorded data indicated that the significant differences for Seed recovery percentage with respect to pollen viability of pollen parent, irrespective of stigma receptivity of seed parent. Significantly highest seed recovery (0.39) percentage was recorded in P_2 (Two day stored pollen) and followed by P_1 (One day stored pollen) (0.36) and the lowest Seed recovery (0.28) percentage was noticed in P_0: [Pollination immediately after collection (fresh pollen)]

Table 13. Effect of pollen viability of pollen parent and stigma receptivity of seed parent on Seed weight per fruit, Seed weight per plant and Seed recovery percentage in hybridseed production of tomato under shade house

Treatments	Seed weight per fruit(g)	Seed weight per plant(g)	Seed recovery (%)
Pollen viability of pollen parent (P)			
P_0	0.25	4.89	0.28 (3.03)
P_1	0.32	6.26	0.36 (3.43)
P_2	0.36	7.02	0.39 (3.56)
P_3	0.30	5.79	0.35 (3.37)
mean	0.31	5.99	0.34 (3.35)
SEm±	0.00	0.08	0.01(0.03)
CD	0.01	0.24	0.02 (0.08)
Stigma receptivity of seed parent (R)			
R_0	0.21	4.05	0.27 (2.96)
R_1	0.32	6.14	0.35 (3.39)
R_2	0.38	7.44	0.40 (3.62)
R_3	0.35	6.80	0.37 (3.49)
R_4	0.28	5.52	0.32 (3.25)
Mean	0.31	5.99	0.34 (3.35)
SEm±	0.00	0.09	0.01 (0.03)
CD	0.01	0.26	0.02 (0.08)
Interaction (PxR)			
P_0 x R_0	0.16	3.11	0.22 (2.71)
P_0 x R_1	0.27	5.31	0.30 (3.14)
P_0 x R_2	0.31	6.09	0.33 (3.29)
P_0 x R_3	0.27	5.31	0.29 (3.07)
P_0 x R_4	0.24	4.60	0.26 (2.93)
P_1 x R_0	0.23	4.54	0.29 (3.10)
P_1 x R_1	0.32	6.16	0.36 (3.42)
P_1 x R_2	0.39	7.65	0.41 (3.68)
P_1 x R_3	0.37	7.13	0.39 (3.58)
P_1 x R_4	0.30	5.83	0.34 (3.36)
P_2 x R_0	0.25	4.92	0.31 (3.17)
P_2 x R_1	0.36	7.00	0.39 (3.56)
P_2 x R_2	0.46	8.94	0.47 (3.91)
P_2 x R_3	0.42	8.23	0.44 (3.80)
P_2 x R_4	0.31	6.03	0.34 (3.34)
P_3 x R_0	0.19	3.63	0.25 (2.87)
P_3 x R_1	0.31	6.09	0.36 (3.45)
P_3 x R_2	0.36	7.06	0.40 (3.62)
P_3 x R_3	0.34	6.54	0.38 (3.52)
P_3 x R_4	0.29	5.64	0.35 (3.38)
Mean	0.31	5.99	0.34 (3.35)
SEm±	0.01	0.19	0.01 (0.06)
CD	0.03	0.53	0.03 (NS)

P_0: Immediately after collection and pollination
P_1: One day Stored Pollen
P_2: Two day Stored Pollen
P_3: Three day Stored Pollen

R_0 : Pollination on the same day of emasculation
R_1 : Pollination one day after emasculation.
R_2 : Pollination two days after emasculation.
R_3 : Pollination three days after emasculation
R_4 : Pollination four days after emasculation

LEGEND

Pollen viability of pollen parent (P)

P_0: Immediately after collection and pollination

P_1: One day stored Pollen

P_2: Two day Stored Pollen

P_3: Three day Stored Pollen

Stigma receptivity of seed parent (R)

R_0 **:** Pollination on the same day of emasculation

R_1 : Pollination one day after emasculation.

R_2 : Pollination two days after emasculation.

R_3 : Pollination three days after emasculation

R_4 : Pollination four days after emasculation

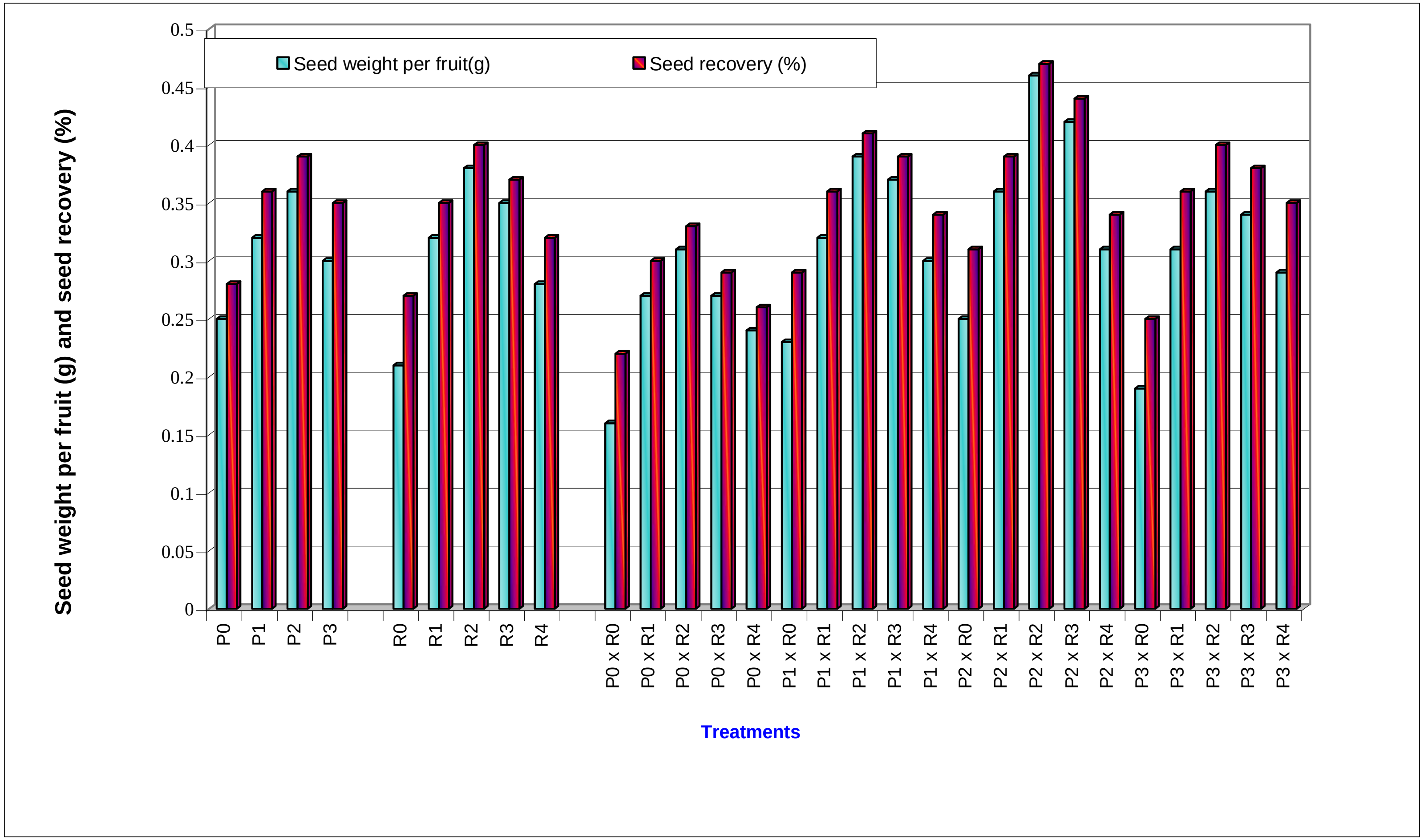

Fig. 12 : Effect of pollen viability of pollen parent and stigma receptivity of seed parent on seed weight per fruit and seed recovery Percentage in hybrid seed production of tomato under shade house

The stigma receptivity of seed parent had significant affect on seed recovery percentage irrespective of pollen viability of pollen parent among which R_2 Pollination two days after emasculation had observed higher seed recovery (0.40) percentage followed by R_2 Pollination one day after emasculation (0.37%) and the lowest Seed recovery (0.27%) percentage was noticed in stigma treatment of R_0 (Pollination on the same day of emasculation)

In the interaction between pollen viability of pollen parent and stigma receptivity of seed parent were found to be significant with respected to seed recovery percentage, the significantly highest seed recovery (0.47%) percent was observed in P_2R_2 (Two day stored pollen used for Pollination two days after emasculation) followed by P_2R_3 (two day stored pollen used for Pollination three days after emasculation) (0.44%) and significantly lowest seed recovery (0.22%) produced in P_0R_0 (P_0: Pollination immediately after collection (fresh pollen) with R_0 : Pollination on the same day of emasculation).

. 4.2.8 100 seed weight (g)

The data on 100 seed weight as influenced by pollen viability of pollen parent (P), stigma receptivity of seed parent (R) and their interaction affect results are presented in Table 15 and depicted in Fig. 13.

The 100 seed weight significantly differed with respect to pollen viability of pollen parent, irrespective of receptivity of seed parent. Significantly, the highest 100 seed weight (0.700g) was recorded in P_2 two day stored pollen and followed by P_1(One day stored pollen) (0.674g) and the lowest (0.555g) was noticed in P_0: Pollination immediately after collection (fresh pollen)

The stigma receptivity of seed parent (R) had significant affect on 100 seed weight irrespective of pollen viability of pollen parent (P) among which R_2 pollination two days after emasculation had observed higher 100 seed weight (0.704g) followed by R_3 Pollination three day after emasculation (0.683g) and the lowest 100 seed weight (0.556g) was noticed in stigma treatment of R_0 (pollination on the same day of emasculation)

The interaction between Pollen viability of pollen parent (P) and stigma receptivity of seed parent (R) were found to be significant with respect 100 seed weight. The P_2R_2 (two day stored pollen used for pollination two days after emasculation) recorded higher 100 seed weight (0.743g) followed by P_2R_3 (Two day stored pollen with pollination three days after emasculation) (0.743g). The P_0R_0 [P_0: Pollination immediately after collection (fresh pollen)] with R_0: Pollination on the same day of emasculation).produced the lowest 100 seed weight (0.456g).

4.2.9 Germination (%)

The data on germination percentage as influenced by pollen viability of pollen parent (P), stigma receptivity of seed parent (R) and their treatment combination are presented in Table 14 and depicted in Fig. 14.

The significant differences for germination percentage with respect to pollen viability of pollen parent, irrespective of stigma receptivity of seed parent was noticed, were significantly higher germination (92.40) percentage was recorded in P_2 (Two day stored Pollen) followed by P_1 (one day stored pollen) and the lowest germination (86.13) percentage was noticed in P_0 [Pollination immediately after collection (fresh pollen)].

The stigma receptivity of seed parent had significant affect on germination percentage irrespective of pollen viability of pollen parent among which R_2 (Pollination two days after emasculation) had observed higher germination percentage (94.33) followed by (92.75) R_3 (Pollination three days after emasculation) and the lowest germination percentage (82.42) was noticed in stigma treatment of R_0 [Pollination immediately after collection (fresh pollen)].

The interaction between pollen viability of pollen parent (P) and stigma receptivity of seed parent (R) were found to be significant. The P_2R_2 (Two day stored pollen used for pollination two days after emasculation) recorded higher germination percentage (97.33) followed by P_2R_3 (two day stored pollen used for pollination three days after emasculation) (96.33). The P_0R_0 (P_0: Pollination immediately after collection (fresh pollen) with R_0 : Pollination on the same day of emasculation). produced the lowest Germination percentage (77.00)

4.2.10 Seedling vigour index

The data on Seedling vigour index as it was influenced by pollen viability of pollen parent (P), Stigma receptivity of seed parent (R) and their interaction affect results are presented in Table 15 and depicted in Fig. 14.

The seedling vigour index significantly differences with respect to pollen viability of pollen parent, irrespective of stigma receptivity of seed parent, the significantly highest seedling vigour index (1648) was recorded in P_2 (Two day stored pollen) and followed by P_1(One day stored pollen) (1587) and the lowest (1441) was noticed in P_0 [Pollination immediately after collection (fresh pollen)].

The stigma receptivity of seed parent had significant affect on seedling vigour index irrespective of pollen viability of pollen parent among which R_2 Pollination two days after emasculation had observed higher Seedling vigour index (1760) followed by R_3 Pollination three day after emasculation (1679) and the lowest seedling vigour index (1231) was noticed in stigma treatment of R_0 (Pollination on the same day of emasculation).

The interaction between pollen viability of pollen parent (P) and stigma receptivity of seed parent (R) were found to be significant with respect Seedling vigour index. The P_2R_2 (Two day stored pollen used for pollination two days after emasculation) recorded higher Seedling vigour index (1934) followed by P_2R_3 (Two day stored pollen with Pollination three days after emasculation) (1830). The P_0R_0 [P_0: pollination immediately after collection (fresh pollen)] with R_0: Pollination on the same day of emasculation).produced the lowest Seedling vigour index (1105).

4.2.11 Root length (cm)

Data on root length (cm) as influenced by pollen viability of pollen parent (P) stigma receptivity of seed parent (R) and their treatment combination are presented in Table 14.

The marked differences on root length were observed due to pollen viability of pollen parent (P), irrespective of stigma receptivity of seed parent among the treatments significantly higher root length (9.7cm) was recorded in P_2 (Two day stored pollen) and followed by P_1 (one day stored pollen) (9.4 cm) and the lowest root length (9.3cm) was noticed in P_0: pollination immediately after collection (fresh pollen).

Significant affect also observed on root length due to stigma receptivity of seed parent (R) irrespective of pollen viability of pollen parent, were R_2 (pollination two days after emasculation) had observed higher root length (10.2 cm) followed by R_3 (pollination three day after emasculation) (9.9 cm) and the lowest root length (8.2 cm) was noticed in treatment of R_0 (pollination on the same day of emasculation).

The interaction between pollen viability of pollen parent (P) and stigma receptivity of seed parent (R) were found to be non-significant. Numerically the P_2R_2 (Two day stored pollen used for pollination two days after emasculation) recorded highest root length (10.9cm) followed by P_2R_3 (Two day stored pollen with pollination three days after emasculation) (10.3 cm). The P_0R_0 [P_0: Pollination immediately after collection (fresh pollen)] produced the lowest root length (7.9cm).

4.2.12 Shoot length (cm)

The observed data on shoot length as influenced by pollen viability of pollen parent, stigma receptivity of seed parent and their treatment combination are presented in Table 14

The marked differences on shoot length were observed due to pollen viability of pollen parent (P), irrespective of stigma receptivity of seed parent among which significantly higher shoot length (8.0 cm) was recorded in P_2 (Two day stored pollen) and followed by P_1 (one day stored pollen) (7.9 cm) and the lowest shoot length (7.4 cm) was noticed in P_0 [Pollination immediately after collection (fresh pollen)]

Significant affect also observed on shoot length (cm) due to stigma receptivity of seed parent irrespective of pollen viability of pollen parent were R_2 (Pollination two days after emasculation) had observed higher shoot length (8.4cm) which was on par with R_3 (Pollination three day after emasculation) (8.2 cm) and the lowest shoot length (6.8cm) was noticed in treatment of R_0 (Pollination on the same day of emasculation).

Table 14. Effect of pollen viability of pollen parent and stigma receptivity of seed parent on 100 seed weight, germination (%) and seed vigour index, in hybridseed production of tomato under shade house

Treatments	100 seed weight (g)	Germination (%)	Seedling vigour index
Pollen viability of pollen parent (P)			
P_0	0.555	86.13 (68.4)	1441
P_1	0.674	91.13(73.0)	1587
P_2	0.700	92.40(74.6)	1648
P_3	0.646	88.93(70.9)	1477
mean	0.644	89.65(71.7)	1538
SEm±	0.004	0.35(0.3)	8
CD	0.011	1.00(1.0)	23
Stigma receptivity of seed parent (R)			
R_0	0.558	82.42(65.3)	1231
R_1	0.656	90.83(72.5)	1552
R_2	0.704	94.33(76.5)	1760
R_3	0.683	92.75(74.6)	1679
R_4	0.620	87.92(69.7)	1470
Mean	0.644	89.65(71.7)	1538
SEm±	0.004	0.39(0.4)	9
CD	0.012	1.12(1.1)	26
Interaction (PxR)			
P_0 x R_0	0.453	77.00(61.3)	1105
P_0 x R_1	0.557	87.33(69.1)	1435
P_0 x R_2	0.633	91.00(72.5)	1671
P_0 x R_3	0.607	89.67(71.2)	1614
P_0 x R_4	0.527	85.67(67.7)	1379
P_1 x R_0	0.587	85.33(67.5)	1297
P_1 x R_1	0.693	92.67(74.3)	1628
P_1 x R_2	0.728	95.33(77.5)	1773
P_1 x R_3	0.713	93.00(74.3)	1693
P_1 x R_4	0.650	89.33(71.0)	1542
P_2 x R_0	0.610	86.33(68.3)	1332
P_2 x R_1	0.710	92.33(73.9)	1622
P_2 x R_2	0.753	97.33(80.7)	1934
P_2 x R_3	0.743	96.33(79.0)	1830
P_2 x R_4	0.683	89.67(71.2)	1524
P_3 x R_0	0.580	81.00(64.1)	1191
P_3 x R_1	0.663	91.00(72.5)	1523
P_3 x R_2	0.700	93.67(75.4)	1661
P_3 x R_3	0.667	92.00(73.6)	1579
P_3 x R_4	0.620	87.00(68.8)	1433
Mean	0.644	89.65(71.7)	1538
SEm±	0.008	0.78(0.8)	18
CD	0.024	2.24	52

P_0: Immediately after collection and pollination
P_1: One day Stored Pollen
P_2: Two day Stored Pollen
P_3: Three day Stored Pollen

R_0 : Pollination on the same day of emasculation
R_1 : Pollination one day after emasculation.
R_2 : Pollination two days after emasculation.
R_3 : Pollination three days after emasculation
R_4 : Pollination four days after emasculation

LEGEND

Pollen viability of pollen parent (P)

P_0: Immediately after collection and pollination

P_1: One day stored Pollen

P_2: Two day Stored Pollen

P_3: Three day Stored Pollen

Stigma receptivity of seed parent (R)

R_0 : Pollination on the same day of emasculation

R_1 : Pollination one day after emasculation.

R_2 : Pollination two days after emasculation.

R_3 : Pollination three days after emasculation

R_4 : Pollination four days after emasculation

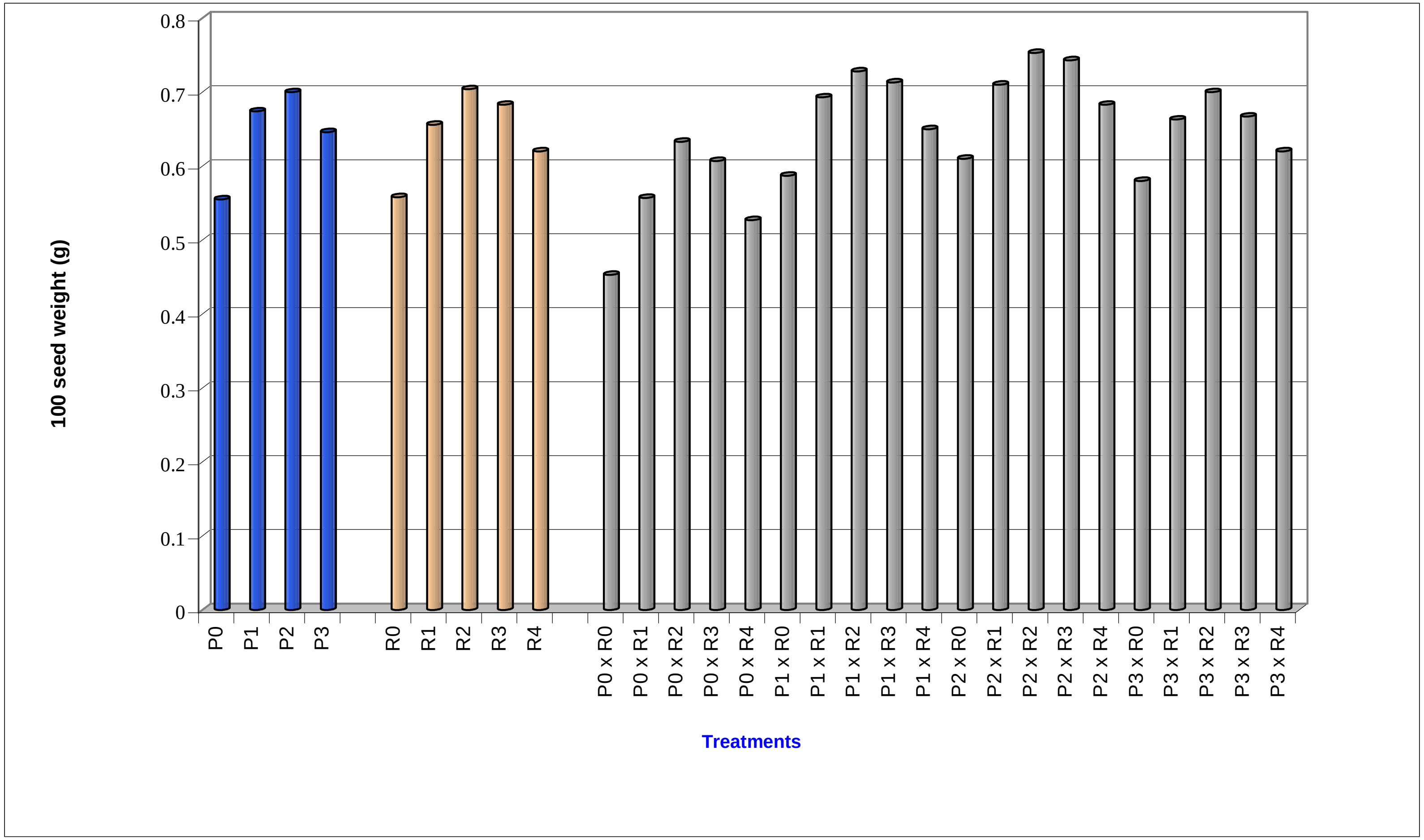

Fig. 13 : Effect of pollen viability of pollen parent and stigma receptivity of seed parent on 100 seed weight in hybrid seed production of tomato under shade house

LEGEND

Pollen viability of pollen parent (P)

P_0: Immediately after collection and pollination

P_1: One day stored Pollen

P_2: Two day Stored Pollen

P_3: Three day Stored Pollen

Stigma receptivity of seed parent (R)

R_0 : Pollination on the same day of emasculation

R_1 : Pollination one day after emasculation.

R_2 : Pollination two days after emasculation.

R_3 : Pollination three days after emasculation

R_4 : Pollination four days after emasculation

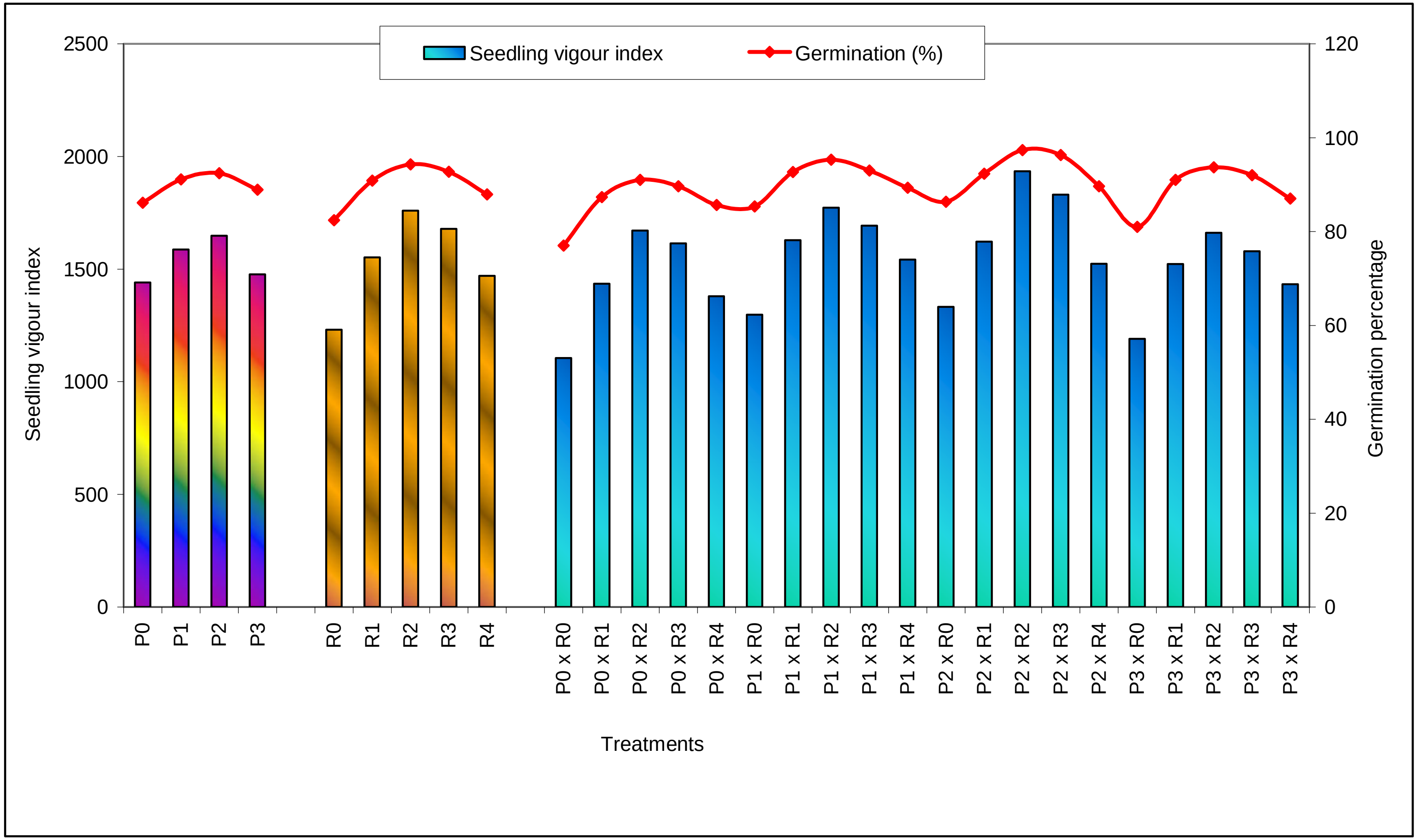

Fig. 14 : Effect of pollen viability of pollen parent and stigma receptivity of seed parent on germination (%) and seedling vigour index in hybrid seed production of tomato under shade house

Table 15. Effect of pollen viability of pollen parent and stigma receptivity of seed parent on root length, shoot length and seedling dry weight in hybrid seed production of tomato under shade house

Treatments	Root length (cm)	Shoot length (cm)	Seedling dry weight (mg^{-10})
Pollen viability of pollen parent (P)			
P_0	9.3	7.4	5.21
P_1	9.5	7.9	5.32
P_2	9.7	8.0	5.50
P_3	9.1	7.4	5.27
mean	9.4	7.7	5.33
SEm±	0.1	0.1	0.05
CD	0.2	0.2	0.14
Stigma receptivity of seed parent (R)			
R_0	8.2	6.8	4.87
R_1	9.5	7.6	5.21
R_2	10.2	8.4	5.86
R_3	9.9	8.2	5.70
R_4	9.2	7.5	4.99
Mean	9.4	7.7	5.33
SEm±	0.1	0.1	0.06
CD	0.2	0.2	0.16
Interaction (PxR)			
P_0 x R_0	7.9	6.4	4.57
P_0 x R_1	9.2	7.2	5.07
P_0 x R_2	10.2	8.2	5.87
P_0 x R_3	10.1	7.9	5.70
P_0 x R_4	9.1	7.0	4.87
P_1 x R_0	8.2	7.0	4.80
P_1 x R_1	9.6	7.9	5.27
P_1 x R_2	10.1	8.5	5.87
P_1 x R_3	9.9	8.3	5.67
P_1 x R_4	9.4	7.9	5.00
P_2 x R_0	8.3	7.1	4.97
P_2 x R_1	9.7	7.9	5.37
P_2 x R_2	10.9	9.0	6.13
P_2 x R_3	10.3	8.7	5.93
P_2 x R_4	9.4	7.6	5.10
P_3 x R_0	8.2	6.5	5.13
P_3 x R_1	9.3	7.4	5.13
P_3 x R_2	9.8	7.9	5.57
P_3 x R_3	9.3	7.8	5.50
P_3 x R_4	9.0	7.5	5.00
Mean	9.4	7.7	5.33
SEm±	0.2	0.1	0.11
CD	NS	NS	NS

NS – Non significant

P_0: Immediately after collection and pollination
P_1: One day Stored Pollen
P_2: Two day Stored Pollen
P_3: Three day Stored Pollen

R_0 **:** Pollination on the same day of emasculation
R_1 : Pollination one day after emasculation.
R_2 : Pollination two days after emasculation.
R_3 : Pollination three days after emasculation
R_4 : Pollination four days after emasculation

The interaction between pollen viability of pollen parent and stigma receptivity of seed parent were found to be non-significant. Numerically, the P_2R_2 (Two day stored pollen used for Pollination two days after emasculation) recorded higher shoot length (9.0cm) followed by P_2R_3 (Two day stored pollen with pollination three days after emasculation) (8.7cm). The P_0R_0 (P_0: Pollination immediately after collection [fresh pollen)] produced the lowest Shoot length (6.4cm).

4.2.13 Seedling dry weight (mg^{-10})

The data on Seedling dry weight as influenced by pollen viability of pollen parent (P), Stigma receptivity of seed parent (R) and their interaction affect results are presented in Table 15.

The Seedling dry weight significantly differences with respect to pollen viability of pollen parent, irrespective of receptivity of seed parent. Significantly, the highest seedling dry weight (5.50 mg^{-10}) was recorded in P_2 Two day stored pollen and followed by P_1(One day stored pollen) (5.32 mg^{-10}) and the lowest (5.21 mg^{-10}) was noticed in P_0: Pollination immediately after collection (fresh pollen)

The stigma receptivity of seed parent (R) had significant affect on seedling dry weight irrespective of pollen viability of pollen parent (P) among which R_2 pollination two days after emasculation had observed higher seedling dry weight (5.86 mg^{-10}) followed by R_3 Pollination three day after emasculation (5.70 mg^{-10}) and the lowest Seedling dry weight (4.87 mg^{-10}) was noticed in stigma treatment of R_0 (Pollination on the same day of emasculation).

The interaction between pollen viability of pollen parent (P) and stigma receptivity of seed parent (R) were found to be significant with respect seedling dry weight. The P_2R_2 (Two day stored pollen used for pollination two days after emasculation) recorded higher seedling dry weight (6.13 mg^{-10}) followed by P_2R_3 (Two day stored pollen with pollination three days after emasculation) (5.93 mg^{-10}). The P_0R_0 [P_0: Pollination immediately after collection (fresh pollen)] with R_0: Pollination on the same day of emasculation).produced the lowest seedling dry weight (4.57 mg^{-10}).

DISCUSSION

The growth, development and productivity of any crop species largely depend on the interaction between the genetic constitution of the plants and the environmental conditions under which they are grown. Although, every plant species has its own specific inherent characters such as colour, size and growth rate, the climatic conditions under which is grown has a large bearing on the realization of its genetic potential. Tomato is one such crop which responds very well to favorable environmental conditions and gets affected very easily to pest and disease. Hence the studies were undertaken to know the potentiality of using shade house for hybrid seed productivity of tomato with varied levels of spacing and to determine the pollen viability of pollen parent and stigma receptivity of seed parent involved in hybrid seed production of tomato under shade house and the results of the study are discussed in this chapter.

5.1 Experiment – I : Effect of growing conditions and plant spacing on growth, seed yield and quality of tomato hybrid seed production

5.1.1 Influence of growing condition on growth, seed yield and quality of tomato hybrid seed production.

To increase productivity there are mainly two approaches, first by improvement in genetic base and second by maintenance of favorable environment. In a given genetic material the yield potential is fully exploited only when a favorable growing environment is provided. The favorable environment refers to light, temperature, air composition and nature of root medium. Traditionally it is possible to control only nature of root medium by way of tillage, nutrition, irrigation *etc*. whereas in shade house which is a protected cultivation where the house structure has control over growing environmental condition to some extent.

Under shade house growing condition the productivity and quality of the produce increases since optimum growing conditions are provided as per the requirement of the crop the shading condition influence the crop to grow very slow and for long duration, and also protect the crop from insect pest, harsh wind speed and sun light. In the present investigation, the growing condition has shown significant variations on crop growth and flowering parameters irrespective of spacing.

In general, the shade house condition registered higher plant height (70.58 cm, 140.38 cm and 186.54 cm) and number of branches (23.59, 41.70 and 74.87) at 30, 60 and 90, DAT respectively compared to open field condition.

The increase in plant height may be attributed due to the favorable microclimate such as diffused sunlight and shading will cause etiolating due to which plant grow upwards in shade house and inside shade house temperature affect the plant metabolic activities like photosynthesis and respiration resulted in increased number of nodes inturn and then higher number of branches. Similar results of higher growth rate under protected condition have been reported by Nagalakshmi *et al.* (2001), Thangam and Thamburaj (2008), Parvej *et al.* (2010), Kengar (2001) and Harish (2011) in tomato and Megharaja (2000), Pandey *et al.* (2005), Zende (2008) and Sharma *et al.* (2010) in capsicum.

The higher leaf area (dm^2 $plant^{-1}$) and leaf area index (15.35, 78.37, 131.75 dm^2 $plant^{-1}$ and 0.50, 2.56 and 4.32) at 30, 60 and 90, DAT respectively recorded under shade house condition. This might be due to the availability of optimum climatic condition, such as sun light promoting cell division and cell elongation eventually led to more leaf area and little higher carbon dioxide under shade house might have affected the leaf physiology lead to increased the number of stomata and leaf photosynthesis this lead to higher leaf area and leaf area index These results are in accordance with findings of Parvej *et al.* (2010) Harish (2011) in tomato and Sharma *et al.* (2010) in capsicum.

With respect to flowering and fruit maturity, shade house condition took significantly more number of days for 50 per cent flowering (36) and days for fruit maturity (91.42) compared to open field condition (31.83 days) and (79.17) respectively. Early flowering in shade house was due to accumulation of maximum photosynthates as a result of better and long vegetative growth stage and lead to delayed reproductive stage where as in open field condition due to higher harsh temperature the crop plant will be in hurry up to complete life cycle whereas on other side plant in shade house enjoyed the favorable micro climate, due to shading and absence of heavy environment the fruit matured very slowly and lead to delayed fruit maturity. These results are in conformity with Thangam and Thamburaj (2008) in tomato.

Irrespective of spacing, the growing condition had revealed significant differences between the shade house and open field condition with respect to fruit and seed yield components such as fruit set (%) number of fruits per plant, individual fruit weight (g), number of seeds per fruit, seed weight per fruit (g), seed yield per plant (g), seed yield per plot (g), yield per hectare (kg) and seed recovery (%).

Under the shade houses the favorable environmental conditions such as higher humidity that promotes better pollen germination Henny (1985) and van Ravestijn (1986) and also improves pollen adhesion to the flower stigmatic surface Van koot and Van Ravestijn (1963), Van Ravestijn (1986) and optimum temperature in shade house structures is mainly responsible for higher fruit setting it has been reported by several workers, that lower wind speed and sunlight prevents early drying up of stigma which all lead to effective and successful crossing under shade house

whereas in open field condition the emasculated stigma face the problem of drying up due to harsh sunlight and wind speed, sometimes wash out pollens from stigma tip due to heavy rain or in some case due to visit of vibration creating insects whereas in under shade house condition all these problems are absent due to protection by the structure all around under which seed crop is grown.

One more important practices of hybrid seed production under shade house condition is that, crossing the emasculated stigma under shade house the pollen were collected from the pollen parent grown under shade house itself due to which good quality of pollens were used to cross the stigma under shade house but under open field condition pollen use for crossing of stigma where collected from open field gowned male plants itself where pollen parent in open field face the adversed climatic condition lead to poor and low quality pollen production

Hence the shade house recorded significantly higher fruit set percentage (67.6%), number of fruit per plant (18), number of seeds (139) per fruit and seed weight per fruit (0.323g) and Bakker (1989) reported that higher fruit set (%) observed in sweet pepper under glasshouse at higher humidity treatment.

The seed yield per hectare (187.1 kg) was higher under shade house because seed yield is a function of yield components and also better assimilation and translocation established in the plant system under shade house resulted in higher source to sink relationship due to favorable climatic condition under shade house and as above discussed point were the higher fruit set (%) and number of fruit per plant were significantly higher under shade house due to which seed yield per plant (5.8g), seed yield per plot (280.7g) were also higher under shade house as reported by Harish (2011).

The seed recovery (0.402%) was higher under shade house due to higher seeds weight per fruit under shade house which had direct relation with seed recovery percentage and the seed weight per fruit higher under shade house because of effective crossing and delayed fruit maturity lead to long contact of seed and mother plant due to which slow and complete development of seed took place which lead to good heavy seeds harvest..

Seed quality parameters such as 100 seed weight, germination percent, seedling vigour index, root length, shoot length, dry weight of seedlings and TDH Activity were found to differ significantly between the growing condition, irrespective of the spacing. On an average, all the seed quality parameters showed consistently more values (0.307g, 92.5%, 1766, 10.9 cm, 8.2 cm, 6.84 mg^{-10}, and 1.93 respectively) under shade house condition compared to open condition (0.39g, 87%, 1479, 9.6 cm, 7.3 cm, 5.62 mg^{-10}, and 1.64 respectively). This may be due to the better development of seeds and more assimilation and translocation of photosynthates from source to sink relationship in the plant system and delayed in fruit maturity under shade house proved plenty of time to seeds to get well connected with mother seed plant for long time and develop completely with healthy and mature embryo. Hence, it was observed higher 100 seed weight and bold seeds in shade house condition which inturn might have influenced on other seed quality parameters these results are in confirm with Harish (2011) in tomato.

5.1.2 Influence of plant spacing on growth, fruit and seed yield of tomato.

One of the main factors affecting crop productivity is plant population which is mainly governed by the plant architecture, soil fertility, time of planting *etc*. Maintenance of optimum plant density especially under cover assumes greater importance since it accounts for many fold increase in yield when other factors are non-limiting and to make it more cost effective. Under modern vegetable technology a great emphasis is being given to have the appropriate plant densities in order to boost up the production per unit area.

The investigation revealed that the significant differences on crop growth, fruit and seed yield and quality parameters with four levels of spacing. Among the spacing, closer spacing of 50 cm x 45 cm resulted in higher plant height at 30, 60, and 90 days stages of the crop growth (69.37 cm, 122.03 cm and 164.21cm, respectively). This might be due to the great competition for space and light there by forcing the plants to grow taller reported by (Prasad, 2001), Similar increase in growth rate at closer spacing was noticed by Rajeshwar *et al.* (1981), Papadopoulos and Ormrod (1991), Ravinder *et al.* (1998), Sharanabasava *et al.* (2000) and Harish (2011) in tomato.

Higher number of branches per plant at 60 and 90 DAT of crop growth were noticed in medium spacing of 60 cm x 60 cm (25.63, 41.63 and 64.75 respectively). This might be due to stout plants produced by exploiting the available space, nutrients and light resources favouring fast vegetative growth, improved the synthesis and accumulation of more photosynthates helping for promotion of more auxiliary buds in putting forth new shoots earlier noticed by Prasad, (2001), Dharmatti (1986), Maya *et al.* (1999) in sweet pepper, Balaraj *et al.* (2002) in chilli and Harish (2011). Higher leaf area at 30, 60, and 90 DAT was observed at 60 cm x 60 cm spacing (15.67, 60.39 and 104.74 dm^2/ plant) respectively, perhaps due to the availability of more space to spread, more moisture and nutrients in the soil and more solar radiation. The same results were obtained by Pandey *et al.* (1996) and Harish (2001) in tomato. Leaf area index was significantly higher in 50 cm x 45 cm spacing at 30, 60 and90 DAT (0.52, 2.33 and 4.35) respectively. This may be due to higher plant density. These results are in conformity with Maya *et al.* (1999) in capsicum Harish (2011) in tomato and Papdopoulos and Ormrod (1988).

With respect to flowering and fruit maturity, closer spacing of 50 cm x 45 cm took significantly less number of days (31.17 and 81.33) for 50 per cent flowering and maturity respectively compared to S_1: 75 x 60 cm (34 and 85.17), S_3: 60 x 45 cm (33.50 and 86.17) and S_3: 60 x 60 cm (36.33 and 88.5) spacing. This might be due to greater competition for space and light there by forcing the plants to grow at faster rate and complete the vegetative phase early and induction of flowering early. Similar results of early flowering with closer spacing were reported by Mehla (1999) and Harish (2011) in tomato and Dharmatti (1986) in capsicum.

The investigation on the four spacing's showed significant differences on fruit and seed yield components such as fruit set (%) number of fruits per plant, individual fruit weight(g), number of seeds per fruit, seed weight per fruit(g), seed yield per plant (g), seed yield per plot (g), seed yield per hectare (kg), seed recovery (%)irrespective of growing condition.

The fruit set (%), number of fruits per plant and fruit weight was significantly higher at medium spacing of 60 cm x 60 cm (71.1%, 19 and 91g respectively). This could be attributed to increased intake of nutrients and build up of sufficient photosynthates enabling the vigorous growth of plants leading to more fruits per plant and individual fruit weight, an increase in plant density is positively correlated with fruit yield but negatively correlated with fruit weight due to an insufficient supply of photoassimilates to each fruit. Similar results in case of more fruits per plant are observed by Dimir and Lal (1988), Hanchul *et al.* (1997) in tomato. And similar result observed in case of individual fruit weight by Papdopoulos and Ormrod (1990), Mantur *et al.* (2007b), Mantur and Patil (2008) and Harish (2011) in tomato.

Least number of fruits per plant was noticed at a closer spacing of 50 cm x 45 cm (13) which may be due to shading effect leads to heavy plant canopy, production of less number of flowers and also dropping of flowers similar findings by Harish (2011) in tomato.

The number of seeds per fruit, seed weight per fruit(g), seed yield per plant seed recovery (%) was significantly higher at medium spacing of 60 cm x 60 cm (139, 0.323g, 6g and 0.351 %, respectively). This might be due to the well distribution of plant nutrients which has helped proper development of the seed, as a result of which there was also increase in 100 seed weight. These results are in confirmation with the reports of Dharmatti and Kulkarni (1988) and Sharma and Peshin (1994) in capsicum.

Medium spacing 0f 60 cm x 45 cm recorded significantly higher seed yield per plot (256.0g) and seed yield per hectare (170.6 kg/ha). Though the plant population per unit area is lesser compared to the closer spacing, but due to the fact that higher number of fruits per plant, mean fruit weight, number of seeds per fruit, seed weight per fruit and seed yield per plant resulted in higher seed yield per hectare.

Wider spacing of 75 cm x 60 cm recorded significantly lower seed yield per hectare (96.0kg/ha). Because of lesser plant population per unit area, the total seed yield per hectare was lower with this treatment. Similar results have been reported by Sharma *et al.* (2001) in tomato and Dharmatti and Kulkarni (1988) in capsicum.

5.1.3 Influence of spacing on seed quality of tomato hybrid seeds

The spacing showed significant difference on seed quality. All the seed quality parameters *viz*. 100 seed weight (0.322 g), seed germination (92.3%), seedling vigour index (1815), root length (11.3cm), shoot length (8.3cm), seedling dry weight (7.08 mg^{-10} seedlings) and TDH activity (1.80) showed significantly higher values with 60 x 60 cm spacing. Better seed quality attributes with medium spacing might be due to better plant nourishment resulting in proper development of seed, which reflected in higher 100 seed weight and other seed quality parameters. Similar results are also reported by Kalappa (1982) and Dharmatti and Kulkarni (1988), Sharma and Peshin (1994) in bell pepper, Balaraj *et al.* (2002) in chilli and Harish (2011) in tomato.

5.1.4 Interaction effects (GxS)

Among the interaction between growing condition and spacing (GxS), showed significantly higher plant height at 60 and 90 DAT (155.97 cm, and 200.47) and leaf area index at 30 60 and 90 DAT (060, 3.29 and 5.67 respectively) was noticed under shade house condition with 50 cm x 45 cm spacing. Higher number of branches per plant was recorded at 60 90 DAT (27.80, 48.17 82.30) and leaf area (18.32, 85.90 and 137.87) and the interaction between growing condition and spacing (GxS) were found to be significant for fruit, seed yield and its attributing parameters *viz*., fruit set (%) number of fruits per plant, number of seeds per fruit, seed weight per fruit, seed yield per plant (74.6%, 22, 155, 0.363g and 7.9g) respectively under treatment combination of G_1S_4 (shade house with 60 x 60 cm spacing level).

The shade house with spacing of 60 cm x 60 cm resulted in higher number of fruits per plant (22.00) because of more flower production and more fruit setting percentage and also might be due to increased intake of nutrients and build up of sufficient photosynthates enabling vigorous growth of plants leading to more fruits per plant besides favourable climatic condition and shade house with 60 x 45 cm recorded highest seed yield per plot and per hectare (342.0 g and 228.0kg) due to more number of plant per unit area and advantages of shade house.

Seed yield per plant was significantly higher at a spacing of 60 cm x 60 cm under shade house (7.9 g). This may be due to the availability of optimum space for better growth of the plant attributed to increase intake of assimilates and well distribution of plant nutrients which has helped in proper development of the seed, as a result of which there was increase in number of seeds per fruit and seed weight per fruit resulted in higher seed yield coupled with congenial micro climate under shade house.

The interaction between growing condition and spacing (GxS) were found to be significant with respect to seed quality parameters such as seed seedling vigour index (2041), Better seed quality attributes under shade house with medium spacing 60 x 45 cm might be due to better plants nourishment under shade house with medium spacing resulting in proper development of seed, which reflected in numerically higher 100 seed weight and other seed quality parameters These results are in agreement with the reports of Harish (2011) in tomato.

5.2 Experiment – II: Studies on pollen viability of pollen parent and stigma receptivity of seed parent in hybrid seed production of tomato under shade house

Tomato is one of the important vegetable crops grown throughout India. Now a days it has emerged as the most popular fruit vegetable and its demand is growing rapidly, since its fruit is rich in natural vitamins, mineral, hormones and other nutrients essential for maintaining general health of the people. Hence, it has emerged as an excellent nutritional crop

The average seed yield of tomato hybrid seed production were influenced by several aspects such as growing condition, mother plant nutrition, plant spacing, time of pollination, pollen storage, fruit yield, time of harvesting, drying methods and post harvest operations, *etc.* Although, time and again, the several studies have been carried out in tomato to enhance its average commercial yield in open field condition as an investigation to search new venue for growing healthy and productive crop.

The shade house structures were emerged as a best alternative structure use against the environmental problems, the crop such as tomato where hand emasculation and hand pollination were carried out most commonly in India due to plenty of man power keeping these points in view such systematic studies have been carried out from the point of seed production in enhancing the average seed yield and quality of tomato particularly in tomato hybrid under shade.

5.2.1 Effect of pollen viability of pollen parent on fruit set, seed yield and its components

The knowledge of pollen viability and stigma receptivity is very important in hybrid seed production, particularly in crop like tomato where the manual emasculation and pollination are involved and the today's investigation and gained knowledge on pollen viability and stigma receptivity under protected condition such as shade house is a need of today's and tomorrow's seed industry. This will enable the protected structure adopted hybrid seed producers to know how long old pollen is used for pollination and how long pollination can be continued and what is the best combination between them under shade house.

Collection of pollen and its storage for use in artificial pollination are important especially under weather conditions which are not favorable for pollination and the value of techniques become especially apparent, if pollen need to be transported to far places and utilized where pollen parent growth development is not satisfactory.

In this experiment, pollen viability of pollen parent has significant influence on various fruiting and seed yield components, irrespective of stigma receptivity of seed parent However, the results exhibited significant differences for pollen viability of pollen parent on fruits set percentage, fruit weight, number of seeds per fruit, seed weight per fruit, seed weight per plant, seed recovery percentage irrespective of stigma receptivity of seed parent. All these parameters were significantly highest (66.61%, 92.47g, 106.47, 0.36g, 7.02g and 0.39%), respectively in the fruits obtained from crossing with two days stored pollen compare to one day stored pollens (61.87%, 89.01g, 97.13 g, 0.32 g, 6.26 g and 0.36%, respectively). The marked increase in various fruiting and seed yield components noticed in two days stored pollens followed by one day stored pollen as against three days stored pollen and fresh pollen

This may be attributed to the fact that the two days stored pollens may have more number of mature and viable pollens and this might have resulted in higher fruit setting and seed yield components. Irrespective of stigma receptivity of seed parent fresh pollens recorded significantly the lowest values for fruit setting and seed yield components followed by three days stored pollens which may be attributed to the immature pollens and also the shorter pollen viability period respectively and it might have resulted in the poor fruit and seed yield components compared to two days stored pollens.

These results are in agreement with findings of Petrova *et al.* (1981), Islam and Khan (1998) and Patil (2005) in brinjal, Yogesha *et al.* (1999) and Jolli (2004) in tomato and Bellad (2012) in water mellon.

The in vitro determination of pollen viability through Acetocarmine stain, the treatment P_0 fresh pollen recorded significantly higher (92) percentage of dark stained pollens (viable) because the fresh pollen have highest no of viable pollen including both mature and immature pollens (both both mature and immature pollens get stained) due to which it showed the highest stained pollen

5.2.2 Effect of pollen viability of pollen parent on seed quality parameters

The significant differences due to pollen viability of pollen parent were seen with respect to various seed quality parameters studied such as germination percentage, root length , shoot length , seedling vigour index, seedling dry weight (mg^{-10}). In general, all these seed quality parameters were significantly higher (92.40%, 9.73 cm, 8.0 cm, 1648 and 5.50 mg^{-10} respectively) in the seeds extracted from the fruits of two days stored pollens treatments used for crossing followed by one day stored pollens as against three days and fresh stored pollens (91.13%, 9.46 cm, 7.9 cm, 1587 and 5.32 mg^{-10} respectively).

The significant increase in germination percentage, root length, shoot length, seed vigour index, seedling dry weight noticed in the two days stored pollens may be related to the higher seed weight coupled with bolder and well developed seeds obtained from the fruits of two days stored pollens compared to those obtained from fruits of one day stored pollens. These findings were also confirmed by the work of other research workers like Chen (2003) and Patil (2005) in brinjal and Jolli *et al.* (2008) in tomato and Bellad (2012) in watermelon.

5.2.3 Effect of stigma receptivity of seed parent on fruit set, seed yield and its components

The investigation found that stigma becomes fully receptive, as revealed by the per cent fruit set, in by pollination two days after emasculation in female parent and there after declined, beyond which stigma was found to be either less receptive or non receptive most of the observations.

Stigma receptivity of seed parent was found to be significant for fruits set percentage, fruit weight, number of seeds per fruit, seed weight per fruit, seed weight per plant, seed recovery percentage except for number of flowers pollinated per plant irrespective of pollen viability of pollen parent. On an average, the highest Fruits set percentage, fruit weight, number of seeds per fruit, seed weight per fruit, seed weight per plant, seed recovery percentage were observed when pollination was done two day after emasculation (67.68%, 95.13g, 114.83, 0.38g, 7.44g and 0.40%). This suggest that the peak stigma receptivity was on pollination two days after emasculation at Dharwad condition under shade house and on the other hand delayed pollination, particularly pollination four days after emasculation leads to the lowest fruit set and lesser number of seed per fruit. This may be due to the drying of stigmatic surface that led to the reduction in fruit set percentage and early in pollination that is pollinating the fresh stigma and immature stigma resulted in reduced fruit set leads to the lesser number of seed per fruit. These findings are in agreement with the reports of Sidhu *et al.* (1980), Yogesha *et al.* (1999) Jolli (2007) in tomato and kivadasannavar (2008) in chilli.

5.2.4 Effect of stigma receptivity of seed parent on seed quality parameters

Seed produced from treatment, pollination two day after emasculation recorded significantly higher seed germination percentage, root length (cm), shoot length (cm), seed vigour index, seedling dry weight (mg^{-10}) (94.33%, 10.24 cm, 8.4 cm, 1760 and 5.86 mg^{-10} respectively) over pollination on same day, one day three days and four days after emasculation. This may be due to higher seed weight and also bolder seeds harvested from this treatment. The increase in seedling vigour can also be attributed to higher per cent of germination, root length and shoot length, seedling vigour index obtained by multiplication of germination percentage with the sum total of root and shoot length. Such results were reported earlier by Dev (1998), Yogeesha *et al.* (1999), Chithra Devi (2000) and Jolli (2007) in tomato and Kivadasannavar (2008) in chilli.

5.2.5 Interaction affect

The interaction between the pollen viability of pollen parent and stigma receptivity of seed parent observed significant difference with respect to fruit set, seed yield and seed quality parameters such as fruits set percentage, fruit weight, number of seeds per fruit, seed weight per fruit, seed weight per plant, seed recovery percentage, germination percentage, and seed vigour index.

The significantly higher fruits set percentage, fruit weight, number of seeds per fruit, seed weight per fruit, seed weight per plant and seed recovery percentage (75.16%, 98.87g, 129.00, 0.46g, 8.94g, 0.47 %, 97%, 10.87 cm, 9.0 cm, 1934 and 6.13 mg^{-10}) respectively observed in combination of two days stored pollen use for pollinating stigma two days after emasculation followed by two days stored pollen with pollination three days after emasculation (72.17% 96.37g, 121.00, 0.42g, 8.23g 0.44%, 96.33% 10.33 cm, 8.7 cm, 1934 and 6.13mg^{-10}).

This may be due to the best combination of mature pollen used for pollinating stigma which attended peak receptivity two days after emasculation compared to all other treatment combinations and use of fresh pollen to pollinate fresh stigma soon after emasculation recorded significantly lower (32.39%, 71.70g, 59.33, 0.16 g, 3.11g 0.22%, 77%, 7.93cm, 6.4cm, 1105 and 4.57 mg^{-10}, respectively) this is because of poor combinations between fresh immature pollen and fresh non-receptive stigma. These findings are in agreement with the reports of Jolli (2004) in tomato

Practical utility

1. Higher yield and quality of tomato hybrid seeds can be obtained under shade house condition compared to open field condition.
2. For obtaining higher seed yield a spacing of 60 × 45 cm can be adopted under shade house condition.
3. The better fruits set percentage, seed yield and quality can be achieved by use of two days old stored pollen for pollination of female parental line stigmas in hybrid seed production of tomato under shade house.

4. The higher fruits set percentage, seed yield and better seed quality can be obtained by use of two days old stigma for crosses in hybrid seed production of tomato under shade house.
5. In combination two day old stored pollen with two days old stigma give better combination affect leads to better fruits set percentage, seed yield and seed quality in hybrid seed production of tomato under shade house.

Future line of work

1. The performance of different parental lines of different hybrids of tomato should be screened for seed yield and quality under different growing conditions.
2. Comparative studies on quality pollen production methods and there positive effect on seed yield and quality of tomato can be initiated under open field, shade house, net houses and polyhouse condition.
3. Standardization of plant spacing levels for better seed yield and quality of tomato under different growing condition like shade house, net house and polyhouse need to be studied.
4. Standardization of pollination time, crossing duration, crossing ratio of male to female buds in hybrid seed production of tomato under shade house, net houses and polyhouse condition need to be taken up.
5. Comparative studies on pollen viability of pollen parent and stigma receptivity of seed parent under different growing condition like shade house, net house and polyhouse need to be investigate.
6. Working out of economics for hybrid seed productivity under different protected conditions needs to be taken up.

SUMMARY AND CONCLUSIONS

The field experiments were conducted to study the effect of growing conditions and spacing on growth, seed yield and quality of tomato hybrid seed production and to know the pollen viability of pollen parent and stigma receptivity of seed parent in hybrid seed production of tomato Pusa hybrid-2 parental line under shade house. The experiments were located at shade house Hi-Tech Horticulture unit, Saidapur farm and seed quality analysis were carried out at Seed Quality Testing And Research Laboratory National Seed Project, University of Agricultural Sciences, Dharwad during 2012-13. The results of these experiments were summarized in this chapter.

Experiment – I: Effect of growing conditions and plant spacing on growth, seed yield and quality of tomato hybrid seed production

The experiment consisted of two growing condition *viz*. Shade house condition (G_1) and open field (G_2) as main factor and four levels of spacing *viz*. 75 cm x 60 cm (S_1), 50 cm x 45 cm (S_2), 60 cm x 45 cm (S_3) and 60 cm x 60 cm (S_4) as sub factor. It was conducted in two factorial RCBD design in three replications during *Rabi* 2012-13.

Growing condition (G)

Between the growing condition, the shade house condition registered significantly higher plant height at 30, 60 and 90 DAT (70.58 cm, 140.38 cm and 186.54 cm respectively), number of branches per plant (23.59, 41.70 and 74.87 respectively), leaf area (15.35 $dm^2 plant^{-1}$, 78.37 $dm^2 plant^{-1}$, 131.75 $dm^2 plant^{-1}$ respectively) and leaf area index (0.50, 2.56 and 4.32 respectively) compared to that of open field condition.

Shade house condition took significantly more number of days to 50 per cent flowering (36 days) and days to fruit maturity (91.42 days) compared to open field condition.

Significantly higher fruit set (67.6%) number of fruits per plant (18) number of seeds per fruit (139), seed weight per fruit (0.323g) , seed recovery (0.402%) seed yield per plant (5.8g), seed yield per plot (280.7g) and seed yield per hectare (187.1kg) were recorded under shade house condition compared to that of open condition and significantly higher individual fruit weight (91.8 g) was recorded in open field condition compared to shade house condition.

The shade house growing condition has recorded significantly higher values for seed quality parameters such as 100 seed weight, seed germination, seedling vigour index, root length, shoot length, , dry weight of seedlings, and total dehydrogenize activity compared to open field condition (0.307 g, 92.5%, 1766, 10.9 cm, 8.2 cm, 6.84 mg^{-10}, and 1.93 respectively).

Spacing (S)

Among the spacing's, the closer spacing of 50 cm x 45 cm recorded significantly higher plant height at 30, 60 and 90 DAT (69.37 cm, 122.03 cm and 164.21 cm, respectively) and leaf area index at (0.55, 2.33 and 4.35, respectively) and took significantly less number of days for 50 per cent flowering (31.17 days) and fruit maturity (81.33 days).

The spacing of 60 cm x 60 cm recorded significantly higher values for number of branches per plant at 30, 60 and 90 DAT (25.63, 41.63 and 64.75 respectively) and leaf area (15.67 $dm^2 plant^{-1}$, 60.39 $dm^2 plant^{-1}$ and 104.74 $dm^2 plant^{-1}$respectively).

The significantly higher number of fruit set (71.1%) fruits per plant (19) fruit weight (91g) number of seeds per fruit (134), seed weight per fruit (0.313g) and seed yield per plant (6.0 g) seed recovery (0.351%) were recorded at spacing of 60 x 60 cm.

The spacing level 60 x 45 cm recorded significantly higher values for seed yield per plot (256.0g) and seed yield per hectare (170.6kg) compare to other spacing levels.

The medium spacing of 60 cm x 60 cm recorded significantly higher values for seed quality parameters such as 100 seed weight (0.322g), seed germination (92.3%), seedling vigour index (1815), root length (11.3cm), shoot length (8.3cm), dry weight of seedlings (7.08 mg^{-10}) as compared to S_1 . S_2 and S_3.

Interaction effects (GXS)

The interaction effect between growing condition and plant spacing (GxS), revealed significantly higher plant height at 60 and 90 DAT (155.97 cm, and 200.47 cm) and leaf area index at 30 60 and 90 DAT (0.60, 3.29, 5.67 respectively) under shade house condition with 50 cm x 45 cm spacing higher number of branches per plant was recorded at 60 and 90 DAT (48.17 and 82.33) and leaf area (18.32 dm^2plant^{-1}, 85.90 dm^2plant^{-1} and 137.87 dm^2plant^{-1}) at 30, 60 and 90 DAT respectively under shade house condition with 60 cm x 60 cm spacing.

Significantly higher fruit and seed yield and its attributing parameters *viz.*, fruit set (%) number of fruits per plant, number of seeds per fruit, seed weight per fruit, seed yield per plant (74.6 %, 22.00, 155, 0.363 g and 7.9) were recorded high in G_1S_4 shade house and 60 x 60 cm spacing significantly higher seed yield per plot and seed yield per hectare (342.0g and 228.0kg,) were recorded in shade house with 60 x 45 cm spacing.

Significantly higher values of seed quality parameters were recorded under shade house at 60 x 60 cm spacing levels with respect to seedling vigour index (2041) and numerically higher 100 seed weight (0.369g).

Experiment – II: Studies on pollen viability of pollen parent and stigma receptivity of seed parent in hybrid seed production of tomato under shade house

The experiment was conducted during *Rabi* 2012-2013 under shade house at Dharwad condition. To know the pollen viability of pollen parent and stigma receptivity of seed parent in hybrid seed production of tomato under shade house. Parental lines of Pusa hybrid-2 were raised in different male (pollen parent) and female (seed parent) blocks under shade house.

Pollen Viability of Pollen Parent (P)

Pollen viability study of pollen parent exhibited significant differences for various parameters such as fruits set percentage, fruit weight, number of seeds per fruit, seed weight per fruit, seed weight per plant and seed recovery percentage which were significantly higher (67.68%, 95.13g, 114.83, 0.38g, 7.44g and 0.40% respectively) in the two day stored pollen P_2 used for crossing.

The significantly higher values were recorded for seed quality parameters such as 100 seed weigh, germination percentage, root length, shoot length, seed vigour index and seedling dry weight (0.700g, 92.40%, 9.73 cm, 8.0 cm, 1648 and 5.50 mg^{-10} respectively) when two day stored pollen (P_2) is used for crossing.

Stigma Receptivity of seed parent (R)

Among the different stigma receptivity treatments studies of seed parent the treatment pollination two days after emasculation of stigmas (R_2) recorded significantly higher observation such as fruits set percentage, fruit weight, number of seeds per fruit, seed weight per fruit, seed weight per plant, seed recovery percentage (67.68%, 95.13g, 114.83, 0.38g, 7.44g and 0.40%) followed by the R_3, compare to R_2, R_4 and $R_{0.}$

The R_2 (pollination two days after emasculation) recorded significantly higher values for seed quality parameters such as 100 seed weight, germination percentage, root length, shoot length, seed vigour index and seedling dry weight (0.704g, 94.33%, 10.24 cm, 8.4 cm, 1760 and 5.86 mg^{-10} respectively) followed by the R_3, compare to R_2 , R_4 and $R_{0.}$

Interaction effects (PXR)

Among the interaction between pollen viability of pollen parent (P) and stigma receptivity of seed parent (R) (PxR), significantly higher Fruits set percentage (75.2%), fruit weight (98.87g), number of seeds per fruit (129), seed weight per fruit(0.46g), seed weight per plant(8.94g), seed recovery percentage (0.47), 100 seed weight (0.753) germination percentage (97.33%) and seed vigour index (1934) were recorded in treatment combination of P_2R_2 (Two day stored pollen used for pollination two days after emasculated Stigma) followed by the combination of P_2R_3, compared to all other combinations between pollen viability of pollen parent (P) and stigma receptivity of seed parent.

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STUDIES ON STANDARDIZATION OF HYBRID SEED PRODUCTION TECHNIQUES UNDER SHADE HOUSE AND OPEN FIELD CONDITIONS IN TOMATO (*Solanum lycopersicum* L.)

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ABSTRACT

A field experiment was carried out at Hi-Tech Horticulture unit, Saidapur farm and seed quality analysis at seed quality testing and research laboratory National Seed Project, UAS Dharwad during 2012-13 to study the effect of growing conditions and plant spacing on growth, seed yield and quality of tomato hybrid seed production and to know the pollen viability of pollen parent and stigma receptivity of seed parent in hybrid seed production of tomato Pusa hybrid-2 parental line under shade house.

The growing condition shade house registered significantly higher plant height at 90 DAT (186.54 cm), leaf area (131.75 $dm^2 plant^{-1}$), leaf area index (4.32) more number of days to 50 per cent flowering (36 days), days to fruit maturity (91.42 days), fruit set (67.6%), seed yield per hectare (187.1kg), seed germination (92.5%) and seedling vigour index (1766). Hance higher yield and quality of tomato hybrid seeds can be obtained under shade house condition compared open condition

The spacing 60 x 60 cm recorded significantly higher number of fruit set (71.1%), seed yield per plant (6.0 g), seed germination (92.3%) and seedling vigour index (1815) and spacing 60 x 45 cm recorded significantly higher seed yield per hectare (170.6kg).

The significantly higher fruits set (67.68%), number of seeds per fruit (114.83), germination percentage (92.40%), seed vigour index (1648) and seedling dry weight (5.50 mg^{-10}) recorded when two day stored pollen is used for crossing and pollination two days after emasculation of stigmas recorded significantly higher fruits set (67.68%), number of seeds per fruit (114.83), germination (94.33%), seed vigour index (1760) and seedling dry weight (5.86 mg^{-10}).

Significantly higher Fruits set (75.2%), number of seeds per fruit (129), germination (97.33%) and seed vigour index (1934) were recorded in treatment combination of two day stored pollen used for pollination of two days after emasculated Stigma and this treatment combustions better fruits set percentage, seed yield and seed quality