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# Effect of planting time and spacing on growth characteristics of yellow lantern chilli (*Capsicum chinense*)

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ABSTRACT

Yellow lantern chilli [(*Capsicum chinense* (Jacq.)], the world's hottest chilli is mostly grown in the north eastern part of India. The crop is cultivated by traditional ways since time immemorial. However, very little research towards scientific cultivation has been conducted in the past and until now scientific package of practices is not available. In the present investigation, the effect of various planting time and spacing on the growth characteristics of the hottest chilli, yellow rantern chilli (*bhoot jolokia*) was studied in north-eastern hill region of India. Seeds of the variety local cultivar, *bor Bhoot of bhoot jolokia* were planted in four different dates i e September 15 ($P_1$), October 15 ($P_2$), January 15 ($P_3$) and February 15 ($P_4$) with three spacings *viz.* 75cm × 75cm ($S_1$), 90cm × 90cm ($S_2$) and 105cm × 105cm ($S_3$). The results revealed that the growth parameters and yield attributing characters were significantly influenced by different planting dates and spacings. Sowing in September 15 ($P_1$) and with a spacing 105cm × 105cm ($S_3$) were recorded the highest plant height, number of primary branches, number of fruits/plant, fruit weight and fruit yield/plant. In case of phyllochron index September 15 sowing showed maximum days to phyllochron but closest spacing 75cm × 75cm showed maximum phyllochron. Among all the treatments, the crop sown in September with a spacing of 105cm × 105cm showed better performance for all the parameters studied and can be considered basis for studying the effects of other agronomic practices.

**Keywords:** *Bhoot Jolokia,* Yellow lantern chilli, *Capsicum chinense,* Hottest chilli, Planting time, Spacing

Ghost chilli (king chilli), *Capsicum chinense* also known as *Bhoot Jolokia* in Assamese, *Naga Jolokia* in Nagamese and *U-morok* in Manipuri, is extensively grown in the north-eastern region of India, predominantly in Asom, Manipur and Nagaland. It belongs to family Solanaceae with chromosome number 24 (2n=24). This crop is considered to be an interspecies hybrid, more of *Capsicum chinense* and some genes of *Capsicum frutenscens* (Paul *et al.* 2007). After Professor Paul Bostland of New Mexico State University found that this chilli has 1 001 304 Scoville Heat Units beating red Savina Habanero, it was recognized as the world's hottest pepper in the Guinness Book of Worlds Record, 2007 (Shaline 2007).

The crop is very important for the economy and sustainability of agriculture for the farmers of the north-eastern region of India. People from this region of India, consisting of about 67 major ethnic groups (Devi *et al.* 2008), prefer this chilli over other chillies because of its peculiar aroma, taste and medicinal property. People use this chilli for curing stomach ailments. The pepper is also used as remedy for summer heat (Anon. 2007). The chilli is rich in vitamin C and vitamin A, even superior to that of tomato and brinjal (Bora 2000). It is the highest source of capsaicin which in turn has many industrial and medicinal uses. Defence Research and Development Organisation, India, is trying to include this chilli for defence purposes for example preparation of aerosol spray (Anon. 2009).

The plant is woody perennial sub-shrub of 45 to 120 cm in height, with multiple stems. The fruit is sub-conical to conical in shape with rough skin about 6 to 8.5 cm length and 2.5 to 3 cm of breadth. The mature fruit may weigh up to about 9g with 19 to 34 seeds. The colour of the fruit is green at the earlier stage and turns shining red or deep orange when mature. The crop is usually sown during falls (September to

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October) traditionally. Farmers are constantly facing low productivity (average of 10 fruits/plant/annum) and low viability of the seeds. There are no available package of practices for this crop and no systematic studies being done on various agronomic inputs. Farmers are growing this crop as per their experiences and traditional knowledge as learnt by them from forefathers. The traditional major production practices include large-scale production in fields or small scale production in the kitchen gardens. The crop can be grown perennially on the periphery of sub-plots in the kitchen gardens. It is usually sown in winter and fruiting occurs in summer. The crop had been grown on hills (up to about 2000m above mean sea level) as well as in low laying valleys of sea level. The development of above and underground organs, fruit production and seed quality of crops are dependent upon efficient use of all available resources, including competition which affect the photosynthetic efficiency and thereby fruit yield and quality.

The crop is cultivated by traditional ways since time immemorial in north-eastern part of India. However, very little research towards scientific cultivation has been done in the past and until now scientific package of practices is not available. Various cultivation aspects of this traditional crop are still not standardized and no work has been reported for the effects of planting time and spacing on growth, seed quality and productivity of ghost chilli (*Capsicum chinense*). The study of this plant is very important for farmers to obtain higher yield, quality fruit production, and economy as well as to the researchers as the optimal planting time and spacing will serve as a starting point to develop scientific package of practices, standardization of growing of this plant for other researches such as quality assessment, post harvest technologies, etc. Hence, the present studies were undertaken to find out the optimum planting time and spacing of yellow lantern chilli *(Capsicum chinense)* for growth, yield and seed quality. This is the first report on optimum planting time and spacing for this crop.

## MATERIALS AND METHODS

The study was conducted in 2007 and 2008 at Horticulture Experimental Farm, Jorhat, Assam Agricultural University (26° 47' N Latitude, 94° 12' E longitude), which lies in north-eastern part of India which is a mega biodiversity hot spot of the world. The experiment was laid out in a randomized block design with three replications and the seeds were sown on four different dates namely 15 September, 15 October, 15 January and 15 February. The plants were spaced at three different spacings of 75 cm × 75 cm, 90 cm × 90 cm and 105 cm × 105 cm. The variety taken for the experiment was the local cultivar of Assam known as *Bor Bhoot*. The seeds were obtained from All India Co-ordinated Research Project on Vegetable crops, Assam Agricultural University, Jorhat. The seeds of *Bor Bhoot* were first treated with MH @ 150 ppm for 4 hr and were sown in the beds. The beds were then covered with banana leaves and were watered regularly. Then, 40–60 days old seedling having 4–6 leaves, were selected and transplanted in individual plots at different dates viz., September, October, January, February with three spacings of 75 cm × 75 cm, 90 cm × 90 cm and 105 cm × 105 cm. Liming was done at the rate of 1.7 tonnes/ha 30 days before sowing. farmyard manure @ 10 tonnes/ha and NPK in the ratio of 120:60:60 kg/ha were applied as per the dose of chilli. All other cultural practices were uniform for all the planting times.

Data on yield and yield components of different treatments were recorded. Observation were recorded on days to 50% flowering, days to 50% fruiting, plant height, number of primary branches/plant, fruit yield/plant, fruit yield/ha, self-life of the harvested fruits, number of seeds/ fruits, 1000-seed weight and germination percentage. Meteorological data collected during growing season were presented in Table 1. Five fruits from each treatment were placed under ambient temperature (approx 25° C) right after the harvesting. The days required to the fruit shrivelling was recorded as the shelf-life of the fruits. For examining 1 000 seed weight and viability test, the seeds were extracted manually from the fully ripe red fruit and counted for the number of seeds. 1 000 seeds in three replications were selected randomly from sun-dried seeds and weight was taken. For the seed viability test, 100 seeds in three replications were tested for germination just after harvest, 30, 60 and 90 days after harvesting. Seeds were sown on double layer of wet filter paper in Petri-dishes at room temperature (approx 25° C). Number of days required for germination and number of germinated seeds were counted.

Statistical analysis was performed with SAS Version 9.2 (SAS, 2010, SAS Institute Inc., Cary, NC, USA). SAS's PROC GLM procedure was used to conduct Analysis of Variance (ANOVA) to know the individual effects of planting time and spacing and also interaction on growth characteristics and yield components of yellow lantern chilli. Furthermore, multiple means comparison was completed for significant ($P$ <0.05) by comparing the least squares means of the corresponding treatment combinations.

## RESULTS AND DISCUSSION

As per the results shown in Table 2, the two factors significantly affected the response measurements either individually (main effects) or jointly (interaction effects). Planting time affected days to 50% flowering, plant height, primary branches/plant, phyllochron index, days to 50% fruiting, fruits/plant, shelf-life of fruit, seeds/fruit and yield/plant individually regardless of spacing; Spacing affected days to 50% flowering, plant height, phyllochron index, days to 50% fruiting, fruits/plant, seeds/fruit and yield/ plant individually regardless of planting time; The interaction effect of planting time and spacing was significant on plant height, days to 50% fruiting, fruits/plant, seeds/fruit and yield/plant.

Table 1 Meteorological data during growing season of yellow lantern chilli from September 2007 to August 2008

| Month | Temperature | | Relative humidity (%) | | Total rainfall | No. of rainy days |
|---|---|---|---|---|---|---|
| | Maximum | Minimum | Morning | Evening | | |
| September 2007 | 31.1 | 24.4 | 95 | 77 | 345.3 | 17 |
| October 2007 | 30.3 | 22.2 | 94 | 73 | 33.8 | 7 |
| November 2007 | 26.9 | 16.5 | 94 | 69 | 30.0 | 4 |
| December 2007 | 24.2 | 11.1 | 97 | 62 | 19.7 | 2 |
| January 2008 | 22.2 | 12.0 | 96 | 70 | 28.1 | 9 |
| February 2008 | 22.7 | 11.1 | 94 | 64 | 7.8 | 7 |
| March 2008 | 26.5 | 16.3 | 92 | 65 | 102.4 | 15 |
| April 2008 | 28.0 | 19.5 | 92 | 69 | 158.2 | 16 |
| May 2008 | 31.0 | 23.5 | 92 | 70 | 241.0 | 22 |
| June 2008 | 32.5 | 25.7 | 97 | 80 | 378.8 | 24 |
| July 2008 | 31.9 | 25.7 | 93 | 78 | 382.4 | 23 |
| August 2008 | 30.7 | 25.3 | 95 | 82 | 311.1 | 27 |

Table 2 Analysis of variance (ANOVA), F values, P values and effect of planting time, spacing and interaction effects (planting time × spacing) on different plant characters on growth and yield characteristics of yellow lantern chilli

| Planting time | Spacing | DFF | PH | PB | PI | DFFR | FPP | SL | SPF | TW | YPP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | S1 | $105.70^{a}$ | $91.27^{b}$ | $3.30^{abc}$ | $13.00^{a}$ | $129.00^{a}$ | $118.00^{c}$ | $6.63^{a}$ | $69.33^{d}$ | $5.08^{a}$ | $0.81^{b}$ |
| P1 | S2 | $102.47^{b}$ | $94.33^{ab}$ | $3.47^{ab}$ | $12.33^{a}$ | $124.00^{b}$ | $126.00^{b}$ | $6.17^{ab}$ | $71.33^{b}$ | $5.10^{a}$ | $0.95^{a}$ |
| P1 | S3 | $100.00^{bc}$ | $96.03^{a}$ | $4.00^{a}$ | $12.00^{a}$ | $122.67^{bc}$ | $136.00^{a}$ | $6.93^{a}$ | $73.67^{a}$ | $5.11^{a}$ | $1.05^{a}$ |
| P2 | S1 | $98.97^{cd}$ | $75.37^{d}$ | $3.13^{bcd}$ | $12.33^{a}$ | $120.67^{c}$ | $92.67^{e}$ | $5.57^{b}$ | $67.33^{e}$ | $5.03^{a}$ | $0.75^{b}$ |
| P2 | S2 | $96.80^{de}$ | $83.53^{c}$ | $3.13^{bcd}$ | $10.33^{b}$ | $118.00^{d}$ | $102.67^{d}$ | $5.50^{b}$ | $69.33^{d}$ | $5.04^{a}$ | $0.79^{b}$ |
| P2 | S3 | $94.07^{e}$ | $85.70^{c}$ | $3.33^{abc}$ | $9.67^{bc}$ | $115.67^{d}$ | $118.33^{c}$ | $5.20^{cb}$ | $70.33^{c}$ | $5.05^{a}$ | $0.83^{b}$ |
| P3 | S1 | $75.50^{f}$ | $62.57^{e}$ | $2.67^{cd}$ | $8.67^{c}$ | $106.33^{e}$ | $60.00^{h}$ | $4.33^{cd}$ | $46.33^{h}$ | $4.92^{a}$ | $0.34^{cd}$ |
| P3 | S2 | $73.33^{fg}$ | $54.60^{f}$ | $2.73^{bcd}$ | $7.00^{de}$ | $96.33^{f}$ | $62.33^{g}$ | $4.40^{cd}$ | $48.67^{g}$ | $4.99^{a}$ | $0.38^{c}$ |
| P3 | S3 | $71.67^{gh}$ | $55.10^{f}$ | $2.90^{bcd}$ | $6.67^{e}$ | $93.33^{g}$ | $69.33^{f}$ | $4.23^{cd}$ | $50.33^{f}$ | $5.01^{a}$ | $0.40^{c}$ |
| P4 | S1 | $74.50^{fg}$ | $54.73^{f}$ | $2.50^{d}$ | $8.33^{cd}$ | $98.33^{f}$ | $50.67^{k}$ | $4.33^{cd}$ | $45.67^{h}$ | $4.64^{a}$ | $0.27^{d}$ |
| P4 | S2 | $69.97^{h}$ | $61.53^{e}$ | $2.73^{bcd}$ | $7.00^{de}$ | $93.33^{g}$ | $57.67^{i}$ | $4.13^{d}$ | $46.10^{h}$ | $4.95^{a}$ | $0.31^{cd}$ |
| P4 | S3 | $69.33^{h}$ | $63.37^{e}$ | $2.83^{bcd}$ | $6.67^{e}$ | $91.33^{g}$ | $53.00^{j}$ | $4.03^{d}$ | $46.33^{h}$ | $4.96^{a}$ | $0.32^{cd}$ |
| Planting time | F value | 2496.55 | 1384.92 | 22.62 | 227.82 | 2768.17 | 1166.77 | 93.89 | 14872.8 | 3.50 | 680.65 |
| | P value | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0001** | **0.0326** | **0.0001** |
| Spacing | F value | 79.73 | 25.24 | 6.00 | 43.72 | 271.06 | 6341.56 | 0.72 | 252.02 | 1.65 | 27.44 |
| | P value | **0.0001** | **0.0001** | 0.0083 | **0.0001** | **0.0001** | **0.0001** | 0.4984 | **0.0001** | 0.2151 | **0.0001** |
| Planting time × spacing | F value | 1.50 | 29.64 | 0.72 | 1.64 | 15.60 | 1034.61 | 1.55 | 19.99 | 0.68 | 4.71 |
| | P value | 0.2242 | **0.0001** | 0.637 | 0.1837 | **0.0001** | **0.0001** | 0.2081 | **0.0001** | 0.6662 | **0.0032** |

*Effect on growth-attributing characteristics*

Critical observation of plant height revealed significantly different results in respect to environmental changes in different dates of planting and at different spacings. It was seen that sowing in September and October produced comparable height, but thereafter environmental temperature come down rendering the plant to be dwarf with little growth. $P_1$ (15 September) recorded the maximum plant height (93.86 cm) which decreased significantly with each successive delay in planting time. It was evident therefore that sowing in September and October had induced normal vegetative growth, whereas the last two dates were unfavourable for normal growth. The trend of present result is in agreement with the finding of Kadam *et al.* (1991) who also observed that conducive climatic conditions, particularly the higher temperature and optimum rainfall resulted in greater photosynthesis and higher mobilization of assimilates. Early flowering and fruiting occurs at the cost of vegetative growth. Negative effect of late planting on vegetative growth of the crop was also observed by Wankhade and Morey (1981). Plant height recorded maximum at wider spacing of $S_3$ (105 cm × 105 cm) compared to closer spacing of 75 cm × 75 cm and 90 cm × 90 cm might have been due to less competition among growing plants. Gradual reduction in plant height in closer spacing was also reported by Singh *et al.* (2004).

*Effect on yield-attributing characters*

Days to 50% flowering and fruiting were maximum during 15 September planting time and in 75 cm × 75 cm spacing which was significantly higher as compared to later dates of planting and wider spacing (Table 2). This may be due to the prevalence of low temperature during the early stage of crop growth and less competition among growing plants in this region (Table 1). Similarly, significantly higher values for number of primary branches/plant and number of fruits/plant were also recorded at 15 September sowing and at wider spacing $S_3$ (105 cm × 105 cm) (Table 2).

For each response, mean values followed by the same letter are not significantly differ at the 5% level. P1, 15 September; P2, 15 October; P3, 15 January; P4, 15 February; S1, 75 cm × 75 cm; S2, 90 cm × 90 cm; S3, 105 cm × 105 cm; days to 50% flowering (DFF), plant height (PH), primary branches/plant (PB), phyllochron index (PI), days to 50% fruiting (DFFR), fruits/plant (FPP), shelf life of fruit (SL), seeds/fruit (SPF), test weight (TW), yield/plant (YPP); Significant effects are shown in bold face.

Phyllochron index was significantly affected by planting time and spacing. The maximum index was registered in plants sown in ($P_1$) September 15 (12.44 days) while the lowest phyllochron (7.33 days) was in February ($P_4$) sowing. The highest phyllochron index (10.55 days) was recorded with plants of highest density 75 cm × 75 cm ($S_1$) while the lowest of phyllochron (8.75 days) with the plants at lowest density 105 cm × 105 cm ($S_3$). The number of fruits/plant was significantly influenced by planting time and spacing. Planting in September 15 ($P_1$) produced the highest number of fruits/plant (126.66) while, minimum number of fruits (53.78) was recorded in $P_4$ (February 15) sowing. A deceased trend was noticed towards later dates of planting. Among spacings, $S_3$ (105 cm × 105 cm) recorded the maximum number of fruits/plant (94.17) while, minimum number of fruits was recorded in $S_1$ (75 cm × 75 cm).

The fruit yield/plant was significantly affected by planting date and spacing. A maximum yield of 0.93kg was recorded in September 15 sowing ($P_1$) and 0.79 kg in P3 (October 15). Sowing the crop in January 15 (P3) or February 15 (P4) produced comparable results (Table 2). Unlike planting time, spacing had significant effect on fruit yield/plant. The maximum yield of 0.650 kg/plant was recorded in $S_3$ (105 cm × 105 cm) and was at par with $S_2$ (0.61 kg) while, the minimum yield of 0.540 kg was recorded in $S_1$ (75 cm × 75 cm).

*Effect on fruit and seed quality*

The highest test weight of seeds was obtained from September sown crop (5.09 g) with wider spacing of 105 cm × 105 cm (5.03 g) and lowest was recorded with February sown crops (4.85 g) with closest spacing of 75 cm × 75 cm (4.91 g). There was no significant difference for shelf-life of fruit at different spacings. The crops which are sown in September showed better performance for shelf-life of fruit. The shelf-life of fruit was longest (6.57 days) in September sown plants and lowest (4.16 days) in February 15 sown plants. There was significant difference in seed viability among the different dates of sowing. The maximum germination percentage was obtained with the seeds harvested from 15 September sown plants and at a spacing of 105 cm × 105 cm and minimum germination percentage was observed in the case of February sown crops and in 75 cm × 75 cm spacing. This may be due to the fact that plants were having longer time for bold seed development at their disposal as compared to later planting time.

*Interaction effect*

The Interaction effect of planting time and spacing were found to be significant. Number of days to flowering (105.70), days to fruiting (129.00), phyllochron index (13.00) were found to be maximum in $P_1S_1$ and minimum number of days to flowering (69.33) days to fruiting (91.33), phyllochron index (6.67) and fruit/plant (53.00) were found in $P_4S_3$. Plant height (96.03cm, 54.60cm), number of primary branches (4.00, 2.50), number of seeds/fruit (73.67, 45.67) and test weight (5.11 g, 4.64 g) were found to be maximum in $P_1S_3$ and minimum was recorded in $P_4S_1$. Longest shelf-life of 6.93 days was found in $P_1S_3$ but minimum of 4.03 days was found in $P_4S_3$. Significant differences between treatment interactions were graphically represented by diffogram using PROC GLM SAS (SAS Institute, Version 9.2) (Fig 1).

In agreement with previous studies conducted in various spacing (Shabnum *et al.* 2004), shows significant effect on gradual reduction in plant height in closer spacing and decreasing trend was also noticed with closer spacing. There was significant effect of planting time and spacing on number of primary branches/plant. September sowing produced highest number of branches and was at par with closer spacing but sowing thereafter exposed the crop to low temperature renders plants to produce significantly lesser branches than those which experienced high temperature. Closely spaced plants had a very little space for their lateral development as compared to widely spaced plants, which have more unit area/plant for its expansion and the competition among plants for nutrient and light is also less and hence more number of branches was recorded at widest plant spacing is in accordance with the results of most of the previous studies (Sharma and Peshin 1994, Patel *et al.* 2002, Hosmani 1982).

Phyllochron serves as a good index of the vegetative growth rate of any plant. The time interval between the production of successive leaves was significantly affected by planting time. February 15 planting produced lowest

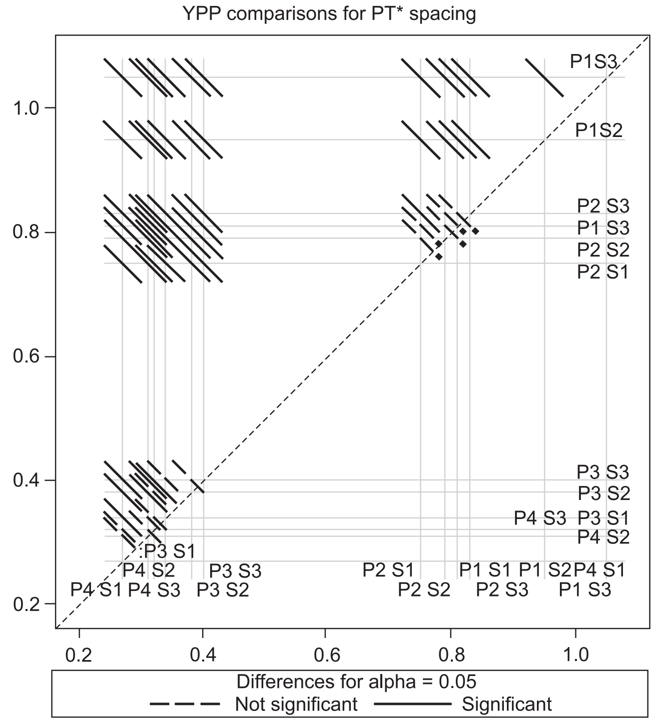


Fig 1 Diffograms showing significant differences between the planting time and spacing. The small lines passing through the squares diagonally represent non-significant or significant difference between the corresponding interactions. YPP, Yield/plant; PT, planting time; P1, 15 September; P2, 15 October; P3, 15 January; P4, 15 February; S1, 75 cm × 75 cm; S2, 90 cm × 90 cm; S3, 105 cm × 105 cm

phyllochron due to high temperature and light intensity at vegetative growth stage in contrast to that in September 15 planting. At wider spacing phyllochron index was lowest and at closer spacing it was highest. This might be due to the fact that large number of plant/unit area provided less light intensity causing longer phyllochron in the closer spacing (Azhakiamanavalan and Madhava Rao 1980). Low light might have resulted a decreased rate of leaf production, resulting in increase in the mean phyllochron which was also recorded by Turner and Hunt (1983). Similarly, Days to 50% flowering and fruiting showed significant response to different spacing. The number of days to 50% flowering was reduced significantly when compare the planting time of September and in closer spacing (75 cm × 75 cm) with later dates of planting and wider spacing which is in accordance with the result of Singh *et al.* (2004).

The highest fruit yield/plant was recorded in September sowing and the lowest in February sowing. This might be due to conducive temperatures at the vegetative and reproductive growth stage. The September sown plants have to pass through a season of low temperature during day and night at the reproductive phase. Significantly higher fruits/plant in wider spacing plants were subjected to less competition for space, nutrients, light and moisture because of low plant densities, so such plants produced more number of fruits, while with closer spacing plants were subjected to more competition for space, nutrients, light and moisture because of high plant densities and thus produced less number of fruit/plant. These results are in close conformity with those of Pundir and Porwal (1999), who reported that wider spacing resulted in more number of fruits/plant. Similar results were also reported by Dimitrov (1960), Narasimaraju (1979), Stoffela and Bryan (1988) who stated that the number of fruits/plant decreased in response to higher plant population.

The crop sown in September and at wider spacing showed better performance for shelf-life of fruit, number of seeds and yield/plant. The higher values with respect to all these characters were obtained on 15 September planting with a spacing ($S_3$) of 105 cm × 105 cm which were also statistically significant over the remaining planting times and spacing. The possible reason for maximum number of seeds/fruit and yield/plant at 15 September planting (P1) may be attributed to the better vegetative growth of the crop. Duczmal and Kaczmarkiewicz (1984) also reported similar results. However, Increase in yield/ha was significantly higher in closer spacing mainly due to increase in plant density. Similar results have been obtained by Gretzmachar (1978). In agreement with our results, non-significant effect of spacing was observed on the shelf life; however, 1000 seeds weight and germinating percentage was significantly higher in wider spacing.

The results of this study indicate that the crop sown in September with a spacing of 105 cm × 105 cm showed better performance for all the parameters studied. The maximum values, with respect to days to flowering, fruiting, phyllochron index, number of seeds/fruit and shelf-life of the fruits were obtained at the closest spacing, ie 75 cm × 75 cm. However, the maximum values with respect to plant height, primary branches, fruit per plant, yield/plant, test weight and germination percentage were obtained at the wider spacing, i e 105 cm × 105 cm. The productivity shown for 15 September sowing is much higher than the ones produced traditionally. The study showed low temperature during growth phase and high rainfall during flowering period were harmful to the plants significantly reducing seed quality and crop productivity. Sowing on earlier dates may not be effective as the crop is sensitive to high rainfall which is prevalent situation in north-eastern part of India.

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