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Effect of different spacing and planting ratio on seed yield and quality parameters of chilli (*Capsicum annuum* L.) hybrid GAVCH 1

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Abstract

An investigation was carried out to find the effect of spacing and planting ratio on seed yield and quality parameters in chilli at Main Vegetable Research Station, Anand and Department of Seed Science and Technology, BACA, AAU, Anand during *Kharif-Rabi* season of the year 2019-20. Plant spacing 90 × 60 cm (S_2) recorded significantly highest seed yield per plant (23.98 g), number of fruits per plant (103.13), germination per cent (95.11 %), seedling root length (4.71 cm), seedling shoot length (4.54 cm), seedling length (9.24 cm), seedling fresh weight (381.3 mg), seedling dry weight (20.53 mg), seedling vigour index I (879.90) and seedling vigour index II (1954.4). Irrespective of plant spacing, among the three planting ratios, planting ratio 2:1 (P_2) recorded significantly higher number of fruits per plant (115.58), weight of fruit (1.018 g), fruit length (9.32 cm) and fruit girth (3.97 cm), number of seeds per fruit (42.16), 1000 seed weight (5.76 g), seed surface area (8.74 sq. mm), seed yield per plant (27.54 g), germination (94.67%), seedling root length (4.61 cm), seedling shoot length (4.45 cm) and seedling length (9.06 cm), seedling fresh weight (384.1 mg), seedling dry weight (20.81 mg), seedling vigour index I (858.92) and seedling vigour index II (1971.80). However, significantly higher fruit to seed ratio (4.77) was found in 3:1 planting ratio (P_3) in seed parent of chilli hybrid.

Key words: Chilli, spacing, planting ratio, hybrid seed yield, seed quality

Introduction

Chilli (*Capsicum annuum* L.) also known as hot pepper belongs to family Solanaceae is one of the most important spice crops in India. Total area cultivated in India is 752 thousand ha with an annual production of around 2149 thousand MT with average productivity of 2.86 MT/ha of dried chilli and major chilli producing states are Andhra Pradesh, Karnataka, Telangana, West Bengal, Maharashtra, Madhya Pradesh, Odisha, Tamil Nadu, Bihar, Chhattisgarh and Rajasthan. Gujarat occupies an area of 11.35 thousand ha with production of 22.07 thousand MT and 1.95 MT/ha productivity (Anon 2018). Chilli is an important source of vitamins A, C and E. Green chilli fruits contain slightly lesser vitamin C than the red ones. Fresh green chilli contains more vitamin C than citrus fruits and fresh red chilli has more vitamin A than carrot (Osuna-García et al. 1998; Marin et al. 2004). Chilli is also a rich source of folic acid. Chilli has pleasant aromatic flavour, pungency and high colouring substances 'Oleoresin'. The pungency in chilli is due to an active principle 'Capsaicin'. Chilli can be grouped into an often-cross pollinated crop where cross pollination is reported up to 63%. Cross-pollination is done both by the insects and wind. Hybrid seed production at present is the most commercial venture in vegetable cultivation as it is giving high income per unit area. The use of hybrid seed in chilli registered an increasing trend because of high yield, uniformity and ultimately profit. Commercial feasibility of chilli hybrid seed production is always profitable as the value of hybrid seed will always be 2-3 times higher than the seed production cost.

Plant spacing is an important factor for determining the growth, yield and quality of vegetable crop. Reducing the intra-row spacing of two pepper varieties from 50 cm to 40 cm significantly decreased plant height, number of fruits and diameter of fruits while total fruit yield per hectare was conversely increased (Bosland and Votava 2000). Therefore, judicious assessment for the spacing is most essential to get sufficient nutrients, light and air for the optimum growth and development of plant. Another basic requirement in hybrid seed production is the optimum planting ratio of seed parent (female) to pollen parent (male) for getting better seed set. Planting

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ratio between female and male parents will decide the amount of hybrid seed produced and is influenced by the vigour of the parents (male and female) and especially the pollen producing ability of the male parent (Venkatesh et al. 2017). Hence, there is need to standardize the optimum female to male crossing ratios in pollination specific to each hybrid combination, based on flowering habits of the seed parent. Therefore, there is a need to standardize the techniques for optimum planting ratio of female to male and plant spacing to increase the hybrid seed yield with better quality.

Materials and Methods

The investigation was undertaken at Main Vegetable Research Station, AAU, Anand and Department of Seed Science and Technology, BACA, AAU, Anand on chilli hybrid cv. GAVCH 1 during *Kharif-Rabi* season of the year 2019-20. The seed material of female and male parent of chilli hybrid cultivar GAVCH 1 was obtained from the Main Vegetable Research Station, AAU, Anand. Seeds of female and male parents were sown separately on raised nursery bed of 15 to 20 cm height from ground, in rows 3 to 5 cm apart with 1.2 m width. It was watered alternately and plant protection measures were taken regularly as required. The bed was kept weed free with manual weeding during the nursery period. Only uniform sized healthy true to type male and female seedlings of chilli hybrid parents were transplanted on 14th October, 2019 in three adjacent parental blocks of the field preferably in the evening time. Seedlings were planted at different spacing and planting ratio according to the field layout. Light irrigation was given immediately after planting to get quick and uniform plant establishment. Two experiments were conducted in this investigation. These experiments were conducted in Randomized Block Design (Factorial) and Completely Randomized Design (Factorial) in field and laboratory respectively with three repetitions. Both the field and laboratory experiment consisted of nine treatment combinations involving three different spacing *viz.,* S_1: 60 × 60 cm, S_2 : 90 × 60 cm and S_3 : 120 × 60 cm and three planting ratios (number of female row per male row) *viz.,* P_1 : one female row per male row, P_2 : two female rows per male row and P_3 : three female rows per male row. An isolation of 200 m has been maintained from other variety of same crop which is planted in separate block as recommended by the Indian Minimum Seed Certification Standard.

Each treatment block was covered with net for control of cross pollination within the treatment blocks. The days to 50 % flowering was determined by recording the number of days following transplanting (DAT) until 50 % of plants in each plot had at least one open flower. The matured fruits were harvested at ripened stage from five tagged plants and number of fruits per plant was recorded and from that five fruits were collected randomly from each replication and further used for measuring fruit weight, fruit length and fruit girth. From five matured fruits seeds of each fruit were extracted by manual method. The number of seeds per fruit was counted by computerised seed counting machine and average number of seeds per fruit were recorded. 1000 seed weight were estimated by using the procedure suggested by ISTA (Anon. 1999). The fruit to seed ratio was expressed as the total fruit weight to its total seed weight. The total seed weight was recorded and later seed weight per plant in grams was computed as average seed yield per plant. The surface area of harvested chilli seeds was measured by INDOSAW seed image analyser and is expressed in units of sq.mm. The germination test was conducted by adopting "Top of Paper (TP)" method. 100 seeds in four replications were taken at random from the seed lot of each treatment and placed uniformly on germination paper in a petri dish at temperature of 25 °C and the relative humidity was maintained at 95 ± 1%. The final count of germination percentage was recorded on 14th day of germination test. Final count was observed on 14th day and ten normal seedlings were selected randomly and their root length and shoot length were measured. To record seedling fresh weight, ten seedlings were counted and weighed while still moist and for seedling dry weight weighed seedlings were placed at 80°C in an oven for 24 h for drying. Thereafter, the seedlings were removed and cooled in desiccator for one hour before weighing on an electronic balance. The seedling vigour index I and II were calculated using the procedure suggested by Abdul-Baki and Anderson (1973) and expressed in whole number. The electrical conductivity of seeds was measured by soaking 1 gram of the harvested seeds of each treatment in three replications in 25 ml of distilled water for 24 hours at room temperature. Later the seeds will be decanted and volume will be made up to 25 ml by adding distilled water. The EC of seed leachate will be measured through electrical conductivity meter and is expressed in dS/m. (Agrawal and Dadlani 1992). The analysis of variance and interpretation of data were done as per procedure given by Steel and Torrie (1960) and Panse and Sukhatme (1967) for Randomized Block Design (Factorial) using software developed by Department of Agriculture statistics, AAU, Anand.

Results and Discussion

Number of fruits per plant, seed yield and seed quality parameters were influenced by the different spacing and

planting ratios. The data on seed yield and quality parameters as influenced by spacing, planting ratios and their interaction effect are presented in Table 1 & 2.

Effect of different spacing on seed yield parameters: The results showed that among the three plant spacing, spacing at 90 × 60 cm (S_2) recorded significantly highest hybrid seed yield per plant (23.98 g) and number of fruits per plant (103.13). However, all the other attributes *viz.,* weight of fruit (0.996 g), fruit length (9.18 cm) and fruit girth (3.89 cm), number of seeds per fruit (41.08), 1000 seed weight (5.58 g) and seed surface area (8.00 sq.mm) were numerically higher at 90 × 60 cm (S_2) plant spacing in seed parent of chilli hybrid. However, numerically higher fruit to seed ratio (4.66) and lower days to 50 % flowering (41.00) were found at 120 × 60 cm (S_3) plant spacing. Plant spacing showed significant differences for seed quality attributes. Plant spacing at 60 × 60 cm (S_1) recorded significantly higher germination per cent (95.11 %), seedling root length (4.71 cm), seedling shoot length (4.54 cm), seedling length (9.24 cm), seedling fresh weight (381.3 mg), seedling dry weight (20.53 mg), seedling vigour index I (879.90) and seedling vigour index II (1954.4) whereas EC (1.10 dS/m) recorded lowest values.

The spacing 90 × 60 cm (S_2) recorded significantly higher number of fruits per plant. It might be due to the availability of more feeding area in terms of sufficient nutrients, moisture and sunlight per plant due to the low plant density in comparison to plants at closer spacing. Similar results were observed by Singh *et al.* (2018) in okra where the maximum number of fruits per plant was recorded at the wider plant spacing. The increase in seed yield per plant in 90 × 60 cm (S_2) spacing may be due to more number of fruits per plant and the wider spacing facilitated the plants to develop properly with less inter and intra plant competition for utilizing the available resources in S_2 as compared to S_1 spacing resulting in higher seed yield per plant. On the other hand, in higher population density reduced yield per plant might be attributed to lesser seed yield per plant. Similar results are also reported by Kamboj and Sharma (2015) in bell pepper and Revanappa et al. (1997) in chilli. The increase in germination per cent and other seed quality parameters at 60 × 60 cm (S_1) spacing might be due to better plants nourishment resulting in proper development of seed. Similar results are also reported by Harish and Birdarpatil (2014) in tomato and Singh et al. (2018) in okra.

Effect of different planting ratio on seed yield parameters: Irrespective of plant spacing, the result indicated that among the three planting ratios, planting ratio 2:1 (two female rows per male row) (P_2) recorded significantly higher number of fruits per plant (115.58), weight of fruit (1.018 g), fruit length (9.32 cm) and fruit girth (3.97 cm), number of seeds per fruit (42.16),

Table 1: Effect of spacing and planting ratio on seed yield attributes in seed parent of chilli hybrid GAVCH 1

Treatment	Character									
	Days to 50 % Flowering	Number of fruits per plant	weight of fruit (g)	Fruit length (cm)	fruit diameter (cm)	Number of seeds per fruit	Fruit to seed ratio	Seed yield per plant	1000 seed weight (g)	Seed surface area (sq.mm)
Plant spacing (S)										
S_1 - 60 × 60 cm	41.11	86.49	0.950	8.94	3.80	37.48	4.64	18.03	5.51	8.00
S_2 - 90 × 60 cm	41.44	103.13	0.996	9.18	3.89	41.08	4.41	23.40	5.58	8.40
S_3 - 120 × 60 cm	41.00	95.71	0.985	9.03	3.84	39.21	4.66	21.13	5.56	8.05
S. Em±	0.41	4.77	0.02	0.13	0.06	1.12	0.12	1.26	0.08	0.27
CD @ 5%	NS	14.31	NS	NS	NS	NS	NS	3.78	NS	NS
Planting ratio (P)										
P_1- 1:1	42.00	79.11	0.910	8.84	3.75	37.32	4.30	15.85	5.37	7.73
P_2- 2:1	40.56	115.58	1.018	9.32	3.97	42.16	4.65	27.54	5.76	8.84
P_3- 3:1	41.00	90.64	1.003	8.98	3.82	38.30	4.77	19.18	5.51	7.97
S. Em±	0.41	4.77	0.02	0.13	0.06	1.12	0.12	1.26	0.08	0.27
CD @ 5%	NS	14.31	0.07	0.38	0.18	3.37	0.36	3.78	0.23	0.81
Interaction (S × P)										
S_1P_1	42.33	77.13	0.864	8.65	3.71	34.85	4.24	14.12	5.29	7.56
S_1P_2	39.67	95.73	1.010	9.34	3.93	41.56	4.79	22.72	5.70	8.50
S_1P_3	41.33	86.60	0.976	8.83	3.76	36.05	4.90	17.25	5.55	7.93
S_2P_1	41.67	84.33	0.935	9.03	3.81	39.64	4.09	18.00	5.36	7.87
S_2P_2	41.00	131.47	1.033	9.33	4.00	43.35	4.61	31.09	5.78	9.25
S_2P_3	41.67	93.60	1.019	9.18	3.85	40.27	4.54	21.12	5.59	8.07
S_3P_1	42.00	75.87	0.932	8.84	3.73	37.46	4.57	15.41	5.47	7.76
S_3P_2	41.00	119.53	1.010	9.30	3.97	41.56	4.55	28.82	5.79	8.48
S_3P_3	40.00	91.73	1.014	8.94	3.84	38.60	4.88	19.16	5.40	7.92
S. Em±	0.71	8.27	0.04	0.22	0.10	1.95	0.21	2.18	0.13	0.47
CD @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV %	2.98	15.06	6.79	4.34	4.58	8.58	7.98	18.12	4.08	9.98

Table 2: Effect of spacing and planting ratio on seed quality attributes of chilli hybrid GAVCH 1

Treatment	Character								
	Germination (%)	Seedling root length (cm)	Seedling shoot length (cm)	Seedling length (cm)	Seedling fresh weight (mg)	Seedling dry weight (mg)	Seedling vigour index I	Seedling vigour index II	Electrical conductivity (dS/m)
Plant spacing (S)									
S_1 - 60 × 60 cm	95.11	7.71	4.54	9.24	381.3	20.53	880	1954	1.10
S_2 - 90 × 60 cm	93.78	4.44	4.15	8.59	372.3	19.76	807	1852	1.13
S_3 - 120 × 60 cm	91.33	4.26	4.11	8.37	344.1	18.56	765	1699	1.14
S. Em±	0.74	0.10	0.10	0.17	9.22	0.39	18.89	40.09	0.03
CD @ 5%	2.19	0.30	0.30	0.50	27.40	1.15	56.13	119.10	NS
Planting ratio (P)									
P_1- 1:1	91.78	4.20	4.06	8.26	346.1	18.52	759	1703	1.19
P_2- 2:1	94.67	4.61	4.45	9.06	384.1	20.81	859	1972	1.02
P_3- 3:1	93.78	4.60	4.28	8.88	367.6	19.51	833	1830	1.16
S. Em±	0.74	0.10	0.10	0.17	9.22	0.39	18.89	40.09	0.03
CD @ 5%	2.19	0.30	0.30	0.50	27.40	1.15	56.13	119.10	0.07
Interaction (S × P)									
S_1P_1	95.33	4.61	4.08	8.70	334.7	19.70	829	1878	1.15
S_1P_2	96.67	4.73	4.97	9.70	409.0	22.20	938	2146	1.01
S_1P_3	93.33	4.78	4.56	9.34	400.3	19.70	872	1839	1.14
S_2P_1	91.33	4.06	4.00	8.06	360.0	20.07	737	1832	1.20
S_2P_2	94.00	4.76	4.30	9.06	391.3	19.87	851	1868	1.01
S_2P_3	96.00	4.50	4.16	8.66	365.7	19.33	831	1855	1.19
S_3P_1	88.67	3.92	4.10	8.02	343.7	15.80	711	1400	1.22
S_3P_2	93.33	4.35	4.09	8.43	352.0	20.37	787	1901	1.03
S_3P_3	92.00	4.53	4.13	8.66	336.7	19.50	797	1796	1.17
S. Em±	1.28	0.17	0.18	0.29	15.98	0.67	32.73	69.44	0.04
CD @ 5%	NS	NS	NS	NS	NS	1.98	NS	206.29	NS
CV %	2.37	6.73	7.15	5.78	7.56	5.89	6.94	6.55	6.58

1000 seed weight (5.76 g), seed surface area (8.74 sq. mm), seed yield per plant (27.54 g) whereas days to 50 % flowering (40.56) was numerically lower. However, significantly higher fruit to seed ratio (4.77) was found in 3:1 planting ratio (P_3) in seed parent of chilli hybrid. Planting ratio 2:1 (P_2) recorded significantly higher germination per cent (94.67 %), seedling root length (4.61 cm), seedling shoot length (4.45 cm) and seedling length (9.06 cm), seedling fresh weight (384.1 mg), seedling dry weight (20.81 mg), seedling vigour index I (858.92) and seedling vigour index II (1971.80) compared to other planting ratio in seed parent of chilli hybrid.

The significantly higher number of fruits per plant, fruit weight, fruit length, fruit girth were recorded in planting ratio 2:1 might be due to sufficient pollen availability for fertilization of sterile population of female parent and the plant population of female line in this ratio was sufficient enough to produce optimum amount of fruit as compared to other ratios. An increase in number of seeds per fruit, 1000 seed weight, seed surface area and hybrid seed yield in 2:1 planting ratio might be attributed to the higher load of pollen on stigma and with a linear increase in quantity of pollen placed on the stigma. Whereas, in 1:1 ratio, due to insufficient amount of pollens might not have completely fertilized all the ovules thus it leads to lower number of seeds per fruit, 1000 seed weight, seed surface area and hybrid seed yield. These results are in conformity with the findings of Thakur *et al.* (2020) in chilli, Khurana *et al.* (2002) in chilli and Korat *et al.* (2018) in brinjal. The increase in germination per cent and other seed quality parameters at 2:1 planting ratio may be due to higher reserve found in the seeds of these ratio. Higher 1000 seed weight was recorded in this ratio which confirms the higher seed quality in 2:1 ratio. These results are in agreement with the findings of Sanjeevkumar et al. (2008) in tomato and Padmini et al. (2011) in tomato. The effect of interaction between spacing and planting ratio (S × P) showed non-significant differences for different spacing and female to male planting ratio except for seedling dry weight and seedling vigour index II. The treatment combination of S_1P_2 recorded higher seedling dry weight (22.20 mg) and seedling vigour index II (2146.0) compared to other treatment combinations.

Conclusion

Seed production of chilli hybrid GAVCH 1can be practiced at 2:1 female to male planting ratio which resulted in higher hybrid seed yield and quality parameters. Plant spacing 90 × 60 cm proved to be more effective for obtaining higher number of fruits per plant, hybrid seed yield and better quality of hybrid seeds. Therefore, 2:1 planting ratio at 90 × 60 cm plant spacing may be used for the higher seed yield and quality of chilli hybrid GAVCH 1 after evaluations over locations and years.

सारांश

मिर्च की फसल में अंतर और रोपण अनुपात का प्रभाव उसकी उपज और गुणवत्ता मानकों पर होने वाले प्रभाव को जानने के उद्देश्य से एक अध्ययन का प्रतिपादक, मुख्य सब्जी अनुसंधान केन्द्र और बीज विज्ञान और प्रौद्योगिकी विभाग, आनन्द (गुजरात) के सहयोग से वर्ष 2019–20 के खरीफ–रबी मौसम के दौरान किया गया। इस अध्ययन के दौरान सांख्यकीय मानकों के अनुरूप, मानक संख्या एस.–2, पौध अंतर 90 x 60 सेमी. ने सर्वाधिक प्रति पौधा फलों की संख्या (103.13), अंकुरण प्रतिशत (95.11 प्रतिषत) अंकुर के जड़ की लंबाई (4.71 सेमी.) अंकुर के प्ररोह की लम्बाई (4.54 सेमी.), अंकुर की लम्बाई (9.24 सेमी.), ताजे अंकुर का वजन (381.3 मिग्रा.), सूखे अंकुर का वजन (20.53 मिग्रा.) अंकुर शक्ति सूचकांक–1 (879.90), अंकुर शक्ति सूचकांक–2 (1954.4) और प्रति पौध बीज की उपज (23.98 ग्राम) हेतु पायी गयी। पौधों की दूरी के निरपेक्ष (3 रोपण अनुपात में से, रोपण अनुपात 2:1 पी.–2) ने सांख्यकीय मानकों पर सर्वाधिक प्रति पौध फलों की संख्या (115.58), फलों का वजन (1.018 ग्राम), फलों की लम्बाई (9.32 सेमी.) और फलों की परिधि (3.97 सेमी.), प्रति फल बीजों की संख्या (42.16), 1000 बीजों का भार (5.76 ग्राम), बीज का सतही क्षेत्रफल (8.74 वर्ग मिमी.), प्रति पौध बीज की उपज (27.54 ग्राम), अंकुरण प्रतिशत (94.67), अंकुर के जड़ की लम्बाई (4.61 वर्ग मिमी.), अंकुर के प्ररोह की लम्बाई (4.45 सेमी.) और अंकुर की लम्बाई (9.06 सेमी.), अंकुर का वजन (384.1 मिग्रा.), सूखे अंकुर का वजन ((20.81 मिग्रा.) अंकुर शक्ति सूचकांक–1 (858.92) और अंकुर शक्ति सूचकांक–2 (1971.80), दर्ज किया गया। हालांकि सांख्यकीय तौर पर फल से बीज का अनुपात (4.77), संकर मिर्च के बीज जनक, रोपण अनुपात 3:1 (पी. –3) में भी काफी अधिक पाया गया।

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