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Effect of Spacing and Nutrient Management on Growth and Yield of King Chilli (*Capsicum chinense* Jacq.) Grown Under Protected Condition

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A B S T R A C T

The experiment entitled "Effect of Spacing and Nutrient Management on Growth and Yield of King Chilli (*Capsicum chinense* Jacq.) grown under Protected Condition" was carried out during the year 2017-2018 under polyhouse at College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. Nine treatments with two factors (spacing and Nutrient) *i.e.* 3 spacing levels S_1 (60 cm x 60 cm), S_2 (60 cm x 75 cm), S_3 (60 cm x 90 cm) and 3 nutrient levels N_1 (90:45:45 kg NPK/ha + 20 t FYM/ha), N_2 (120:60:60 kg NPK/ha +15 t FYM/ha) and N_3 (150:75:75 kg NPK/ha + 10 t FYM/ha) were arranged in factorial RBD design, in order to study the effect of various spacing and nutrient level on growth and yield of king chilli under protected condition. The plants grown in lowest spacing level S_1 obtained the maximum plant height (205.73 cm), highest number of leaves/plant (1125.29), the least number of days to first flowering, 50% flowering first fruiting, 50% fruiting, longest fruit length (73.16 mm) and fruit girth (106.11 mm). While spacing level S_3 resulted in highest number of fruit/plant (175.72), fruit yield/plant (1.35 kg). The nutrient level N_3 resulted in highest plant growth parameters, number of fruits/plant (142.53), fruit yield/plant (1.13 kg). The least number of days required to first flowering and fruiting, 50% flowering and fruiting days to red ripe maturity, maximum fruit length and girth was obtained in S_1N_1. While maximum number of fruits 185.13/plant, fruit yield 1.45 kg/plant were obtained from S_1N_3 *i.e.* 60 cm x 90 cm + 150:75:75 kg NPK/ha + 10 t FYM/ha.

Introduction

King chilli (*Capsicum chinense*) is extensively grown in the north-eastern region of India, predominantly in Assam, Manipur and Nagaland. King chilli is native to Northeast India. It comes under the family solanaceae and genus *Capsicum* and species *chinense* with chromosome number 2n=24.

Capsicum chinense is a domesticated species and share a common ancestral gene pool with *C. frutescens*, *C. annuum* and belongs to *C. annuum* species complex (Peter, 2008). King chilli is a perennial sub-shrub and woody at base. It has strong taproot and numerous horizontal lateral roots. The growth habit of the crop is rigidly upright with 2-3 primary branches which lead to 4-6 numbers of secondary branches, its leaves are medium green to dark green, usually ovate in shape and apex of the leaf is acute. The leaves are crinkled, and it is a unique character that differs king chilli from other chilli species.

Under favourable condition the plant grow from 0.6-2 m in height with leaves ranging from 350-900. Fruit length of *Capsicum chinense* varies from 50-75 mm and girth ranges from 75-116 mm, weighing 6-10 g/fruit. Fruits are light green which changes into red colour when the fruit attain full maturity. The fruit of *Capsicum chinense is* considered as a berry possessing 4-5 locules and bears about 25-60 slightly wrinkled seeds. TSS ranges from 3.3-4.2 °Brix in green fruits and 6.2-7.4 °Brix in mature red king chilli fruits. Ascorbic acid content in fruit ranges from 68-90 mg/100g. The pungent principle is due to presence of capsaicin ($C_{18}H_{27}NO_3$) synthesized in the epidermal cells of placenta of the fruit and possesses anti-inflammatory and antioxidant activities (Roy, 2016). It has also been used conventionally in treating various human ailments since time immemorial by the indigenous people of the Northeast India. Capsaicin has anticancer properties and is effective in treating gastric cancer and lung cancer (Cao *et al.,* 2015). Low quantities of the ripe fruit consumed orally on regular basis helps in curing asthma. Oral consumption of the fruit on low quantity regularly is recommended for those having gastro-intestinal abnormalities. Hot infusions of fruits are applied locally against toothache and muscle pain (Baruah *et al.,* 2014). Light intensity has significant effect on capsaicinoid production in different cultivars of chilli (Jeeatid *et al.,* 2017).

King chilli is grown at 1 m x 1 m plant to plant spacing in protected cultivation in Manipur. Transplanting of king chilli is done at a spacing of 50 cm x 50 cm in open condition in Manipur (Meitei and Devi, 2006). September sowing with 105 cm x 105 cm spacing is recommended for growing of *Capsicum chinense* in North-eastern hill region (Moirangthem *et al.,* 2012). Vigorous plant growth and higher plant height is reported in 60 cm x 60 cm spacing (Barik *et al.,* 2017). KVK, Dimapur, ICAR, Nagaland centre recommended a spacing of 75 cm x 75 cm under organic production. In Arunachal Pradesh, seedlings are planted at 90 cm plant to plant and 100 cm row to row depending on the soil fertility gradient. Plant population required around 12,346 seedlings in 1 ha area. ICAR, Arunachal Pradesh Centre, Basar recommended fertilizer dose of 120:50:50 kg NPK/ha (Singh, 2015). While the recommended dose of fertilizer in Manipur is 120:60:60 kg NPK/ha. Plant spacing had significant influence in almost all the growth and yield components of green pepper except the fruit length. Closer spacing of 30 cm x 40 cm resulted in higher fruit girth, number of leaves and plant height (Edgar *et al.,* 2017). Spacing (45 cm x 30 cm) resulted in maximum plant height (137.46 cm) early flower initiation as well as 50% flowering (52.24 days), yield (82.13 t/ha) and maximum number of leaves (122.29), number of days for fruit set (66.20), least number of days to first harvest (89.06 days), and fruit weight of Capsicum grown in naturally ventilated poly house (Thakur *et al.,* 2018). Spacing had significant effect on growth and yield of chilli. The highest plant height (171.21 cm), maximum number of fruits/plant and yield was recorded in 45 cm x 30 cm spacing (Kumar and Chandra, 2014). Number of branches/plant, number of fruits/plant and yield/plant were increased with the increasing of plant spacing but plant height and number of leaves significantly increase with the decreasing plant spacing (Sharma and Kumar, 2017). Spacing had significant influence on the growth and yield of chilli under greenhouse condition. 50 cm × 50 cm obtained highest yield also chilli performed better under greenhouse condition than in open condition during rainy season (Bai and Sudha, 2015). NPK @ 155:55:45 kg/ha gave the best result in terms of yield and quality. Higher economic return was also obtained in highest fertilizer dose (Dubey, 2017). The highest plant growth

and yield parameters of chilli was observed in 50% more than RDF treatment (100:75:75 kg/ha NPK) in low cost polyhouse (Sharma, 2016). Fruit length, fruit width and fruit weight increased significantly with increasing fertilizer treatment (nitrogen, phosphorus and potash 120:40:60 kg/ha) levels (Bahuguna *et al.,* 2016)

The maximum plant growth of hybrid capsicum (*Capsicum annuum L. var. grossum*) and highest yield/plant was obtained in NPK treatment of 450 kg/ha (Ngupok *et al.,* (2018). plant growth and number of branches and number of fruits/plant increased significantly with increasing fertilizer dose *i.e.* nitrogen @ 75 kg/ha and potassium @ 60 kg/ha resulted in giving maximum plant height, number of branches and fruit yield/plant (Bhuvaneshwari *et al.,* 2013) Application of nitrogen @ 140 kg/ha along with 60 kg P_2O_5/ha produced maximum yield and yield contributing characters of chilli (Islam *et al.,* 2018). Keeping the above in view, the current experiment was undertaken.

Materials and Methods

The experiment was undertaken in a polyhouse at Vegetable Research Farm, College of Horticulture and Forestry, CAU, Pasighat, Arunachal Pradesh (28˚04′45″N, 95˚19′33″E) with three spacing levels and three nutrient levels. Treatment details are given below.

S_1N_1 (60 cm x 60 cm + 90:45:45 kg NPK/ha + 20 t FYM/ha), S_1N_2 (60 cm x 60 cm + 120:60:60 kg NPK/ha +15 t FYM/ha), S_1N_3 (60 cm x 60 cm + 150:75:75 kg NPK/ha + 10 t FYM/ha), S_2N_1 (60 cm x 75 cm + 90:45:45 kg NPK/ha + 20 t FYM/ha), S_2N_2 (60 cm x 75 cm + 120:60:60 kg NPK/ha +15 t FYM/ha), S_2N_3 (60 cm x 75 cm + 150:75:75 kg NPK/ha + 10 t FYM/ha), S_3N_1 (60 cm x 90 cm + 90:45:45 kg NPK/ha + 20 t FYM/ha), S_3N_2 (60 cm x 90 cm + 120:60:60 kg NPK/ha +15 t FYM/ha), S_3N_3 (60 cm x 90 cm + 150:75:75 kg NPK/ha + 10 t FYM/ha).

The seeds of king chilli for the experiment was collected from Ukhrul District, Manipur (25˚10′25″ N, 99˚26′23″ E) and sowing was done on 9th October, 2017 and transplanted on 21st November, 2017. From five tagged plants plant heights and number of leaves were recorded at 30, 60, 90, 120, 150 and 180 days after transplanting. The total number days taken for first flowering, 50% flowering, first fruiting, 50% fruiting and days required to red ripe maturity after transplanting were recorded from five tagged plants of each treatments.

Results and Discussion

The plant heights at different days after transplanting are presented in Table 1(a) and the interaction effects are given in Table 1(b). The spacing level S_1 recorded the highest plant height 205.73 cm and the crops grown with wider spacing S_3 levels had the lowest height. The highest nutrient dose N_3 expressed the highest plant height (201.33 cm) which was obviously due to higher soil nutrient availability for the crop leading to vigorous growth. Interaction of S_1N_3 resulted in highest plant height (217.05 cm) after 180 days of transplanting, which was due to competition among the plants for sunlight and space coupled with higher nutrient dose making its growth vigorous. (Sharma, 2016) and (Ngupok *et al.,* 2018) also reported similar results. The number of leaves/plant at different days of transplanting is presented in Table 1(a) and the interaction effects are given in Table 1(b). Spacing level S_1 produced plants with highest number of leaves (1125.29) and nutrient level N_3 resulted in maximum number of leaves/plant with an average of 1057.92 after 180 days of transplanting and Interactions treatment S_1N_3 recorded the maximum number of leaves/plant (1150.30).

Effect of various spacing and nutrient levels on flowering and fruiting parameters are presented in Table 3(a) and the interaction effects are given in Table 3(b). The minimum number of days required for first flowering, 50% flowering, first fruiting and 50% fruiting and was observed in spacing level S_1 and nutrient level N_1 similar findings was reported by (Thakur *et al.*, 2018), while the maximum number of days for first flowering, 50% flowering, first fruiting and 50% fruiting was observed in highest nutrient level N_3. This may be due to abundant soil nutrient availability for the crop enabling the plant to have more vegetative growth. The interaction of S x N levels had no significant influence on the number of days to first flowering, 50% flowering, first fruiting and 50% fruiting.

Different plant spacing had significant influence on days required to red ripe maturity. The fruit exposed toward sunlight matures by turning into dark green fruit with reddish tinge and later on became fully red, while those fruit at lower side of the branches or not exposed to sunlight matures by changing its colour from green into slightly yellowish tinge and later on turns into red ripe fruit. Among the different spacing level the minimum days required to red ripe maturity was observed in S_1 (134.89) and the maximum number of days to red ripe maturity (145.56) was observed in S_3.

The result conforms to maturity in calendar date as homogeneous environment (optimum light and temperature) are made available on all treatments in protected condition but in open field condition the result can be found otherwise. The interaction of S x N levels had significant influence on the number of days to red ripe maturity. S_1N_1 recorded the minimum days to red ripe maturity (132.0) and maximum (146.7) days after transplanting in S_3N_3 which was due to more vegetative growth in higher spacing and higher nutrient levels and slow initiation of reproductive phase as compared to S_1N_1.

Effect of various spacing and nutrient levels on yield attributing parameters are presented in Table 4(a) and the interaction effects are given in Table 4(b). The highest fruit length and fruit girth was recorded from lowest spacing level S_1 and nutrient level N_3. The result obtained may be because of lesser number of fruits in lower spacing coupled with higher nutrient dose making it possible for the crop to develop fruits with more fruit length and girth while wider spacing level produced more number of the fruits (Edgar *et al.*, 2017) and (Bahuguna *et al.*, 2016) obtained similar findings on increased fruit length as a result of higher nutrient level. The interaction of S x N levels had no significant influence on the fruit length and fruit girth.

Among the different spacing levels, the highest fruit weight was obtained from S_2 (8.69 g) and the lowest (7.84 g) was obtained in spacing level S_3. The findings obtained may be due to lesser number of fruits in spacing level S_2 while spacing level S_3 had more number of fruits resulting in fruits with lesser fruit weight (Thakur *et al.*, 2018) also obtained similar findings on Capsicum when grown in a naturally ventilated polyhouse. Higher nutrient level N_3 resulted in higher average fruit weight of 8.52 g and lowest 8.02 g was obtained from nutrient level N_1. The interaction of S x N levels had significant influence on average fruit weight. S_2N_3 recorded the highest fruit weight (9.04 g) and minimum (7.76 g) in S_3N_1 which may be attributed to more number of fruits in S_3N_1 while S_2N_3 had lesser number of fruits but with higher weight.

The maximum number of fruits/plant (175.72) was obtained from spacing level S_3 and lowest number was obtained from S_1 (109.09 fruits/plant).

Table.1 (a) Effect of various spacing and nutrient levels on plant height (cm)

Treatments	Plant height (cm)					
	Days after Transplanting					
	30	60	90	120	150	180
Spacing levels						
S_1	6.16	28.16	53.03	108.51	154.41	205.73
S_2	5.49	26.41	45.51	94.58	141.31	188.07
S_3	5.38	25.45	45.61	92.08	135.57	186.35
SE(d)±	0.47	1.20	0.94	0.94	1.31	1.22
C.D. 5%	NS	NS	2.02	2.00	2.79	2.61
Nutrient levels						
N_1	5.22	25.47	47.67	93.21	135.91	184.54
N_2	6.05	27.61	49.1	99.32	143.81	194.27
N_3	5.75	26.95	47.39	102.63	151.57	201.33
SE(d) ±	0.47	1.20	0.94	0.94	1.31	1.22
C.D. 5%	NS	NS	NS	2.00	2.79	2.61

Table.1 (b) Interaction effect of S x N levels on plant height (cm) at various days after transplanting

Treatments	Plant height (cm)					
	Days after Transplanting					
S x N levels	30	60	90	120	150	180
S_1N_1	5.96	26.69	52.15	104.78	145.51	192.1
S_1N_2	6.83	30.61	56.08	107.55	154.45	208.03
S_1N_3	5.68	27.19	50.88	113.19	163.29	217.05
S_2N_1	5.01	25.6	44.52	89.02	132.91	182.20
S_2N_2	5.63	25.81	47.58	96.37	141.00	185.23
S_2N_3	5.81	27.82	44.45	98.36	150.00	196.77
S_3N_1	4.69	24.11	46.35	85.85	129.32	179.32
S_3N_2	5.69	26.41	43.65	94.07	135.99	189.55
S_3N_3	5.77	25.84	46.83	96.34	141.39	190.18
SE(d) ±	0.81	2.08	1.64	1.62	2.26	2.11
C.D. 5%	NS	NS	NS	NS	NS	4.52

Table.2 (a) Effect of various spacing and nutrient levels on number of leaves/plant

Treatments	Number of leaves/plant					
	Days after Transplanting					
	30	60	90	120	150	180
Spacing levels						
S_1	11.69	35.36	109.81	351.17	712.37	1125.29
S_2	11.07	30.93	77.46	321.64	662.10	1003.38
S_3	10.49	28.40	80.62	305.23	646.21	981.37
SE(d)±	0.62	1.21	1.49	2.14	2.38	3.65
C.D. 5%	NS	2.58	3.19	4.57	5.09	7.80
Nutrient levels						
N_1	10.40	27.72	86.35	318.34	661.77	1014.12
N_2	11.99	34.99	88.04	324.67	679.00	1037.99
N_3	10.86	31.98	93.50	335.03	679.91	1057.92
SE(d) ±	0.62	1.21	1.49	2.14	2.38	3.65
C.D. 5%	NS	2.58	3.19	4.57	5.09	7.80

Table.2 (b) Interaction effect of S x N levels on number of leaves/plant

Treatments	Number of Leaves/plant					
	Days after Transplanting					
S x N levels	**30**	**60**	**90**	**120**	**150**	**180**
S_1N_1	11.80	31.67	112.37	341.17	703.06	1096.20
S_1N_2	12.78	41.83	113.17	346.11	712.62	1129.37
S_1N_3	10.48	32.57	103.89	366.22	721.44	1150.30
S_2N_1	10.22	28.13	71.46	314.22	650.78	981.87
S_2N_2	11.56	31.57	73.20	322.11	673.44	1005.77
S_2N_3	11.43	33.10	87.71	328.59	662.11	1022.50
S_3N_1	9.18	23.37	75.23	299.62	631.45	964.30
S_3N_2	11.63	31.57	77.74	305.82	650.98	978.83
S_3N_3	10.67	30.27	88.89	310.32	656.20	1000.97
SE(d) ±	1.08	2.09	2.59	3.7	4.12	6.31
C.D. 5%	NS	4.46	5.53	7.91	8.81	NS

Table.3 (a) Effect of various spacing and nutrient levels on flowering and fruiting parameters

Treatments	Days to first flowering	Days to 50% flowering	Days to first fruiting	Days to 50% fruiting	Days to red ripe maturity
Spacing levels					
S_1	84.78	87.89	91.67	95.11	134.89
S_2	87.33	91.33	94.11	98.33	140.44
S_3	88.89	93.11	97.56	100.22	145.56
SE(d) ±	0.44	0.40	0.47	0.36	0.75
C.D. 5%	0.94	0.87	1.00	0.76	1.61
Nutrient levels					
N_1	85.11	88.78	92.78	95.78	137.44
N_2	86.78	90.11	94.22	97.44	140.22
N_3	89.11	93.44	96.33	100.44	143.22
SE(d)±	0.44	0.40	0.47	0.36	0.75
C.D. 5%	0.94	0.87	1.00	0.76	1.61

Table.3 (b) Interaction effect of S x N levels on flowering and fruiting parameters

Treatments	Days to first flowering	Days to 50% flowering	Days to first fruiting	Days to 50% fruiting	Days to red ripe maturity
S x N levels					
S_1N_1	83.0	86.3	90.3	93.3	132.0
S_1N_2	84.7	87.0	91.3	94.7	134.0
S_1N_3	86.7	90.3	93.3	97.3	138.7
S_2N_1	85.7	89.3	92.3	96.3	136.0
S_2N_2	87.0	91.0	94.0	98.3	141.0
S_2N_3	89.3	93.7	96.0	100.3	144.3
S_3N_1	86.7	90.7	95.7	97.7	144.3
S_3N_2	88.7	92.3	97.3	99.3	145.7
S_3N_3	91.3	96.3	99.7	103.7	146.7
SE(d)±	0.76	0.70	0.81	0.62	1.30
C.D. 5%	NS	NS	NS	NS	2.79

Table.4 (a) Effect of various spacing and nutrient levels on yield attributing parameters

Treatments	Fruit length (mm)	Fruit girth (mm)	Average Fruit weight (g)	No. of fruits /plant	Fruit yield/plant (g)
Spacing levels					
S_1	73.16	106.01	8.25	109.09	866.26
S_2	70.13	101.12	8.69	125.9	986.35
S_3	68.49	98.00	7.84	175.72	1349.93
SE(d) ±	0.62	1.16	0.07	2.85	3.13
C.D. 5%	1.33	2.48	0.16	6.10	6.69
Nutrient levels					
N_1	69.32	102.11	8.02	129.49	1006.1
N_2	70.62	100.50	8.23	138.71	1072.96
N_3	71.85	100.50	8.52	142.53	1132.45
SE(d)±	0.62	1.16	0.07	2.85	3.13
C.D. 5%	1.33	NS	0.16	6.10	6.69

Table.4 (b) Interaction effect of S x N levels on yield attributing parameters

Treatments	Fruit length (mm)	Fruit girth (mm)	Average Fruit weight (g)	Number of fruits /plant	Fruit yield/plant (g)
S x N levels					
S_1N_1	71.43	107.29	8.05	101.40	818.01
S_1N_2	73.13	106.11	8.12	110.50	867.39
S_1N_3	74.93	104.65	8.56	115.37	913.36
S_2N_1	69.11	101.04	8.25	123.93	966.67
S_2N_2	69.80	100.93	8.77	126.67	981.34
S_2N_3	71.49	101.42	9.04	127.10	1011.03
S_3N_1	67.42	98.01	7.76	163.07	1233.63
S_3N_2	68.92	94.45	7.81	178.97	1370.13
S_3N_3	69.14	95.44	7.94	185.13	1445.97
SE(d)±	1.08	2.01	0.13	4.94	5.42
C.D. 5%	NS	NS	0.27	NS	11.58

The plants grown in spacing level S_1 resulted in fewer numbers of fruits which may be because of intense competition among the plants for nutrients, sunlight and water resulting in higher plant height but lesser number of fruits/plant. (Edgar *et al.*, 2017) and (Sharma and Kumar, 2015) also obtained similar findings on the number of fruits/plant from different spacing levels. The number of fruits/plant was found highest in nutrient level N_3 with 142.53 fruits/plant and lowest in N_1 with an average of 129.47 fruits/plant. (Islam *et al.*, 2018), (Nyupok *et al.*, 2018), (Bahuguna *et al.*, 2016) also recorded similar results with different nutrient levels. The interaction of S x N levels had no significant influence on number of fruits/plant.

Different spacing and nutrient levels resulted in significant difference in fruit yield/plant (g). Highest yield of 1349.91 g/plant was obtained from nutrient level S_3 as compared to 866.26 g/plant in S_1. The result can be attributed to less competition for nutrient, water and light in spacing level S_3. (Sharma and Kumar, 2015) and (Moirangthem *et al.*, 2012) also reported similar results. Highest yield was obtained from N_3 (1123.45 g/plant) and lowest in nutrient level N_1 (1006.10 g/plant). The findings obtained can be due to higher nutrient accessibility to the crop at higher nutrient level, ultimately resulting in higher yield. (Nyupok *et al.*, 2018), (Bahuguna *et al.*, 2016) and (Bhuvaneshwari *et al.*, 2013) have also obtained similar results with different nutrient levels.

Significant difference due to interaction of S x N levels was recorded on fruit yield/plant (g). S_3N_3 recorded the highest yield/plant (1445.97 g) and lowest yield (818.01 g/plant) was obtained in S_1N_1.The reason may be attributed to higher fruit yield/plant, when the plants are grown in wider spacing levels and higher nutrient dose despite the higher average fruit weight in S_1N_1.

It can be concluded that, when king chilli (*Capsicum chinense*) was grown at 60 cm x 60 cm spacing (S_1) the growth parameters such as plant height and number of leaves/plant were found highest as compared to S_2 (60 cm x 75 cm) and S_3 (60 cm x 90 cm). The least number of days required for first flowering and fruiting to occur was obtained in S_1 and N_1 which indicate that early harvest of the fruit can be obtained by growing the crop at closer spacing with lower nutrient dose. Also the longest fruit length and girth was obtained from the plants grown at spacing level S_1 (60 cm x 60 cm). However, more number of fruits/plant, yield/plant (g) was obtained from spacing level S_3 (60 cm x 90 cm) and nutrient level N_3 (150:75:75 kg NPK/ha + 10 t FYM/ha) when king chilli was grown under protected cultivation in Pasighat, Arunachal Pradesh.

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