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Effect of different levels of nitrogen and spacing on growth and yield of common onion (*Allium cepa* L.) cv. Prema 178 under Manipur condition

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Abstract
The present experiment on "Effect of different levels of Nitrogen and Spacing on Growth and Yield of Common Onion (*Allium cepa* L.) cv. Prema 178 under Manipur Condition" was carried out during the *rabi* season of 2020-21 at the Horticultural Experimental field, Department of Horticulture, College of Agriculture, Central Agricultural University, Imphal from October 2020 to April 2021. The experiment was conducted in Factorial Randomized Block Design (FRBD) constituting four levels of nitrogen (0 kg N/ha or control, 50 kg N/ha, 100 kg N/ha and 150 kg N/ha) and three levels of spacing (10 cm × 10 cm, 15 cm × 10 cm and 20 cm × 10 cm) with 12 treatment combinations replicated thrice. The physio-chemical status of the soil was slightly acidic, clay in texture with medium in available nitrogen, phosphorus, potassium and organic carbon. From the current study, it was observed that application of higher nitrogen dose of 150 kg N/ha (N_4) produced maximum plant height, number of leaves per plant, neck girth, fresh weight of bulb, polar diameter, equatorial diameter and bulb yield. Parameters like plant height and bulb yield were maximum in closer spacing of 10 cm x 10 cm (S_1), while wider spacing of 20 cm x 10 cm (S_3) produced maximum number of leaves per plant, neck girth, fresh weight of bulb, polar and equatorial diameter. In interaction of nitrogen and spacing, treatment combination T_{10}-N_4S_1 (150 kg N/ha and 10 cm × 10 cm spacing) recorded highest plant height and bulb yield; and maximum number of leaves per plant, neck girth, fresh weight of bulb, polar and equatorial diameter were observed at T_{12}-N_4S_3 (150 kg N/ha and 20 cm × 10 cm spacing). In short, it can be concluded that a combination of maximum nitrogen dose of 150 kg N/ha and closer spacing 10 cm × 10 cm produces plants with better growth and higher yield.

Keywords: Nitrogen, spacing, growth, yield, common onion

1. Introduction
Onion (*Allium cepa* L.) is a cool season bulbous biennial herb belonging to the family Alliaceae and grown under a wide range of climatic conditions like tropical and subtropical. It depends on temperature and day length for development of bulbs in which temperature is important for seed production, whereas day length is important for bulb formation (Thamburaj and Singh, 2001) [47]. Onion is an important culinary item in the kitchen where it is used as a vegetable and as a condiment for seasoning foods. The pungency of onion is due to "allyl propyl disulphide", a volatile oil which is formed by enzymatic reaction only when tissues are damaged and it is higher just before neck fall. Red colour onions are more pungent compared to brown, yellow and white onions. (Dhaliwal, 2017) [10].
Onion bulb is rich in carbohydrates, protein, fibre, vitamins and other minerals (Pareek *et al*., 2017) [38], and it has been reported to have many medicinal properties (Sampath Kumar *et al.*, 2010) [40]. Even though onion has health benefits as well as major contribution in the Indian economy, its production and productivity are lesser in India compared to other countries of the world. There is lesser adoption of improved technology and poor agronomic management practices thereby slowing down the yield potential of the crop.
Being a shallow rooted crop, onion requires proper management of fertilizers to absorb the immobile nutrients of the soil (Brewster, 1994) [7]. Nitrogen plays an important role for optimum yield in onion and is required for increasing the size of bulb and yield in onion. Increasing nitrogen application rates significantly increases plant height, number of green leaves per plant, fresh weight of bulb and bulb yield of onion. (Nasreen *et al*., 2007; Al-Fraihat, 2009) [34, 2]. Determining an optimum plant spacing for each agro-ecological region also helps to increase the bulb production and productivity of onion (Gupta *et al*., 1994) [17].

Growth, yield components and yield of onion are significantly affected by plant spacing (Islam *et al.*, 2015) [22]. Furthermore, the combined treatment of optimum levels of nitrogen and spacing increased the growth and bulb yield of onion (Singh *et al.*, 2017) [44]. Therefore, optimizing proper nitrogen levels and spacing can be adopted for better growth of the plant and to produce higher yield of onion bulbs.

2. Materials and Methods

The experiment was conducted during *rabi* season of 2020-21 at the Horticultural Experimental field, Department of Horticulture, College of Agriculture, Central Agricultural University, Imphal, located at an altitude of 774 m above mean sea level with a latitude of 24.45^{0}N and a longitude of 93.54^{0}E. The experiment was laid out in Factorial Randomized Block Design (FRBD) constituting four levels of nitrogen (0 kg N/ha or control, 50 kg N/ha, 100 kg N/ha and 150 kg N/ha) and three levels of spacing (10 cm × 10 cm, 15 cm × 10 cm and 20 cm × 10 cm) with 12 treatment combinations replicated thrice. The physio-chemical status of the soil was slightly acidic, clay in texture with medium in available nitrogen, phosphorus, potassium and organic carbon. Data on plant height (cm), number of leaves per plant, neck girth (cm), fresh weight of bulb (g), polar diameter of bulb (mm), equatorial diameter of bulb (mm) and bulb yield (t/ha) were recorded and statistically analyzed with the significance of the test (F-test) and critical difference (C.D.) for each treatment read at 0.05 probabilities (Sunderaraj *et al.*, 1972) [45].

3. Results and Discussion

3.1. Plant height (cm)

In the current study, nitrogen had a significant influence on plant height and the maximum plant height was recorded in higher nitrogen dose N_4 – 150 kg N/ha (29.39 cm). The increase in plant height at higher nitrogen dose might be attributed to more availability of nitrogen which enhanced vegetative growth through cell division and cell elongation. Similar results of maximum plant height in higher nitrogen dose were observed by Islam *et al.* (1999) [21], Karsanbhai (2003) [24], Meena *et al.* (2007) [31], Aliyu *et al.* (2008) [3], Godara and Mehta (2013) [16], Thirupathi *et al.* (2014) [48], Gessesew *et al.* (2015) [15], Singh *et al.* (2017) [44] and Gererufael *et al.* (2020) [14].

Different levels of spacing had a significant effect on plant height and maximum plant height was recorded at closer plant spacing S_1 – 10 cm x 10 cm (30.11 cm). The reason for tallest plants at closer plant spacing might be because of competition for sunlight in high planting density, causing the plants to grow taller to exploit the maximum sunlight. The findings were similar to that of Anal (2005) [4], Yadav *et al.* (2013) [50], Misra (2010) [32], Harris *et al.* (2016) [19], Palte (2017) [37] and Fakhar *et al.* (2019) [12].

Plant height was significantly affected by the interaction of nitrogen and spacing; and treatment combination T_{10}-N_4S_1 (150 kg N/ha and 10 cm × 10 cm spacing) recorded the maximum plant height (32.33 cm), while minimum plant height (25.42 cm) was recorded at T_3-N_1S_3 (control-0 kg N/ha and 20 cm × 10 cm spacing). Application of higher nitrogen dose resulting in better vegetative growth and higher competition among the closer spaced plants might be the reason for maximum plant height in this treatment combination. The result was in accordance with the findings of Harris *et al.* (2016) [19].

3.2. Number of leaves per plant

From the analysis, it was observed that plants treated with higher nitrogen dose N_4 – 150 kg N/ha exhibited a significantly higher number of leaves per plant (6.72). The reason might be attributed to more availability of nitrogen which enhances vegetative growth and production of new shoots, thereby increasing the leaf number. The observation was parallel to the findings of Islam *et al.* (1999) [21], Thirupathi *et al.* (2014) [48], Tekle (2015) [46], Nawaz *et al.* (2017) [35] and Singh *et al.* (2017) [44].

Spacing was found to have significant effect on the number of leaves per plant, and planting at a wider spacing S_3 – 20 cm × 10 cm (6.57) produced the maximum number of leaves per plant compared to other spacing levels. Higher number of leaves per plant at wider spacing might be because of less competition for nutrients, sunlight and water among wider spaced plants since the individual plants received more nutrients, sunlight and soil water as compared to closer spaced plants. Similar findings were reported by Islam *et al.* (1999) [21], Kumar *et al.* (2001) [28], Karsanbhai (2003) [24], Anal (2005) [4], Dawar *et al.* (2007) [8], Aliyu *et al.* (2008) [3], Misra *et al.* (2014) [33], Tekle (2015) [46], Ngullie and Biswas (2017) [36] and Singh *et al.* (2017) [44].

Among the interaction of nitrogen and spacing, treatment combination T_{12}-N_4S_3 (150 kg N/ha and 20 cm × 10 cm spacing) recorded significantly higher number of leaves per plant (6.75). The reason could be due to more availability of nitrogen in higher dose which enhanced vegetative growth, thereby increasing the leaf number, and less competition for nutrients, sunlight and water among wider spaced plants. The result was in accordance with the findings of Islam *et al.* (1999) [21], Aliyu *et al.* (2008) [3], Kumar *et al.* (2013) [27], Gessesew *et al.* (2015) [15] and Tekle (2015) [46] who also reported maximum number of leaves per plant in higher nitrogen dose and wider spacing. The lowest number of leaves (5.47) was recorded in T_1-N_1S_1 (control-0 kg N/ha and 10 cm × 10 cm spacing).

3.3. Neck girth (mm)

The neck girth in common onion was significantly affected by nitrogen and the maximum neck girth (9.32 mm) was recorded in higher nitrogen dose N_4 – 150 kg N/ha compared to other nitrogen doses. The reason might be due higher nitrogen enhancing vegetative growth and accelerating the photosynthesis in plants, leading to translocation of photosynthates in storage organ of onion (bulb) resulting in an increased neck girth. The result was in conformity with the findings of Hiray (2001) [20], Farooqui *et al.* (2009) [13], Thirupathi *et al.* (2014) [48], Biru (2015) [6] and Kumari and Kumar (2017) [29].

From the results, it was evident that spacing had a significant effect on the neck and maximum neck girth was observed at wider spacing S_3 – 20 cm × 10 cm (9.40 mm). Maximum neck girth at wider spacing might be due to availability of space between the plants and the individual plants received more nutrients, sunlight and soil water, thereby expanding their bulbs and thus increasing the neck girth. The result was in agreement with the findings of Hiray (2001) [20], Kumar *et al.* (2001) [28], Sikder *et al.* (2008) [41], Thirupathi *et al.* (2014) [48] and Biru (2015) [6].

In interaction of nitrogen and spacing, treatment combination

T_{12}-N_4S_3 (150 kg N/ha and 20 cm × 10 cm spacing) recorded significantly higher neck girth (9.55 mm), while the lowest neck girth (8.07 mm) was recorded in T_1-N_1S_1 (control-0 kg N/ha and 10 cm × 10 cm spacing). The reason for maximum neck girth in treatment combination of 150 kg N/ha and 20 cm × 10 cm spacing could be attributed to higher nitrogen enhancing vegetative growth, photosynthetic rate and translocation of photosynthates in onion bulb, and availability of more nutrients, sunlight and soil water at wider spacing, thereby expanding their bulbs and thus increasing the neck girth. Similar findings were reported by Hiray (2001) [20], Kumar *et al.* (2013) [27] and Singh *et al.* (2018) [43].

Table 1: Effect of nitrogen and spacing on growth parameters of common onion

Treatments		Plant height (cm)	Number of leaves per plant	Neck girth (cm)
0 kg N/ha (control)	N_1	26.23	5.80	8.51
50 kg N/ha	N_2	27.25	5.96	8.64
100 kg N/ha	N_3	28.78	6.44	9.00
150 kg N/ha	N_4	29.39	6.72	9.32
	S.Em(±)	0.24	0.09	0.08
	C.D. (0.05)	0.71	0.26	0.22
10cm×10cm	S_1	30.11	6.03	8.51
15cm×10cm	S_2	27.15	6.08	8.70
20cm×10cm	S_3	26.47	6.57	9.40
	S.Em(±)	0.21	0.08	0.07
	C.D. (0.05)	0.62	0.23	0.19
T_1	N_1S_1	27.66	5.47	8.07
T_2	N_1S_2	25.60	5.53	8.22
T_3	N_1S_3	25.42	6.40	9.25
T_4	N_2S_1	28.91	5.80	8.20
T_5	N_2S_2	26.86	5.60	8.38
T_6	N_2S_3	25.96	6.47	9.33
T_7	N_3S_1	31.53	6.20	8.74
T_8	N_3S_2	27.76	6.47	8.81
T_9	N_3S_3	27.04	6.65	9.45
T_{10}	N_4S_1	32.33	6.67	9.04
T_{11}	N_4S_2	28.39	6.73	9.38
T_{12}	N_4S_3	27.46	6.75	9.55
	S.Em(±)	0.42	0.15	0.13
	C.D. (0.05)	1.24	0.45	0.39
Interaction effect (N x S)		1.24	0.45	0.39

S.Em (±): standard error of mean; C.D (0.05): critical difference at 5% level of significance; NS: non-significant

3.4. Fresh weight of bulb (g)

Statistical analysis of the data revealed that fresh weight of bulb showed significant response to nitrogen, spacing and their interaction. According to the data, highest fresh weight of bulb was recorded in highest nitrogen dose N_4 – 150 kg N/ha (58.97 g) and wider spacing S_3 – 20 cm × 10 cm (54.11 g). The reason for maximum fresh weight of bulb in highest nitrogen dose might be because increased nitrogen supply in plants improved vegetative growth and accelerated greater carbohydrate synthesis, causing carbohydrates to be translocated from leaves to storage organs or bulbs, resulting in increased bulb fresh weight. Similar findings were reported by Karsanbhai (2003) [24], Dilruba *et al.* (2006) [11], Farooqui *et al.* (2009) [13], Biru (2015) [6], Gessesew *et al.* (2015) [15], Nawaz *et al.* (2017) [35] and Singh *et al.* (2018) [43]. Likewise, the explanation for the maximum fresh bulb weight at wider spacing could be that plants grown at the highest spacing received more soil water, nutrients, and solar radiation under less interplant competition, promoting vigorous growth and resulting in larger-sized bulbs and increased bulb weight. The result was at par with the findings of Islam *et al.* (1999) [21], Kumar *et al.* (2001) [28], Khan *et al.* (2002) [25], Sikder *et al.* (2008) [41], Misra *et al.* (2014) [33], Khayer (2017) [26] and Singh *et al.* (2017) [44].

Interaction of nitrogen and spacing significantly influenced fresh weight of bulb and the maximum fresh weight of bulb (61.35 g) was recorded in treatment combination T_{12}-N_4S_3 (150 kg N/ha and 20 cm × 10 cm spacing), while minimum fresh weight of bulb (40.69 g) was recorded in T_1-N_1S_1 (control-0 kg N/ha and 10 cm × 10 cm spacing). The maximum fresh weight of bulb in treatment combination of 150 kg N/ha and 20 cm × 10 cm could be explained as higher nitrogen supply in plants and wider plant spacing enhanced vegetative growth and accelerated carbohydrate synthesis since individual plant received more soil water, nutrients, and solar radiation under less interplant competition, causing carbohydrates to be translocated from leaves to storage organs or bulbs, thereby increasing fresh bulb weight. Aliyu *et al.* (2008) [3], Kumar *et al.* (2013) [27] and Singh *et al.* (2017) [44] reported similar results of maximum fresh weight of bulb in higher nitrogen dose and wider plant spacing.

3.5. Polar diameter of bulb (mm)

According to the data, nitrogen had a significant influence on polar diameter of onion bulb and the maximum polar diameter of the onion bulb was recorded at harvest in higher nitrogen dose N_4 – 150 kg N/ha (53.83 mm). The reason for maximum polar diameter in higher nitrogen dose might be attributed to increased nitrogen availability, resulting in improved vegetative growth and greater carbohydrate synthesis, leading to translocation of carbohydrates to bulbs, thus increasing the bulb length. This result was supported by the findings of Gessesew *et al.* (2015) [15] and Singh *et al.* (2018) [43].

Among spacing levels, the maximum polar diameter of onion bulb was recorded at harvest in wider spacing S_3 – 20 cm × 10 cm (50.65 mm), and it was found that spacing had a significant influence on the polar diameter of common onion. The reason for maximum polar diameter of onion bulb at wider spacing could be explained by the fact that plants grown at the highest spacing received more soil water, nutrients, and solar radiation under reduced interplant competition, promoting better foliage growth and expanding the bulbs, thus resulting in higher bulb length. Islam *et al.* (1999) [21], Kumar *et al.* (2001) [28], Misra *et al.* (2014) [33], Gessesew *et al.* (2015) [15], Khayer (2017) [26], Singh *et al.* (2018) [43], Maurya *et al.* (2019) [30] and Fakhar *et al.* (2019) [12] also made similar report of maximum polar diameter of onion bulb at wider spacing.

Although there was an individual effect of nitrogen and spacing on polar diameter of onion bulb, their interaction showed no significant effect. The maximum polar diameter (54.80 mm) was recorded at harvest in treatment combination T_{12}-N_4S_3 (150 kg N/ha and 20 cm × 10 cm spacing), while minimum polar diameter of bulb (45.00 mm) was observed in T_1-N_1S_1 (control-0 kg N/ha and 10 cm × 10 cm spacing). The result was parallel to the findings of Kumar *et al.* (2013) [27] and Singh *et al.* (2018) [43].

3.6. Equatorial diameter of bulb (mm)

From the analysis, it was observed that nitrogen had a significant influence on onion bulb equatorial diameter, and the highest equatorial diameter was recorded in higher nitrogen dose N_4 – 150 kg N/ha (52.43 mm) at harvest. The reason could be due to increased nitrogen supply which might have boosted vegetative growth and increased carbohydrate synthesis, causing carbohydrate translocation to bulbs, resulting in larger bulbs. The result was in accordance with the findings Harris *et al.* (2016) [19], Nawaz *et al.* (2017) [35], Singh *et al.* (2017) [44] and Singh *et al.* (2018) [43].

Spacing had a significant effect on equatorial diameter of common onion bulb and the maximum equatorial diameter of the bulb was observed at harvest in wider spacing S_3 – 20 cm × 10 cm (50.25 mm). This might be because plants grown at the highest spacing received more soil water, nutrients, and solar radiation under less interplant competition, enabling greater foliage growth and thereby expanding their bulbs, thus consequently resulting in larger bulb diameter. The result was similar to the conclusions of Islam *et al.* (1999) [21], Kumar *et al.* (2001) [28], Sikder *et al.* (2008) [41], Misra *et al.* (2014) [33], Thirupathi *et al.* (2014) [48], Islam *et al.* (2015) [22], Khayer (2017) [26] and Singh *et al.* (2017) [44].

There was no significant influence of the interaction of nitrogen and spacing on the equatorial diameter of onion bulbs. However, the treatment combination T_{12}-N_4S_3 (150 kg N/ha and 20 cm × 10 cm spacing) exhibited the maximum equatorial diameter (53.28 mm) at harvest, while minimum equatorial diameter of bulb (44.93 mm) was recorded in T_1-N_1S_1 (control-0 kg N/ha and 10 cm × 10 cm spacing). The result was similar to the observations of Kumar *et al.* (2013) [27], Tekle (2015) [46] and Singh *et al.* (2017) [44].

3.7. Bulb yield (t/ha)

Data analysis revealed that bulb yield of common onion had a significant response to nitrogen, spacing and their interaction. The maximum bulb yield was obtained in higher nitrogen dose N_4 – 150 kg N/ha (42.13 t/ha) and closer spacing S_1 – 10 cm × 10 cm (47.57 t/ha). The reason for maximum yield in higher nitrogen dose might be due to increased nitrogen supply improving the vegetative growth and accelerating the photosynthesis and the translocation of photosynthates in storage organs or bulbs, resulting in an increased bulb diameter and weight of the bulb, and hence a higher bulb yield. The result was similar to the findings of Reddy *et al.* (2000) [39], Hiray (2001) [20], Karsanbhai (2003) [24], Dilruba *et al.* (2006) [11], Meena *et al.* (2007) [31], Al-Fraihat (2009) [2], Farooqui *et al.* (2009) [13], Thirupathi *et al.* (2014) [48], Nawaz *et al.* (2017) [35], Singh *et al.* (2017) [44], Singh *et al.* (2018) [43] and Kadari *et al.* (2019) [23]. Similarly, the reason for maximum bulb yield in closer spacing might be attributed to more number of plants (bulbs) per unit area in closer plant spacing. The result was similar to the observations of Badaruddin and Haque (1977) [5], Islam *et al.* (1999) [21], Gupta and Sharma (2000) [18], Ushakumari *et al.* (2001) [49], Khan *et al.* (2002) [25], Karsanbhai (2003) [24], Anal (2005) [4], Dawar *et al.* (2007) [8], Sikder *et al.* (2008) [41], Dhakulkar *et al.* (2009) [9], Ademe *et al.* (2012) [1], Godara and Mehta (2013) [16], Misra *et al.* (2014) [33], Thirupathi *et al.* (2014) [48], Islam *et al.* (2015) [22], Ngullie and Biswas (2017) [36] and Kadari *et al.* (2019) [23].

In interaction of nitrogen and spacing, treatment combination T_{10}-N_4S_1 (150 kg N/ha and 10 cm × 10 cm spacing) produced the highest bulb yield in common onion (56.05 t/ha). The reason for maximum bulb yield in this treatment combination could be due to increased nitrogen supply improving the vegetative growth and accelerating the photosynthesis in closer spaced plants which have more number of plants (bulbs) per unit area, thus resulting in a higher bulb yield. This observation was in agreement with the findings of Singh *et al.* (2017) [44] in onion and Singh and Singh (2010) [42] in garlic. The lowest bulb yield (22.77 t/ha) was recorded in T_3-N_1S_3 (control-0 kg N/ha and 20 cm × 10 cm spacing).

Table 2: Effect of nitrogen and spacing on yield and yield contributing characters of common onion at harvest

Treatments		Fresh weight of bulb (g)	Polar diameter (mm)	Equatorial diameter (mm)	Bulb yield (t/ha)
0 kg N/ha (control)	N_1	43.03	46.01	45.38	30.68
50 kg N/ha	N_2	47.72	47.61	47.79	33.84
100 kg N/ha	N_3	53.48	50.95	50.54	37.93
150 kg N/ha	N_4	58.97	53.83	52.43	42.13
	S.Em(±)	0.33	0.36	0.25	0.25
	C.D. (0.05)	0.97	1.04	0.73	0.75
10cm×10cm	S_1	47.57	48.49	48.36	47.57
15cm×10cm	S_2	50.73	49.66	48.51	33.82
20cm×10cm	S_3	54.11	50.65	50.25	27.05
	S.Em(±)	0.29	0.31	0.21	0.22
	C.D. (0.05)	0.84	0.90	0.63	0.65

T_1	N_1S_1	40.69	45.00	44.93	40.69
T_2	N_1S_2	42.86	46.17	45.33	28.58
T_3	N_1S_3	45.55	46.85	45.87	22.77
T_4	N_2S_1	44.12	46.27	46.98	44.12
T_5	N_2S_2	47.34	48.03	47.19	31.56
T_6	N_2S_3	51.68	48.52	49.21	25.84
T_7	N_3S_1	49.40	49.63	49.47	49.40
T_8	N_3S_2	53.18	50.80	49.53	35.45
T_9	N_3S_3	57.85	52.42	52.63	28.92
T_{10}	N_4S_1	56.05	53.06	52.05	56.05
T_{11}	N_4S_2	59.51	53.63	51.97	39.68
T_{12}	N_4S_3	61.35	54.80	53.28	30.68
	S.Em(±)	0.58	0.62	0.43	0.44
	C.D. (0.05)	1.69	1.81	1.26	1.29
Interaction effect (N x S)		1.69	NS	NS	1.29

S.Em (±): standard error of mean; C.D (0.05): critical difference at 5% level of significance; NS: non-significant

4. Conclusion

From the current study, it can be concluded that application of higher nitrogen dose of 150 kg N/ha (N_4) produced maximum growth and yield parameters. Closer spacing of 10 cm x 10 cm (S_1) resulted in maximum plant height and bulb yield, while wider spacing of 20 cm x 10 cm (S_3) produced maximum number of leaves per plant, neck girth, fresh weight of bulb, polar and equatorial diameter.

An interaction of higher nitrogen dose of 150 kg N/ha and closer spacing of 10 cm x 10 cm (T_{10}-N_4S_1) recorded highest plant height and bulb yield; while maximum number of leaves per plant, neck girth, fresh weight of bulb, polar and equatorial diameter were observed in interaction of higher nitrogen dose of 150 kg N/ha and wider spacing of 20 cm x 10 cm (T_{12}-N_4S_3). In short, it can be concluded that a combination of maximum nitrogen dose of 150 kg N/ha and closer spacing 10 cm × 10 cm produces plants with better growth and higher yield.

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