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Standardization of sowing date and covering material under low tunnels for early harvest of longmelon

AK Verma*, BR Choudhary, DK Samadia and D Singh

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Abstract

The field experiment was conducted at research farm of ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan during 2017-18 and 2018-19 to standardize the date of sowing and covering material. Under different dates of sowing and covering material long melon took 41-50, 44-55 and 50-62 days after sowing for first male flower, first female flower and first harvest at marketable stage, respectively. The treatment T3 (20th December with polythene sheet) recorded the highest number of days for last harvest followed by T4 (20th December with non-woven cloth), while the least number of days for last harvest was recorded in T9 (10th February under open condition). The crop raised under tunnel (T2-10th December with non-woven cloth) attained the harvestable maturity on 9th February in comparison to open filed sowing (T9) came in harvesting on 2nd April which was 49 days later than the tunnel. The sowing on second date of sowing with polythene covering (T3-20th December with polythene sheet) recorded the highest yield and fruiting duration followed by the sowing on same date with non-woven cloth covering (T4-20th December with non-woven cloth). An advancement of 24-50 days was recorded with first two dates of sowing as compared to normal season which fetches higher price in the market.

Keywords: Covering material, early harvest, longmelon, low tunnels, sowing date, yield

Introduction

Indian arid zone is one of the largest subtropical deserts of the world of which 20% is arid and rest is semi-arid. Hot arid zone is spread over 31.7 million ha area and mainly confined in the states of Rajasthan, Gujarat, Andhra Pradesh, Punjab and Haryana. The major part of hot arid region of the country lies in western Rajasthan (19.62 million ha) followed by North-western Gujarat (2.16 million ha). It is characterized by high aridity index, extremes of temperature, low and variable precipitation, very high wind velocity and dust storm, high soil pH, high infiltration rate, very limited availability of groundwater and saline ground irrigation water (More 2010). Despite the several constraints, the hot arid region of India offers very good opportunity for cultivation of cucurbits like, watermelon, muskmelon, longmelon, bottle gourd, ridge gourd, tinda, summer squash, cucumber, etc. because it has warm sunny days and cool nights which is favorable for cucurbits. But, under such harsh climatic conditions cultivation of vegetable crops in open condition results in very low and poor-quality yield which fetches less return per unit area. By creating the suitable micro-climate for plant growth round the year cultivation of vegetables can be done under adverse climatic conditions. It is possible through protected cultivation which has tremendous scope in peri-urban areas of the country (Singh and Sirohi 2006). It is the best way to increase the productivity and quality of vegetables, especially cucurbits.

Production of cucurbits in India is mainly restricted to open field cultivation and most of the varieties grown are open pollinated in nature and are mainly grown in two seasons, as a summer and rainy season crop in northern plains of the country. The crops grown under open condition are always affected by several diseases and pests, resulting in low productivity and poor-quality produce. The sowing of cucurbits is generally done in second fortnight of February for summer season crop. The flowering stage of February sown crop coincides with the prevailing high temperature and hot wind (Loo). These climatic conditions lead to high transpiration which results in wilting of plants. Desert soil being sandy in texture gets warm soon which cause burning of pistillate flowers touching the ground. The population of pollinators (honey bee) is decreased considerably during summer season which affect yield. High temperature favours to induce more number of male flowers and

ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan

*Corresponding author, Email: ajayhorti19@gmail.com

less pistillate flowers. Cultivation of cucurbits under such conditions leads to low yield of poor quality (Choudhary and Verma 2018). On the other hand, vegetable markets are flooded with these vegetables during their main season and sometimes the vegetable growers are even not able to recover the cost of cultivation spent on these vegetables. But the same vegetables are sold at very high prices during off season in several parts of the country. The demand of off-season vegetables is increasing rapidly in several big cities of the country because of continuous increase in availability and continuous changing choice of consumers towards off season and high-quality produce. Presently, river bed cultivation is in practice for production of cucurbitaceous vegetables in off-season in northern parts of India, although area under river bed cultivation is very limited, which cannot be extended further. Protected cultivation technologies can provide specific advantage over open field practices which includes protection against both biotic and abiotic stress factors. Normally the economics of protected cultivation directly depends upon the initial cost of fabrication of the protected structure, its running cost and the available market for high quality produce. Therefore, it becomes important to adopt low cost protected structures to ensure maximum benefit against per unit of area and cost invested. The existing low productivity of cucurbits in hot arid regions can be increased by adopting innovative approaches like drip irrigation and fertigation, low tunnel technology, spray of micronutrients and integrated crop management (ICM). Low tunnel technology can be used to raise off-season crop of cucurbits making cultivation more profitable. The use of low cost protected structures particularly low tunnels with some modification may become a viable option for successful cultivation of cucurbits in arid regions (Choudhary et al. 2015). The technology has wide scope in arid regions to produce quality yield of cucurbitaceous crops. It is gaining popularity among the farmers however, there is a need to identify low tunnel responsive varieties and standardize tunnel technology for particular crop along with use of non-woven cloth for tunnel preparation. Keeping the above facts in view, an experiment on low tunnel cultivation of longmelon was taken up to standardize the date of sowing and covering material.

Materials and Methods

The field experiment was conducted at research farm of ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan during 2017-18 and 2018-19. It is located at 28°N latitude, 73° 18°E longitude at an altitude of 234.84 m above sea level. Longmelon var. 'Thar Sheetal'was sown on four different date of sowing *i.e.* 10th December 20th December, 30th December and 10th January under tunnel and10th February under open field. Two types of covering material *i.e.* biodegradable plastic sheet (25 micron) and non-woven cloth (25 gsm) was used. The experiment was conducted in randomized block design in three replications with nine treatments *viz.* T1-10th December with polythene sheet, T2-10th December with non-woven cloth, T3-20th December with polythene sheet, T4-20th December with non-woven cloth, T5-30th December with polythene sheet, T6-30th December with non-woven cloth, T7-10th January with polythene sheet, T8-10th January with non-woven cloth and T9- Normal sowing i.e. on 10th February under open condition. The land was prepared to a fine tilth before construction of low tunnels. About 45-60 cm deep and 45-60 cm wide trenches were made at a distance of 2.0 m in east-west direction. Recommended doses of fertilizers (NPK) were applied in trenches and mixed in the soil thoroughly. For irrigation, one lateral (12-16 mm size) in each trench having drippers of 4 litre/ hour discharge spaced at 60 cm distance was placed. Before sowing, the seeds were allowed to soak in water for 3-4 hours for quick germination. After soaking, seeds were treated with Captan or Thiram @ 2 g/ kg, wrapped in gunny bag and kept at warm place (straw) for 2-3 days to facilitate early germination. Seeds were sown with spacing of 2.0 m × 0.5 m. Two seeds near each dripper were sown to maintain optimum plant density. The trenches were irrigated with drip irrigation prior to sowing. All cultural practices and need based plant protection measure as per package of practices were followed to raise a good crop. The temperature and relative humidity (RH) during crop duration (December-April) and temperature inside the tunnel were also recorded (Table 1). The covering material was removed during second week of February after gradual hardening of the plants. Initially the covering was removed during day time and again covered during night time for continuously 2-3 days followed by complete removal of the covering. The five plants were randomly selected in each treatment for recording various plant growth and yield parameters. Mean values of different characters were used for statistical analysis. The data were recorded on days to first male flower, days to first female flower, days to first harvest, days to last harvest, fruit length (cm), fruit diameter (cm), number of fruits per plant, fruit yield per plant (kg) and fruit yield (q/ha). The fruits selected for recording fruit length were used for measuring fruit diameter in centimeters at middle periphery of fruits with the help of Verneer Callipers. The data generated for both growing seasons were pooled together and then analyzed statistically (Panse and Sukhatme 1978).

Results and Discussion

Weather parameters: The average outside daily maximum air temperature was 25.5°C, 25.4°C and 29.1°C whereas, the average daily minimum air temperature was 6.5°C, 5.3 and 10.3°C in December 2017, January and February 2018, respectively. Similarly, the average outside daily maximum air temperature was 24.7°C, 22.1°C and 23.5°C whereas, the average daily minimum air temperature was 5.0°C, 5.9°C and 7.8°C in December 2018, January and February 2019, respectively (Table 1). From the weather parameter, any cucurbit cannot be grown during winter due to low temperature under open field. The air temperature inside the tunnel was 6-10°C higher than the outside (Fig. 1) which creates the favourable micro-climate required by the crop during winter itself for early season harvest. These temperature differences were because covering material of tunnels retained an increased amount of heat radiating from both, the soil and the plants (Ibarra et al. 2001).

Flower attributing parameters: Under different dates of sowing and covering material it took 7-12 days after sowing for 50% germination. It was found that germination was earlier in biodegradable plastic sheet of 25 micron than non-woven cloth (25 gsm) because the temperature inside the tunnel with polythene cover was comparatively higher than the non-woven cloth. The temperature differences between the coverings might be due to more retention of an increased amount of heat by polythene covering as compared to non-woven cloth. Plant growth inside the tunnels was also better as compared to open field condition. This might be due to the presence of favourable soil and air temperature which is associated with increased plant establishment and growth (Both et al. 2007 and Kumar et al. 2017). Under different treatments days to first male flower exhibited a range of 41-50 days (Table 2 and Fig. 2). Earliest flowering (41 days) was recorded in T3 followed by T4 (43) while T6 took maximum days (50) for first male flowering. Early flowering might be associated with optimum temperature and relative humidity at early sowing during winter under low tunnels which promoted the rapid activation of seed embryo, seed germination and rapid growth of seedlings (Binder et al. 1989). Covering with biodegradable plastic sheet of 25 micron recorded male flowers earlier than non-woven cloth (25 gsm) because the temperature inside the biodegradable plastic sheet was comparatively higher than non-woven cloth and high temperature induces male flowers.

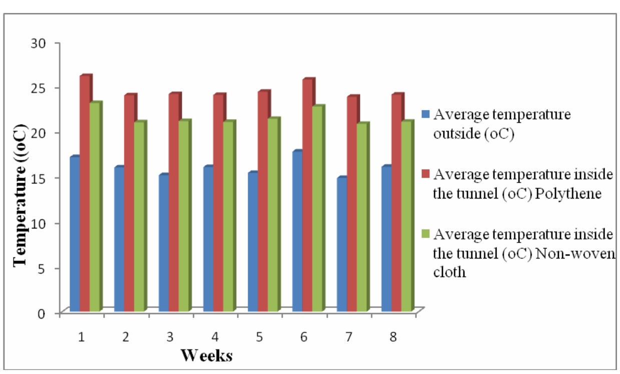

Fig. 1: Temperature profile inside and outside the tunnel

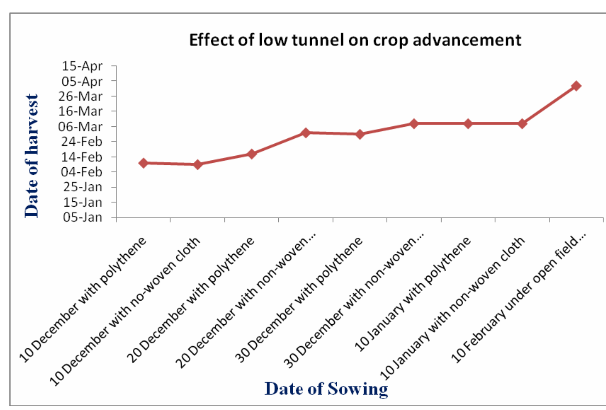

Fig. 2: Effect of date of sowing under tunnel and open condition on date of harvest

Table 1: Meteorological data of winter spring seasons of 2017-18 and 2018-19 at Bikaner

Month	Temperature (°C)		RH		Total rainfall (mm)	Wind speed (kmph)	Evaporation (mm/day)	BSSH
	Max.	Min.	RH1	RH2				
November, 2017	30.4	11.2	69.7	27.2	1.4	2.8	3.4	3.7
December, 2017	25.5	6.5	72.2	31.5	2.0	3.1	2.7	0.0
January, 2018	25.4	5.3	78.6	29.5	0.0	3.1	2.5	0.0
February, 2018	29.1	10.3	70.4	27.8	0.0	4.6	4.1	0.0
March, 2018	35.3	16.5	54.9	19.6	1.4	5.8	7.0	5.4
April, 2018	39.3	22.2	55.6	28.5	0.0	8.1	11.4	9.5
November, 2018	30.6	11.4	69.6	27.4	0.8	2.86	3.7	8.7
December, 2018	24.7	5.0	75.3	31.7	0.0	2.8	3.0	8.6
January, 2019	22.1	5.9	85.3	36.8	2.7	3.5	2.8	6.6
February, 2019	23.5	7.8	82.9	38.3	0.0	4.9	3.8	7.4
March, 2019	30.5	13.1	69.8	34.1	1.8	5.2	5.6	6.9
April, 2019	40.3	21.8	41.3	18.3	4.2	5.8	10.0	9.1

Table 2: Effect of date of sowing and covering material under tunnels on flower attributes of longmelon

Treatments	Days to first male flower (DAS)	Days to first female flower (DAS)	Days to first harvest (DAS)	Days to last harvest (DAS)	Fruiting duration (days)
T1 (10th December with polythene sheet)	45	52	60	105	45
T2 (10th December with non-woven cloth)	47	50	59	106	47
T3 (20th December with polythene sheet)	41	48	56	118	62
T4 (20th December with non-woven cloth)	43	49	54	115	61
T5 (30th December with polythene sheet)	47	55	62	112	50
T6 (30th December with non-woven cloth)	50	54	61	116	55
T7 (10th 10th January with polythene sheet)	45	49	56	105	49
T8 (10th January with non-woven cloth)	47	50	57	107	50
T9 (10th February under open condition)	45	44	50	94	44
CD (P=0.05)	0.46	0.64	0.47	0.66	0.36
C.V.	0.57	0.73	0.46	0.33	0.41

The character days to first female flower exhibited a range of 44 to 55 days. Among the treatments, T9 took minimum days to first female flower (44 days) followed by T3 (48), while maximum was recorded in T5 (55 days). Days to first harvest ranged from 50 to 62 days and the minimum number of days for first harvest (50 days) was recorded in T9 followed by T4 (54), while maximum number of days (62 days) was recorded in T5. The crop raised under tunnel (T2) attained the harvestable maturity on 9th February in comparison to open filed sowing (T9) came in harvesting on 2nd April which was 49 days later than the tunnel. Tunnel facilitates the early harvest of crop which can earn higher market price in off-season than the normal season. Low tunnel creates favourable microclimate condition by increasing the temperature at that time for the crop which induces early flowering, fruiting and harvesting. Modification in climatic conditions, promoting earlier flowering and harvesting by low tunnels has also been reported by Ogden and van Iersel (2009), Kumar et al. (2017) and Kumar et al. (2019). Similarly, Ibarra et al. (2001) also found that muskmelon crop raised under plastic cover reached flowering 24 days earlier than uncovered plants. The mean number of days taken to last harvest ranged from 94 to 118 days. The treatment T3 (118 days) recorded the highest number of days for last harvest followed by T4 (115 days), while the least number of days for last harvest was recorded in T9 (94 days).

Yield attributing parameters: Perusal of data presented in Table 3 revealed that number of fruits per plant, fruit length, fruit diameter, fruit weight, fruit yield per plant and fruit yield per hectare were significantly influenced by the sowing date and covering material. The tender fruits were harvested at marketable stage which were light green and free from bitterness. Number of fruits per plant ranged from 13.6 to 18.2. The treatment T3 recorded the maximum number of fruits per plant (18.2) followed by T4 (17.8) and T5 (17.6) and the minimum was recorded in T2 (13.6). Fruit length ranged from 23.4 to 27.6 cm and the maximum length of fruit (27.6 cm) was recorded in T3 followed by T9 (26.6 cm), T5 (26.5 cm) and T4 (26.2 cm), while the minimum length of fruit was recorded in T5 (23.4 cm). Average fruit diameter ranged from 1.58 to 1.84 cm. The treatment T3 recorded maximum fruit diameter (1.84 cm) followed by T9 (1.80 cm), T4 (1.78 cm) and T6 (1.76 cm) which were statistically at par with each other, while minimum fruit diameter was recorded in T1 (1.58 cm). The mean weight of fruit ranged from 57.3 to 75.8 g. The treatment T3 recorded maximum fruit weight (75.8 g) followed by T4 (74.4 g), T9 (72.6 g) and T6 (71.7 g) and the minimum weight of fruit was recorded in T1 (57.3 g).

Table 3: Effect of date of sowing and covering material under tunnels on yield attributes of longmelon

Treatments	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	No. of marketable fruits/ plant	Marketable fruit yield per plant (kg)	Marketable fruit yield per ha (q)
T1 (10th December with polythene sheet)	24.7	1.58	57.3	14.2	1.25	103.88
T2 (10th December with non-woven cloth)	25.3	1.62	60.4	13.6	1.30	108.03
T3 (20th December with polythene sheet)	27.6	1.84	75.8	18.2	1.96	163.68
T4 (20th December with non-woven cloth)	26.2	1.78	74.4	17.8	1.89	157.65
T5 (30th December with polythene sheet)	23.4	1.67	57.6	17.6	1.38	115.32
T6 (30th December with non-woven cloth)	26.5	1.76	71.7	15.4	1.76	146.98
T7 (10th 10th January with polythene sheet)	23.7	1.69	60.4	16.6	1.49	124.38
T8 (10th January with non-woven cloth)	24.2	1.72	61.3	17.2	1.52	126.71
T9 (10th February under open condition)	26.6	1.80	72.6	16.8	1.64	129.68
CD (P=0.05)	0.37	0.09	0.37	0.18	0.11	1.57
C.V.	0.83	3.06	0.32	0.64	3.34	0.69

The fruit yield per plant ranged from 1.25 to 1.96 kg. The treatment T3 recorded the highest marketable fruit yield per plant (1.96 kg) followed by T4 (1.89 kg), T6 (1.76 kg) and T9 (1.64 kg) and the lowest fruit yield was recorded in T1 (1.25 kg). The fruit yield per hectare ranged from 103.88 to 163.68 q. The treatment T3 recorded the maximum fruit yield per hectare (163.68 q) followed by T4 (157.65 q), T6 (146.98 q) and T9 (129.68 q) and the minimum was recorded in T1 (103.88 q). The higher yield under tunnel might be due to better growth and development of all yield attributing traits than open condition which increases the net photosynthesis and availability of assimilates for individual plants to grow and produce high yield. Similar results were also given by Singh el al. (1989). Higher yield under tunnel than open field condition was also supported by fruiting duration as it was observed that the treatment having the highest yield had 62 days of crop duration in comparison to open field condition which had 44 days of crop duration only. Tunnels benefit vegetable production by extending the growing season, increasing yields, and increasing quality. With the use of tunnels, it is possible to harvest warm season crops up to 50 days earlier in the spring and extend the growing season. This is where low tunnel made the difference in comparison to open field because the produce harvested during second week of February from low tunnel is sold at Rs. 40-50 per kg against Rs. 10-15 per kg from the produce harvested during first week of April from open field. Yield and quality are increased under tunnels due to a longer production season and the exclusion of rain, wind, and severe weather events. These results are in consonance with the earlier findings of Kumar et al. (2017) and Kumar et al. (2018). Ibarra et al. (2001) who achieved early harvests and higher yields with the use of row covers and plastic mulch compared to plants grown without cover. Yan et al. (2014) also reported higher yield of tomato and brinjal under high tunnel. The lowest yield noticed under T1 (Sowing on 10th December), might be due to coincidence of flowering, fruit set and development with low temperature which acts as stress to plants which limit the growth and developments of fruits and also under lower temperature plants failed to produce male flower leads to reduced pollination and fruit set of cucurbits resulting in smaller fruit size and lower yield (Todd et al. 2004; Yonemori and Fujieda 1985).

Economics: Net income and cost benefit ratio are significantly influenced by date of sowing and growing conditions. Net income and cost benefit ratio of sowing under low tunnel was significantly higher than the sowing under open field condition and the highest economics (C:B ratio of 2.16) was achieved by sowing the crop on 20th December under tunnel with non-woven cloth followed by polythene sheet. Though, the cost of cultivation under tunnel was higher than the open field condition, the higher market price of off-season produce from low tunnel resulted in higher economic returns (Net return of Rs. 1,61,502/ha) than open field cultivation (Net return of Rs. 78,468/ha). The similar results have also been reported by Sharon et al. 2010.

Conclusion

From the above experiment, it can be concluded that low tunnel technology can be successfully used to harvest early season produce of longmelon with better quality which fetches higher price in the market than normal season. The sowing on second date of sowing with polythene covering (T3-20th December with polythene sheet) was found the best treatment in terms of yield and fruiting duration followed by the sowing on same date with non-woven cloth covering (T4-20th December with non-woven cloth). Thus, with the adoption of low tunnel technology, the crop of longmelon can be advanced by 24-50 days as compared to normal season thereby ensuring maximum benefit to the farmer against per unit of area and cost invested.

Ikjka'k

ककड़ी में बीज बुवाई और पलवार सामग्री के मानकीकरण हेतु भा. कृ.अनु.प.–केन्द्रीय शुष्क बागवानी संस्थान, बिकानेर (राजस्थान) के अनुसंधान प्रक्षेत्र पर वर्ष 2017–18 एवं 2018–19 में एक प्रयोग किया गया। लो–टनेल के अन्तर्गत बीज बुवाई और आवरण सामग्री की विभिन्न तिथियों में ककड़ी से 41–50, 44–55 व 50–62 दिनों उपरान्त प्रथम नर पुष्पन, प्रथम मादा पुष्प एवं प्रथम बाजार योग्य फलियों की तुड़ाई के आंकड़ें एकत्रित किये गये। उपचार टी$_3$ (20 दिसम्बर पालीथीन चादर के साथ) में सबसे अधिक अन्तिम फली तुड़ाई के लिये पाया गया व इसके बाद टी$_4$ (20 दिसम्बर बिना सिले कपड़े के साथ) का स्थान रहा जबकि सबसे न्यूनतम दिन अंतिम फल तुडाई के लिए टी$_9$ (10 फरवरी मुक्त वातावरण) में पाया गया। मुक्त वातावरण में उगायी गयी फसल (टी$_9$) की तुलना में (20 अप्रैल) टनेल में उगाई गयी फसल (टी$_2$ 10 दिसम्बर बिना सिले कपड़े के साथ) में तुड़ाई की पकाव (9 फरवरी) पायी गयी जो 45 दिन अगेती थी। दूसरी बार बुवाई की गयी तिथियों में पालीथीन की पलवार (टी$_3$ 20 दिसम्बर पालीथीन चादर के साथ) में अधिकतम उपज पायी गयी एवं फलत समय बीज बुवाई की तिथि बिना सिले कपड़े (टी$_4$ 20 दिसम्बर बिना सिले कपड़े के साथ) का स्थान रहा। इस प्रकार प्रथम दो तिथियों में बुवाई में 25–40 दिनों का उन्नयन सामान्य मौसम की बुवाई की तुलना में अच्छा पाया गया। जिससे बाजार में उच्च दाम प्राप्त होता है।

References

Binder RG, Flath RA and Mon TR (1989) Volatile components of bitter melon. J Agric Food Chem 37: 418-420.

Both AJm, Reiss E, Sudal JF, Holmstrom KE, Wyenandt CA, Kline WL and Garrison SA (2007) Evaluation of a manual energy curtain for tomato production in high tunnels. Hort Technology 17: 467-472.

Choudhary BR, Sharma SK and Janakiram T (2015) Cultivation of cucurbits in arid Rajasthan fetches more. Indian Horti (May-June) 60(3): 22-24.

Choudhary BR and Verma AK (2018) Prospects of Protected Cultivation in Hot Arid Region. Technical Bulletin No. 69, Published by ICAR-CIAH, Bikaner, Rajasthan.

Ibarraa L, Floresa J, Carlos J and PeÂrezb D (2001) Growth and yield of muskmelon in response to plastic mulch and row covers. Sci Horti 87: 139-145.

Kumar D, Kumar A, Singh SS and Bala KS (2017) Influence of microclimate condition of under low tunnel on productive responses in bitter gourd (*Momordica charantia*). Bull Env Pharmacol Life Sci 6(3): 46-50.

Kumar D, Kumar A, Singh SS, Prasad RK and Kant S (2018) Effect of Plastic Low Tunnel on Flowering and Fruiting Behaviour during off Season of Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl]. Int J Curr Microbiol App Sci Special Issue-7: 4829-4835.

Maragal SY, Singh AK, Behra TK, Munshi AD and Pachauri N (2018) Effect of planting time and fertilizer dose on growth, yield and quality of bitter gourd grown under polyhouse and net house conditions. Indian J Hort 75(3): 463-469.

More TA (2010) Arid Horticulture-Making greater strides. Agril Spectrum I(X): 26-29.

Ogden AB and MW Van Iersel (2009) Southern highbush blueberry production in high tunnels: temperatures, development, yield, and fruit quality during the establishment years. Hort Sci 44: 1850-1856.

Panse VG and Sukhatme PV (1978) Statistical methods for Agricultural workers, ICAR, New Delhi, pp 328.

Singh B and Sirohi NPS (2006) Protected cultivation of vegetables in India: Problems and future prospects. Acta Hort 710: 339-342.

Singh R, Arora SK, Panditha ML, Kumar J (1989) Effect of plant growth substances on earliness and yield of summer squash (Cucurbita pepo L). Haryana agric Univ J Res 19: 311-317.

Todd CW and Guner N (2004) Growth stage, flowering pattern, yield, and harvest date prediction of four types of cucumber tested at 10 planting dates. Acta Hort 637.

Yonemori S and Fujieda K (1985) Sex expression in *Momondica chorantia* L. Science Bulletin of the College of Agriculture, University of the Rynkyus, Okinawa 32: 183.

Yan Z, Mengmeng Gu, Guihong Bi, Bill E and Richard H (2014) Planting Date Effect on Yield of Tomato, Eggplant, Pepper, Zinnia, and Snapdragon in High Tunnel in Mississippi. J Crop Improvement 28: 27–37.