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Off-Season and Quality Production of Watermelon by Modifying Micro-Climate under Hot Arid Conditions

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Abstract: The field experiment was conducted to standardize the sowing date and covering material for off-season and quality production of watermelon. Under different sowing dates and covering material, watermelon took 54-62 and 83-91 days after sowing for first female flower and first marketable harvest, respectively. The treatment 10th January with polythene sheet recorded the highest number of days for last harvest followed by 10th January with non-woven cloth, while the least number of days for last harvest was in treatment 10th February under open field condition. The crop raised on 20th December with non-woven cloth attained the harvestable maturity on 19th March *i.e.* 52 days earlier as compared to 10th May under open filed sowing (10th February). The sowing under treatment 10th January with polythene sheet recorded the highest yield (256.32 q/ha) as well as fruiting duration, while the lowest yield (156.78 q/ha) was with the treatment 10th February under open condition. Thus, an advancement of 40-50 days was achieved by modifying the micro-climate during winter under tunnel which ultimately fetches higher price in the market as compared to normal season sowing.

Keywords: *Citrullus lanatus*, Covering material, Early harvest, Low tunnels, Micro-climate

Indian arid zone covers a large area and contribute for one of the largest subtropical deserts of the globe. Hot arid zone is distributed in more than 31.7 million ha area which mainly covers the states of Rajasthan, Gujarat, Karnataka, Andhra Pradesh, Haryana and Punjab. Western Rajasthan leads the area of hot arid region covering 19.62 m ha area followed by North-western Gujarat covering 2.16 m ha. This region is known for many constraints such as high aridity index, extremes of temperature (ranging from 0 to 48°C), low and erratic rainfall, high wind velocity and dust storm, high soil pH, less water holding capacity, limited availability of groundwater with saline in nature (More 2010). In spite of these constraints, the hot arid region of the country has ample scope for cultivation of cucurbitaceous crops like watermelon, muskmelon, bottle gourd, ridge gourd, long melon, tinda, summer squash. The cucurbitaceous crops are generally sown during second-third week of February for summer season crop. The flowering stage of this season crop concurs with the prevailing high temperature and *Loo* (hot wind) which lead to high transpiration rate causing wilting of plants. Further, the soil of this region gets warm soon because of its sandy texture, which causes burning of female (pistillate) flowers touching the soil. The honey bee population which is a major pollinator of the cucurbits is also decreased to a large extent during summer season which affects fruit setting and thereby yield. High temperature is known to lower sex ratio in cucurbits by inducing higher number of staminate flowers than the pistillate flowers which again becomes a contributing factor for low yield with poor quality produce (Choudhary et al 2018). These vegetables are over flooded in the markets during their main season (April onwards) which causes glut in the market which ultimately results in very low economic return to the farmers. Sometimes the farmers are even not able to get back the cost of cultivation invested for growing these vegetables. But the same vegetables if grown early (during February-March), get very high prices as compared to normal season harvest in different corners of the country. The demand of early and off-season produce is increasing at faster rate because of shifting of choice of consumers for off season and high quality produce as well as continuous increase in availability of such produce. For production of cucurbitaceous vegetables during off-season, river bed cultivation has been and still is in practice, despite the limitation of area availability and its further extension under this practice. Protected cultivation technologies have specific advantages over open field cultivation practices which include protection against both biotic and abiotic stress factors (Singh and Sirohi 2006). But, the economics of protected cultivation is an important factor because it involves very high initial and running cost. Therefore, it becomes important to create protected structures which have low cost involvement so that maximum benefit against per unit of area and cost invested can be ensured (Choudhary and Verma 2018). The adoption of low cost protected structures like low tunnels with some modification as per local agro-climate may become a viable option for early and off-season harvest of cucurbits in arid regions (Choudhary et al 2015). The technology has wide scope in arid regions and is gaining popularity among the stakeholders however, it lacks the information on use of covering material, availability of low tunnel responsive varieties and complete package of practice. Thus, there is a need to standardize tunnel technology for particular crop along with the use of non-woven cloth for tunnel preparation. Keeping the above facts in view, an experiment on low tunnel cultivation of watermelon was taken up to standardize the sowing date and covering material for off-season and quality harvest of watermelon (*Citrullus lanatus*) under hot arid conditions.

MATERIAL AND METHODS

The field experiment was conducted at research farm of ICAR-Central Institute for Arid Horticulture, Bikaner, Rajasthan during 2018-19 and 2019-20. It is located at 28°N latitude, 73° 18°E longitude at an altitude of 234.84 m above sea level. Watermelon var. 'AHW/BR-40' developed by ICAR-CIAH, Bikaner was taken for the experiment. The experiment was undertaken in randomized block design in three replications with seven treatments (Table 2). The used covering material *i.e.* biodegradable transparent polythene sheet and non-woven cloth were of 25 micron and 25 gsm, respectively. Before construction of low tunnels, the land was brought into a fine tilth by ploughing it 2-3 times. About 45-60 cm wide and 45-50 cm deep trenches were prepared at a distance of 2.0 m in east-west direction. Recommended doses of manure (FYM) and fertilizers (NPK) were applied in trenches and mixed well in the soil (Choudhary and Verma 2018). As low tunnel cultivation is a new practice, the care has to be taken in its construction. For irrigation and fertigation, one lateral (12-16 mm size) was laid down in each trench which has drippers at 60 cm distance with 4 litre/ hour water discharge rate. For construction of low tunnel, the flexible galvanized iron hoops of 4-6 mm thickness were used and 3-4 m distance was kept between two hoops on trenches. The hoops were placed in such a way that width of two ends of hoop and maximum height of the hoop not to go beyond 1.0 m. Before sowing, the seeds were treated with Vitavax @ 2 g/ kg seed followed by wrapping in gunny bag and keeping at warm place for 2-3 days to facilitate quick germination. The trenches were irrigated with drip irrigation prior to sowing. Two seeds near each dripper were sown at the spacing of 2.0 m (row-row) × 0.6 m (plant-plant) to maintain optimum plant density. The trenches were covered with the help of covering materials over the hoops (Fig. 1). The weather parameters including temperature and relative humidity (RH) during crop duration (December-May) of both the seasons (Table 1) and average temperature profile inside and outside the tunnel were also recorded (Fig. 2). 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

Table 1. Meteorological data of winter spring seasons of 2018-19 and 2019-20 under open field conditions at experimental location

Month	Temperature (°C)		RH		Total rainfall (mm)	Wind speed (kmph)	Evaporation (mm/day)	BSSH
	Maximum	Minimum	RH1	RH2				
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	39.6	22.6	87.6	76.6	31	6.1	9.9	3.2
May, 2019	41.4	25.4	72.2	53.5	09	7.4	12.2	10.6
November, 2019	27.1	12.8	84.2	48.6	27.2	3.5	7.8	6.0
December, 2019	20.9	5.0	86.8	45.1	6.8	3.1	6.2	7.0
January, 2020	20.0	5.1	85.9	49.3	21.8	3.8	6.5	6.7
February, 2020	27.0	8.0	76.6	31.3	0.0	4.1	9.6	9.4
March, 2020	29.6	14.1	73.4	32.3	29.8	6.1	5.0	7.3
April, 2020	37.3	21.0	58.5	26.9	7.0	6.4	9.1	9.2
May, 2020	42.3	25.2	55.3	26.0	29.4	8.2	11.3	0.3

complete removal of the covering (Fig. 1). The five plants were selected randomly in each treatment for recording various plant growth and yield parameters. The data were recorded on days to first male flower, first female flower, first harvest, last harvest, fruiting duration, fruit diameter (cm), fruits per plant and fruit yield (q/ha). The quality parameters on fruit cracking were also recorded. The pooled data of both the years were analyzed statistically using OP Stat software (Sheoran et al 1998).

RESULTS AND DISCUSSION

Weather parameters: 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 and 7.8°C in December, 2018, January and February, 2019, respectively. Similarly, the average outside daily maximum and minimum air temperature was low (Table 1). From the weather parameter, it is clear that any cucurbit cannot be grown during winter (December-January) due to low temperature (5-9 °C) under open field in North-Indian plains. But, with the use of low tunnel, it was made possible to grow the watermelon by modifying the micro-climate as per requirement of the crop. The air temperature inside the tunnel was 6-10 °C higher than the outside (Fig. 2) 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).

Fig. 1. A general field view of the experiment

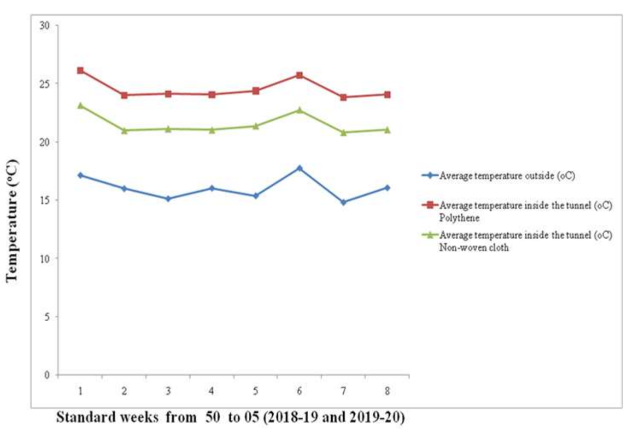

Fig. 2. Average temperature profile inside and outside the tunnel

Flower attributing parameters: Under different dates of sowing and covering material it took 7-15 days after sowing for 50% germination. 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). Under different treatments days to first male flower exhibited a range of 49-57 days (Table 2, Fig. 3). Earliest flowering (49 days) was in T6 followed by T5 and T7 while T2 took maximum days (57) for first male flowering. Early flowering might be correlated with optimum temperature and relative humidity at early sowing during winter under low tunnels which boosted the germination process as well as vigorous growth of seedlings. 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.

The days to first female flower exhibited a range of 54 to 62 days. Treatment T7 took minimum days to first female flower (54 days) followed by T6, while maximum was recorded in T1 (62 days). Days to first harvest ranged from 83 (T5) to 91 (T1) days. The crop raised under tunnel (T2) attained the harvestable maturity on 19th March in comparison to 10th May under open filed sowing (T7) which

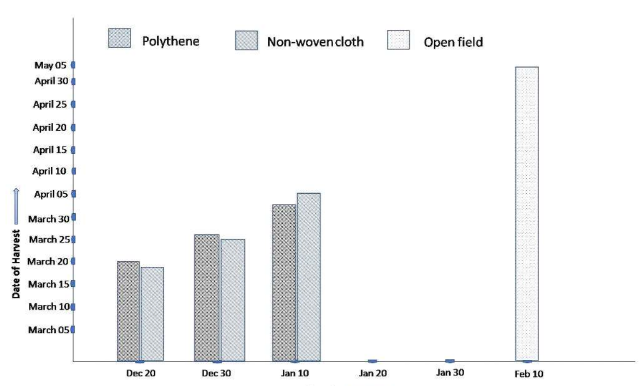

Fig. 3. Effect of sowing time on crop advancement of water melon under low tunnel and open field

was 52 days later than the low tunnel (Fig. 3). Thus, tunnel facilitates the early harvest of crop which can earn higher market price in off-season than the normal season. The importance of early harvest in watermelon for grabbing an early market opportunity has also been mentioned by Anumala et al (2020). 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 earlier researchers (Ogden and Iersel 2009). Ibarra et al (2001) also found that muskmelon crop raised under plastic cover reached flowering 24 days earlier than uncovered plants. Similarly, an advancement of 40-50 days was achieved with the use of low tunnel in long melon crop as compared to crop raised under open field condition (Verma et al 2019). The mean number of days taken to last harvest ranged from 101 (T1) to 109 (T5) days.

Yield attributing parameters: The fruits per plant, fruit diameter, fruit weight and fruit yield were significantly influenced by the sowing date and covering material. The fruits were harvested at marketable stage when fruits were ripened. Total number of fruits per plant ranged from 2.64 (T7) to 3.78 (T5). The treatment T6 recorded maximum fruit diameter (18.3 cm) followed by T5, T4 and T3 which were statistically at par with each other, while minimum fruit diameter was in T7 (15.4 cm). The treatment T6 recorded maximum fruit weight (2.85 kg) followed by T5, T4 and T3 and the minimum weight of fruit was recorded in T7 (2.28 kg). The fruit yield per hectare ranged from 156.78 to 256.32 q. The T5 recorded the maximum fruit yield per hectare (256.32 q) followed by T6, T3 and T4 and the minimum were recorded in T7 (156.78 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. Higher yield under tunnel than open field condition was also supported by fruiting duration as the treatment having the highest yield had 26 days of fruiting duration in comparison to open field condition which had 16 days of fruiting duration only. Low tunnels benefit vegetable production by extending the growing season, increasing yields, and increasing quality. With the use of tunnels, it is possible to harvest watermelon crop up to 50 days earlier in the spring and extend the growing season. Due to this low tunnel made the difference in comparison to open field because the produce harvested during second week of March from low tunnel was sold at Rs. 15-30 per kg against Rs. 5-10 per kg from the produce harvested during first week of May 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. Ibarra et al (2001) achieved early harvests and higher yields with the use of row covers and plastic mulch compared to plants grown without cover. Zhao et al (2014) also reported higher yield of tomato and brinjal under high tunnel. Maragal et al (2018) also found better plant growth, yield and quality of bitter gourd var. Pusa Rasdar under the insect-proof net house. Similarly, Verma et al (2019) also found that better yield and quality produce can be obtained by sowing the long melon crop during winter with the use of low tunnel as compared to open field crop cultivation. The lowest yield in T7 (sowing on 10th February) might be due to coincidence of flowering, fruit set and development with extremes of temperature which acts as

Table 2. Effect of sowing date and covering material under low tunnels on flowering and yield attributes of watermelon

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)	No. of marketable fruits/ plant	Fruit diameter (cm)	Fruit weight (kg)	Marketable fruit yield per ha (q)
T1 (20th December with polythene sheet)	56	62	91	107	16	3.08	16.9	2.53	214.85
T2 (20th December with non-woven cloth)	57	61	89	105	16	2.96	16.7	2.45	209.67
T3 (30th December with polythene sheet)	55	58	87	105	18	3.42	17.3	2.65	221.72
T4 (30th December with non-woven cloth)	54	59	86	102	16	3.35	17.8	2.71	217.25
T5 (10th January with polythene sheet)	51	57	83	109	26	3.78	18.1	2.82	256.32
T6 (10th January with non-woven cloth)	49	56	85	108	23	3.56	18.3	2.85	232.64
T7 (10th February under open condition)	51	54	84	101	16	2.64	15.4	2.28	156.78
CD (p=0.05)	0.41	3.38	3.69	4.03	3.17	0.49	1.75	0.34	22.53

Crop raised under tunnel in fruiting stage

Crop raised under open field in flowering stage

Fruits from open field

Fruits from low tunnel

Fig. 4. Effect of micro-climate modulation on fruit cracking of watermelon

stress to plants which limit the growth and developments of fruits and also under temperature stress, plants failed to produce male flower leads to reduced pollination and fruit set of cucurbits resulting in smaller fruit size and lower yield (Wehner and Guner 2004).

Quality parameters: The crop raised under tunnel produced better quality produce than the crop raised under open field condition. Fruit cracking is a major problem in watermelon under open field condition of hot arid environment. There was significant difference for fruit cracking incidence between the fruits harvested from low tunnel and the fruits harvested from open field condition. Fruit cracking incidence ranged from 35.1-40.5 % under open field harvest as compared to 5.6-10.2 % under low tunnel harvest. The crop grown under tunnel had vigorous growth and attained fruit harvesting during third week of March with less fruit cracking which altogether contributed for better quality produce as compared to open field crop (Fig. 4).

Economics: Net income and cost benefit ratio was 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 (B:C ratio of 2.00) was achieved by sowing the crop on 10^{th} January 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 than open field cultivation .

CONCLUSION

The low tunnel technology can be successfully used to harvest early and off season produce of watermelon with better quality which fetches higher price in the market than normal season. The sowing on 10^{th} January with polythene sheet was the best in terms of yield and fruiting duration followed by the sowing on same date with non-woven cloth covering. Thus, with the adoption of low tunnel technology, the crop of watermelon can be advanced by 40-50 days as compared to normal season (open field) cultivation thereby ensuring maximum benefit to the farmer against per unit of area and cost invested.

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