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Growing Muskmelon (*Cucumis melo* L.) under Low-input System in Arid trans-Himalayan Ladakh, India

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ABSTRACT

Feasibility of growing muskmelon (*Cucumis melo* L.), a warm season crop, was studied under a low-input cultivation system in open field condition in high altitude (elevation 3344 m) trans-Himalayan Ladakh region. The marketable yield of five cultivars in different treatments varied from 5.4±0.4 $t.ha^{-1}$ to 18.8±1.7 $t.ha^{-1}$ and 4.0±0.2 $t.ha^{-1}$ to 15.8±1.0 $t.ha^{-1}$ in 2014 and 2015, respectively. Treatment of black polyethylene mulch (BPM) increased marketable yield by 25 per cent to 155 per cent depending on year and cultivar. The marketable yield of the best performing cultivar (Pusa Madhuras) under BPM was 17.3 $t.ha^{-1}$, which suggested that muskmelon can successfully be grown in open field condition in trans-Himalaya. The fruit become ready for harvest in mid-August. Number of fruit per plant ranged from 2.3 to 6.3, and TSS ranged from 8.9 to 14.1 °Brix depending on cultivar. Temperature 10 cm beneath the BPM was 2.9±0.4 ºC higher than in bare soil. BPM reduced 74 per cent weed and save 77 per cent time in manual weeding.

Keywords: Black plastic mulching; High altitude; Himalaya; Melon; Off-season; Organic

1. INTRODUCTION

Muskmelon (*Cucumis melo* L.), a warm-season crop, is one of the most important dessert cucurbits throughout the world[1]. Consumer preference for this fruit is determined largely by its sweetness (i.e sugar level), flavor or aroma, texture and more recently as a rich source of phytonutrients[2]. The optimal temperature for leaf appearance of the crop is 34 °C[3].

The climatic condition of arid trans-Himalayan region is ideal for production of cole and root crops, but has sub-optimal heat-units for field production of melons. The widely grown vegetables are potato (75.6 percent), peas (10.7 percent), onion (3.4 percent), cabbage (3.3 percent), carrot (2.0 percent) and cauliflower (1.8 percent)[4]. Muskmelon is rapidly gaining popularity in Ladakh region primarily due to growing tourism industry. However, muskmelon is traditionally not grown in trans-Himalayan region and local requirement is transported from outside the region. Importing goods to Ladakh necessitates the shipping of goods by truck across the Himalayas, with passes as high as 5300 m, covering the distance of Manali to Leh (480 km) or Srinagar to Leh (420 km)[5]. A survey conducted in the region in 2015 suggested that approximately 21.4 ml diesel is burn to transport one kilogram of fresh vegetable by truck from a nearby town at 450 km distance, which leads to emission of vehicular pollution in the fragile environment[6]. Therefore, there is a need to study feasibility of growing muskmelon in trans-Himalayan Ladakh region. We hypothesised that muskmelon can be grown in open field condition in trans-Himalaya by modifying the plant microclimate.

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Modification of the plant microclimate has been used to enhance plant growth and yield, and to extend growing season of horticultural crops in cooler climates. Black plastic mulch (BPM) increase soil temperature and offer possibility for early production and higher yields of warm-season vegetable crops[7]. In addition, BPM reduces water evaporation and control weeds. Response of muskmelon crop to BPM has been widely studied under high-input systems[8-11]. However, to the best of our knowledge, studies related to growing muskmelon in arid high altitude regions, particularly in region beyond 3000 m above mean sea level, has not been investigated. Therefore, the objective of the present study was to evaluate feasibility of growing muskmelon in open field condition under low-input system in arid high altitude trans-Himalaya.

2. MATERIAL AND METHODS

2.1 Study Site

Field trials on muskmelon were conducted in 2014 and 2015 at Defence Institute of High Altitude Research in Ladakh, India (34°08.3'N; 77°34.3'E, elevation 3344 m). The mean maximum and minimum relative humidity in 2015, recorded daily during open field cropping season (May-September) was 27.0±1.7 percent and 22.2±1.1percent, respectively, while the mean maximum and minimum temperature was 21.0±2.6 ºC and 8.3±2.0 ºC, respectively. The light intensity during the cropping season at noon was 126870±29072 lux.

2.2 Experimental Design and Treatments

Silver-on-black plastic mulch (30 micron) was used with black surface facing the sun. Randomised block experimental design was used with three replications. Five cultivars were studied on mulch and unmulched conditions. Each replication plot was 10.75 m × 9 m in size. Each plot contained five furrows, each randomly planted with one cultivar of 20 plants. Each furrow was 75 cm wide and spacing between two furrows was 135 cm. Two rows of plants were grown on two sides of the furrow, and plants were spaced at 90 cm within a row. Farm yard manure (6 $t.ha^{-1}$) was applied in the furrows at the time of field preparation. Pesticide, fungicides and weedicide were not used throughout the growing season. Furrow irrigation was done at three days interval during initial plant establishment followed by five days interval at later stages. We made no attempt to determine differences among treatments with regard to evaporative loss of water applied to the plots. BPM was laid manually and transplant holes of 10 cm diameter were made. Seedlings with two to three true leaves, raised in a passive solar greenhouse, were transplanted manually on 2 June in 2014 and 5 June in 2015. Weeding was done twice during the growing season. Weed emergence and time consumed in manual weeding in mulched and unmulched treatments were calculated in terms of fresh weight of weed ($g.m^{-2}$) and time devoted by a single farm worker in weeding ($min.m^{-2}$), respectively. Data were recorded on length of most developed vine and chlorophyll content at 30 days, 60 days, and 90 days after transplanting (DAT). Chlorophyll was measured with Chlorophyll Meter SPAD-502 (Konica Minolta Sensing Inc., Japan). Soil temperature was measured daily at 10 cm depth using a soil thermometer.

Fruit harvest began on 18 August 2014 and 26 August 2015 and repeated twice at two-week interval. At harvest, marketable and cull fruits were weighed and counted. Unripe and undersised fruit were considered non-marketable. Total soluble solids (TSS) content was determined from juice obtained from the flesh using a hand refractometer (ATAGO, Tokyo) and values were corrected at 20ºC. Color attributes were measured using a color comparison device (PocketSpec ColorQA, Colorado). Results originally in RGB color scale, were expressed as L* - lightness, a* – redness, b* – yellowness using a web-based software (www.easyrgb.com).

2.3 Statistical Analysis

All the experiments were performed in three replicates. All measurements were taken on a subsample of five plants or fruit per replicate. The data were analysed separately for each year. Significance of differences between means was determined by Tukey's test $p \leq 0.05$ level. The experimental results were expressed as mean ± standard deviation (SD) using statistical analysis with Statistical Program for Social Sciences (SPSS).

Table 1. Effect of black polyethylene mulch on growth and yield of muskmelon in trans-Himalayan Ladakh

Parameters	Year/ DAT*	Cultivar and treatments: Arkajeet		Rustam		Patasha		Khushbu		Pusa Madhuras	
		Unmulch	Mulch	Unmulch	Mulch	Unmulch	Mulch	Unmulch	Mulch	Unmulch	Mulch
Marketable yield ($t.ha^{-1}$)	2014	5.4±0.4^{a}	7.5±0.5^{b}	6.0±0.7^{a}	13.5±1.2^{e}	9.0±0.5^{c}	12.9±0.9^{de}	12.3±0.7^{d}	16.4±1.5^{e}	8.9±0.9^{c}	18.8±1.7^{f}
	2015	4.0±0.2^{a}	5.0±0.3^{b}	7.0±0.5^{c}	10.1±0.8^{e}	7.4±0.3^{c}	10.2±0.5^{e}	8.2±0.2^{d}	12.9±0.9^{f}	6.2±1.0^{b}	15.8±1.0^{g}
Non-marketable yield ($t.ha^{-1}$)	2014	0.9±0.3^{c}	1.7±0.3^{e}	0.3±0.2^{a}	1.1±0.2^{c}	0.3±0.1^{a}	0.9±1.0^{c}	0.4±0.3^{ab}	0.5±0.1^{b}	1.5±0.0^{d}	1.8±0.1^{e}
	2015	0.6±0.1^{b}	1.3±0.1^{c}	0.1±0.2^{a}	0.8±0.1^{b}	0.1±0.1^{a}	0.7±0.7^{b}	0.1±0.2^{a}	0.2±0.2^{a}	0.9±0.1^{b}	1.4±0.2^{c}
Cull yield ($t.ha^{-1}$)	2014	1.7±0.1^{a}	2.7±0.1^{ab}	2.9±0.3^{ab}	3.7±0.2^{c}	2.9±0.3^{ab}	4.0±0.1^{c}	4.3±0.2^{c}	5.9±1.0^{d}	2.3±0.1^{ab}	4.5±1.3^{c}
	2015	0.9±0.1^{a}	1.9±0.1^{a}	1.1±0.2^{a}	2.3±0.2^{c}	2.1±0.2^{bc}	2.9±0.2^{d}	3.1±0.1^{d}	4.1±0.9^{f}	1.0±0.1^{a}	3.6±1.1^{e}
Total yield ($t.ha^{-1}$)	2014	8.0±0.8^{a}	11.9±0.9^{c}	9.2±1.2^{b}	18.3±1.6^{d}	12.2±0.9^{c}	17.8±2.0^{de}	17.0±1.2^{d}	22.8±2.6^{f}	12.7±1.0^{c}	25.1±3.1^{g}
	2015	5.5±0.4^{a}	8.2±0.5^{b}	8.2±0.9^{b}	13.2±1.1^{e}	9.6±0.6^{c}	13.8±1.4^{e}	11.4±0.5^{d}	17.2±2.0^{f}	8.1±1.2^{b}	20.8±2.3^{g}
No. of fruit per plant	2014	2.3±0.6^{a}	4.7±0.6^{abcd}	3.0±1.0^{ab}	6.3±1.2^{d}	4.3±0.6^{abcd}	5.3±0.6^{bcd}	3.7±0.6^{abc}	5.7±1.2^{cd}	3.3±0.6^{abc}	4.3±1.5^{abcd}
Vine length (cm)	30	19.3±5.5^{a}	54.7±15.0^{bc}	26.3±7.4^{a}	68.5±1.5^{cd}	24.8±8.1^{a}	65.7±9.0^{cd}	33.3±3.0^{ab}	82.1±16.3^{d}	20.3±4.8^{a}	65.9±5.4^{cd}
	60	64.3±10.8^{ab}	96.0±10.1^{bc}	70.3±20.3^{ab}	102.7±20.4^{bcd}	53.3±7.6^{a}	147.0±16.1^{e}	69.0±6.6^{ab}	136.0±5.3^{cde}	37.3±6.8^{a}	140.0±11.1^{de}
	90	88.7±10.1^{ab}	149.0±24.2^{cd}	96.0±39.0^{abc}	132.0±26.2^{bcd}	72.7±5.5^{a}	182.0±13.0^{d}	93.2±5.8^{ab}	152.0±6.1^{d}	67.3±17.1^{a}	174.7±15.3^{d}
Chlorophyll (SPAD)	30	47.2±3.2^{abc}	48.6±1.2^{abcd}	55.2±1.7^{abcd}	55.4±10.5^{bcd}	43.1±3.6^{a}	58.9±2.9^{cd}	47.8±1.1^{abcd}	59.6±3.6^{d}	45.7±4.2^{ab}	50.4±2.0^{abcd}
	60	48.5±1.8^{ab}	51.8±1.8^{abc}	56.9±2.0^{bc}	58.2±7.5^{bc}	45.3±3.4^{a}	59.4±1.1^{c}	50.6±3.6^{abc}	58.9±1.8^{c}	50.9±5.1^{abc}	52.3±2.5^{abc}
	90	43.4±1.3^{a}	47.4±3.4^{ab}	53.5±1.5^{abc}	55.0±6.7^{bc}	43.2±4.1^{a}	59.7±3.0^{c}	47.6±2.6^{ab}	52.8±1.9^{abc}	48.4±4.8^{ab}	48.4±3.0^{ab}

Values represented as mean ± SD

For each row, different lowercase letters indicate significantly different at $p < 0.05$, as measured by Tukey's test between treatments

DAT*: days after transplanting

3. RESULTS AND DISCUSSION

3.1 Plant Growth and Chlorophyll

The vine length was significantly higher on BPM than on bare soil (Table 1). BPM resulted in 172 percent, 127 percent and 89 percent higher mean vine length at 30 days, 60 days, and 90 days after transplanting (DAT), respectively. Therefore, the increase in vine length due to BPM was more pronounced at early growth stage. In comparison, Ekinci and Dursun[9] reported 18.6 percent increase in vine length due to BPM. The leaf chlorophyll content was observed significantly higher under BPM than unmulched condition. However, few exceptions were observed. Mulching resulted in 14 percent, 11.3 percent and 11.5 percent higher mean chlorophyll content (SPAD value) at 30 DAT, 60 DAT, and 90 DAT, respectively.

3.2 Marketable Yield

Number of fruit per plant ranged from 2.3 to 6.3 depending on cultivar and mulching treatment. The mean fruit number under BPM was 5.3 while that of bare soil was 3.3 per plant. Perhaps vigorous vegetative growth due to BPM increased the net photosynthesis capacity of plants, and thus plants produced more fruit per plant. The mean data on muskmelon yield under mulch and bare soil is presented in Table 1. The marketable yield of five cultivars in different treatments varied from 5.4±0.4 $t.ha^{-1}$ to 18.8±1.7 $t.ha^{-1}$ and 4.0±0.2 $t.ha^{-1}$ to 15.8±1.0 $t.ha^{-1}$ in 2014 and 2015, respectively. BPM increased melon marketable yields by an average of 66.1 percent and 64.6 percent relative to the unmulched control in 2014 and 2015, respectively. The marketable yield enhancement due to BPM ranged from 25 percent to 155 percent depending on year and cultivar. Other published data on percent increases in total yield varied greatly. In one report[8], 30 percent increase in yield under BPM was observed. In other reports, increases in yield under BPM ranged from 32 percent[10] to 96 percent[9]. Two years mean marketable yield of the best performing cultivar (Pusa Madhuras) under BPM was 17.3 $t.ha^{-1}$. In comparison, marketable yield of muskmelon have been reported 11.4-22.4[9], 14.1-23.9[1], 27-35.8[10], 29.7-43.1[12], 34.1-59.0[11] and 62-100[13] $t.ha^{-1}$ using high input systems. One reason for lower marketable yield in the present study may be due to lower plant density (9680 plants ha^{-1}). The planting density of melons in high input system ranged from 36,300-72,600 plants ha^{-1} as reported by Kultur[12], *et al.* Studies with wide range of plant densities (3074-72,600 plants ha^{-1}) in muskmelon production has shown that as plant density increases the number of fruit and yield also increases, while the fruit weight and number of fruit per plant decreases[12-17]. The marketable yield obtained in the present study can be enhanced by adoption of high-intensity management practices.

Fruit TSS ranged from 8.9 to 15.3°Brix. In comparison, TSS of muskmelon grown in other parts of the world have been reported 4-12.9[9], 7.1-11.1[10] and 8.7-13.2[1] ºBrix. The fruit flesh colour varied significantly among the cultivars. The mean fruit colour in terms of lightness (L*), redness (a*) and yellowness (b*) were 37.5, 8.3 and 13.7, respectively. In comparison, Ekinci and Dursun[9] reported L*, a* and b* value as 66, 7.4 and 21.2, respectively in muskmelon grown at 1950 m elevation.

Table 2. Quality characteristics of muskmelon fruit grown in trans-Himalayan Ladakh

Cultivar	TSS (°Brix)	Acidity (%)	Fruit flesh colour L*	a*	b*
Arkajeet	11.9±0.1[b]	0.1±0.0[a]	44.8±1.2[d]	0.5±0.4[a]	11.8±2.1[a]
Rustam	14.1±0.1[c]	0.2±0.1[ab]	39.7±0.5[c]	10.1±2.1[b]	12.0±2.7[a]
Patasha	15.3±0.1[d]	0.1±0.0[a]	36.6±1.6[bc]	14.5±0.9[c]	17.6±5.5[a]
Khushbu	11.9±0.2[b]	0.3±0.1[b]	35.1±1.6[b]	6.4±2.2[b]	12.6±1.6[a]
Pusa Madhuras	8.9±0.1[a]	0.3±0.1[b]	31.5±1.2[a]	9.9±1.5[b]	14.6±0.5[a]

Values represented as mean ± SD
For each row, different lowercase letters indicate significantly different at $p < 0.05$, as measured by Tukey's test between treatments
L* Lightness
a* Redness
b* Yellownesss

3.3 Weeding and Soil Temperature

BPM was effective in suppressing weeds. A total of 209±49 $g.m^{-2}$ weed was recorded under BPM as compared to 805±917 $g.m^{-2}$ in unmulched fields. Therefore, at the same level of cultural practices, BPM reduced 74 percent weed. Time consumed in manual weeding was 3±1 $min.m^{-2}$ in mulch as against 13±3 $min.m^{-2}$ in unmulch condition. Therefore, time save due to BPM in manual weeding was 77 percent. Increase in growth and yield under BPM could, in part, be attributed to higher soil temperature under BPM. Temperature 10 cm beneath the BPM was 2.8±0.4 ºC higher than bare soil. The difference in soil temperature between mulch and bare soil was significantly higher at early growth stage than during later stages (4.9±0.2 ºC, 3.6±0.5 ºC, 1.9±0.3 ºC, and 0.8±0.4 ºC in Jun, Jul, Aug and Sept, respectively). Decrease in soil warming by BPM with respect to crop growth stages could be due to increase in foliage and deposition of soil on mulch surface due to flood irrigation. Similar observation was reported earlier in tomato[6].

4. CONCLUSIONS

Muskmelon, a warm season crop, can successfully be grown under low-input cultivation system in open field condition using BPM in trans-Himalayan Ladakh region. Fruit TSS contents is higher than most of the previous reports. Fruit harvested in August and September can be marketed as off-season fruit.

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