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Production techniques and constraints in Muskmelon (*Cucumis melo* L.) cultivation

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Abstract
Muskmelon (*Cucumis melo* L.) also known as nutmeg melon or *kharbooj* is crop of Cucurbitaceae family. Among the cucurbits, muskmelon is known for its unique flavor and taste. Muskmelon is rich in vitamin A and C. It is composed of 90% water and 9% carbohydrates. Monoecious or andro-monoecious vines are existing in muskmelon crop. Muskmelons grows best in well-drained loamy to sandy loamy texture of soil. The optimum temperature for its growth is 20-25 °C. Muskmelon is a summer crop can be cultivated in kharif and rabi season. In Maharashtra 1.5 x 0.5 m spacing is recommended for higher yield and quality fruits in open field conditions. is 500-800 g/ha seed of F1 hybrids sufficient for one-hectare muskmelon plantation. Flowering, fruit setting and fruit development are the important crop growth stages for irrigation. Different growth regulators are used for sex modification. 250 ppm ethrel is often recommended to increase number of female flowers. Muskmelon grafting techniques helps in managing Fusarium wilt, soil-borne disease. One cotyledon or splice grafting, Hole insertionand approach grafting are the commonly used grafting methods. For off-season muskmelon cultivation farmers were adopting low plastic tunnel technique. Balance supply of nutrients is necessary for higher fruit yield and quality production. Bioferilizers like azospirillum and phosphobacteria are used in integrated nutrient management system. Fruit is generally ready for harvesting 90 to 110 days after sowing, depending on variety and agro-climatic conditions. Full slip and half slip stage are the harvesting stages for muskmelon. The harvested fruits can be stored for 5-10 days at 5 °C temperature and 95 percent relative humidity. Powdery mildew, Downy mildew, Fusarium wilt are the important diseases of muskmelon. Aphid, fruit fly attack can significantly reduce the muskmelon yield.

Keywords: Muskmelon, Advances, nutrient management, grafting, off- season, mulching

Introduction
Muskmelon (*Cucumis melo* L.) also known as cantaloupe. It is belonging to Cucurbitaceae family (Bailey, 1976) [2]. It is also known as *Kharbooja* in Hindi. Muskmelon is a highly cross-pollinated, diploid (2n=24) plant. Whitaker and Davis, (1962) [35] reported that muskmelon centre of origin is tropical Africa with central Asia. A secondary center of origin is North - West India. Muskmelon production in India is focused in the tropical and subtropical regions. In India, Muskmelon cultivation area is 0.70 lakh hectares with a production of 15.10 lakh MT (National Horticulture Board, 2021-22) [1]. Uttar Pradesh, Haryana, Punjab, Rajasthan and Madhya Pradesh are the leading states in muskmelon production. Muskmelon is short duration crop. Muskmelon is extremely beneficial to human health. Muskmelon have medicinal and nutritional properties it contains ascorbic acid, carotene, folic acid, potassium, other bioactive substances (Lester & Hodges, 2008) [4] hence it is getting commercial value. It is an important dessert fruit (Reddy, 2013) [25] because Advances in muskmelon production techniques increase the production and quality. Mulching, fertigation, off-season production, high keeping quality are the major technical advances.

Botanical Description
Monoecious or andro-monoecious vines are exist in muskmelon crop. Muskmelon vines generally grown on the ground but trellis system gives additional support and improves fruit quality. Most muskmelon vines are long. Dhami (2021) [5] reported that the muskmelon is a vine crop with ridged stems, sprawling branches and tendrils. It is having a superficial root, broad green leaves, bright yellow flowers. Muskmelon seeds are white, flat, smooth, 5-15 mm long

- **Fruit**: Muskmelon fruit varies is size and shape. Ripe fruit is almost purple, yellowish white or creamy having rough texture with or without netting. Rind can be smooth, ribbed, netted, furrowed, gray- brown, black, purple, fleshy or pink. Most of the fruits are seeded.

- **Leaf**: Muskmelon have dark green, broad leaf. Leaf surface is rough it is having a orbicular, heart or ovate shapepointed by 5-7 lobes. Leaf diameter is 5-8 cm, they are dentate and cord at base. The petioles and simple tendrils are 4-10 cm long. Muskmelon leaves resembles like cucumber leaves, which have highly spiked and flattened lobes.
- **Flower**: Muskmelon is monoecious crop having different male and female flowers on the same plant. Flowers are yellow color. The tiny fruit (ovary) under the petals quickly distinguishes the female flower from male flower. Male flower will fall off the plant after the pollen is poured out. Flowers with a diameter of 1-3 cm are staminate, clustered, pistillate, solitary or hermaphrodite. Calyx measures 5 lobes, 6-8 mm long. The petals are free, shapely round, 2 cm long, with three stamens.

Sex expression

Almost all the cultivars of muskmelon are and romonoecious; only few monoecious cultivars have been noted. Hence the approach in sex modification in muskmelon is to increase the number of perfect flowers and reduce the number of male flowers.

Muskmelon species

Muskmelon species have different characters. It is important to study the species and their characters for varietal improvement

Table 1: Species and their characters

Sr. No.	Species	Characters
1	*C. melo* var, *reticulatus*	Sweet taste e.g. Punjab Rasila, Punjab Sunehri.
2	*C. melo* var, *cantalupensis*	eg. Hara Madhu.
3	*C. melo* var *callosus*	Bitter taste and resistant to fruit fly.
4	*C. melo* var *acidulous*	Sour taste.
5	*C. figarei, C. ficifolius, C. africanus-1, C. meeusii, C. zeyheri-2:*	Resistant to CGMMV.
6	*C. melo var. momordica.*	Snap melon/phoot. Resistant to DM, PM and CGMMV e.g. Pusa Shandar
7	*C. trigonus* (*syn. C. callosus*)	Resistance to fruit fly (*Daucus curbita*) and fusarium wilt.
8	*C. auguria, C. ficifolius and C. metuliferus*	Resistant to nematode.
9	*C. metuliferus*	Resistant to powdery mildew.

(Reddy and Kumar, 2022) [26]

Soil and climate

Soil

It grows well in deep fertile, well-drained, loamy to sandy loamy texture of soil having pH between 6-7.5. (Goutam*et.al* 2020) [9]. Muskmelon cultivation is not suitable for soil with inadequate drainage capability. Early crop can be achieve on lighter soils (Sandy or sandy-loam) whereas heavier soils (clay-loam) gives high yields but in later-season. (Meena, *et.al*, 2018) [16].

Climate

Muskmelon is a hot and dry season crop. Plant growth severely retarded at low temperature below 12 °C. While, plants can easily with stands to very high temperatures up to 40 °C. Muskmelon cannot tolerate heavy frost. Plants shows sever mortality due to frost and high humidity it reduces plant growth, affect fruit quality adversely and promote leaf diseases (Meena, *et al.*, 2018) [16].

Season

Muskmelon is a summer crop can be cultivated in kharif and rabi season. Sowing time varies according to region in North India sowing time is December-January in river beds and February in Plains. While in South India October-November planting is favorable and for offseason early production September planting is done. In Maharashtra main summer season crop is sown in December.

Varieties (Reddy and Kumar, 2022) [26]

- **Hara Madhu:** It is a late maturing, powdery mildew resistant variety having 150 q/ha yield. Fruits do not slip at maturity; netting is not followed for harvesting. TSS is 13%. Seeds are of small in size.
- **Punjab Sunehri:** Cross between Hara madhu × Edisto. Its average weight is about 700-800gm, TSS is 11%. It has good keeping quality. Its average yield is about 150 - 160 q/ha.
- **Punjab Hybrid:** Cross between MS-1× Hara Madhu. It is early maturing variety. Flesh is thick, orange color, juicy and excellent flavor. TSS is 12% and average weight about 800gm. It is resistant to fruit flyand powdery mildew. Its average yield is about 150 -160 q/ha.
- **Pusa Rasraj:** Cross between Monoecious -3 × Durgapur Madhu. First monoecious hybrid.
- **Pusa Sharbati:** Cross between Kutana × PMR-6, TSS 11-12%
- **Arka Jeet:** This variety is rich in vitamin C having TSS 14-17%.
- **Kashi Madhu:** Tolerant to powdery mildew, downy mildew. Long storage capacity.
- **MH-10**: It is a cross between Gynoecious line × Indian cultivar

Spacing

In Maharashtra 1.5 x 0.5 m spacing is recommended for higher yield and quality fruits. (Falodun and Ogedegbe, 2019) [6] reported that the closer spacing of 50 × 50 cm increases the total yield but fruit size is reduced However the wider spacing of 75 × 75 cm spacing produces fruits with higher fruit weight. In muskmelon sowing or transplanting is done. Seeds are sown on raised beds while in riverbed cultivation seeds are sown in pits. In sowing Generally, 5-6 seeds are sown ata depth of 1-1.5 cm. Later on, thinning is done andonly 2 or 3 plants in each pit are allowed to grow and the rest are uprooted. (Dhami, 2021) [5]

Seed Rate

Open pollinated varieties requires 1.5 to 2 kg seeds for one hectare area whereas, for F1 hybrids is 500-800 g seed is sufficient (Dhami, 2021) [5].

Water management

Flowering, fruit setting and fruit development are the important crop growth stages for irrigation. Irregular irrigation during these stages causes flower and fruit drop, fruit cracking. During the summer, irrigation interval is reduced to 4 to 6 days (Goutam *et al*. 2020) [9]. Avoid flooding in the muskmelon field. Avoid frequent irrigation in heavy soil as it will promote excessive vegetative growth. Irrigate only as necessary during maturity, minimize irrigation frequency 3-6 days before harvesting to improve fruit sweetness and flavor. Use of silver black polyethylene mulching and drip irrigation saves waters and increases yield.

Use of plant growth regulators

Muskmelon plant growth regulators modify vine length, sex ratio, number of nodes, leaves and flowers per plant. Different plant growth regulators are having different results. In GA3 (200 ppm), NAA (200 ppm) or Ethrel (200 ppm) can be used for minimizing sex ratio which is desirable while maximum sex ratio was recorded under Control. (Garg, *et al*. 2020) [7].

- **Germination and vine growth:** In muskmelon, bottle gourd, squash, and watermelon, soaking seeds in Ethephon for 24 hours promotes seed germination. (Saimbhi *et al*. 1974) [30]. Foliar application of 60 ppm GA3 significantly increases the number of nodes on main vine. (Chaurasiya *et al*., 2015) [3].
- **Sex modification:** Application of MH 200 and 300 ppm increased the number of perfect flowers while GA had opposite effect (Randhawa and Singh, 1969) [22]. Ethephon (480 ppm) induced perfect flowers at early nodes and delayed male flower production (Saimbhi and Chadha, 1974) [30]. 250 ppm ethrel is often recommended in muskmelon to create a greater number of female flowers. When used at the two- or four-leaf stage, exogenous application of plant growth regulators changes sex ratio and sequence (Rudich *et al*., 1969) [27]. Early staminate can be converted into pistillate phase in monoecious line by Ethrel sprays (150-200 ppm) and using this induced pistillate phase (5-6 nodes) for hybrid seed production with monoecious female parent, was possible, according to More and Seshadri (1975) [19].
- **Male sterility:** 2, 3-dichloroisobutyrate (0.2-8%) induces male sterility in muskmelon (Saimbhi & Brar, 1978) [29].
- **Hybrid seed production:** Production of early temporary female phase on monoecious muskmelon through exogenous application of Ethrel (150-250 ppm) to use as female in F, hybrid seed production. (More & Seshadri, 1975) [19]. silver thiosulphate (100-400 ppm) issued for maintenance of Gynoecious lines in muskmelon (More &Seshadri, 1987) [20].
- **Fruit set:** Ethephon (50-100 ppm) increases fruit set in C. melo var. utilizes. (Sadhu & Das, 1978) [28]
- **Yield:** Folar spray of **NAA (25 mg/l), GA (10 mg/l) and MH (50-200 mg/l)** increased yield. Randhawa & Singh (1970) [23] reported that the Seed treatment with Cytozyme (5%) increased the fruit yield and quality.

Grafting techniques in melons

Grafting is an alternate method for reducing crop damage caused by soil borne diseases and increasing tolerancefor abiotic stress to improve crop yield. Grafted watermelon and muskmelon planting is a routine production practice in Japan. It helps in managing Fusarium wilt, soil-borne disease and grafting **(**Miles and Devi, 2017) [17]. There are three methods for grafting melons that are regularly used:

1. One cotyledon or splice grafting
2. Hole insertion,
3. Tongue-approach

Grafting techniques

1. One-cotyledon grafting

One cotyledon grafting is also known as a splice grafting. It is mostly followed in Korea, Europe, and North America for watermelons and melons. It was created by Japanese engineers due to the simple procedure and speed. It is having relatively low rate of root-stock regrowth (2-3%).

Advantages

a) Grafting automation is easily accomplished.
b) It is the simplest and fastest method for grafting watermelons.

Disadvantages

a) After grafting, humidity, light, and temperature must be carefully controlled.
b) If the healing environment is not ideal, high losses and potential illnesses or physiological abnormalities may emerge.
c) The rootstock may still have some meristem tissue, which will need to be removed later.

2. Hole insertion grafting

Hole insertion grafting method has a high success rate. For grafting scion seedlings should only have the cotyledons or the first true leaf just developing, while root-stock seedlings should have one little true leaf. In order for the scion to fit into a hole formed between the two cotyledons of the rootstock, the diameter of the scion stem must be less than the diameter of the rootstock stem. This grafting procedure has a limited grafting window since seedlings can grow swiftly in a day or two at this early growth stage, and the time of sowing rootstock and scion seeds are crucial. It requires little maintenance required throughout the healing period.

Advantages

a) Grafting clip not required.
b) It is having a high graft success rate.
c) solid graft union is possible as it Increases the contacting surface area between the scion and rootstock.

Disadvantages

a) It requires expertise due to the complexity of the grafting operation.
b) Internal rooting of the scion via the rootstock's pith may occasionally occur, especially when the scion stem is not oriented correctly in the rootstock stem;

3. Approach (tongue) grafting

Approach grafting or tongue grafting is a simple technique effective for small scale farmers. Melon (C. melo) rootstocks tend to have thin stems, it may be difficult to utilize them for

approach grafting method however, melon grafting on squash rootstocks gives higher success as it has thicker stems.

Advantages

a) A relatively simple technique.
b) Shoot regrowth from the rootstock is not obsereved.

Disadvantages

a) As compare toother grafting methods it requires relatively more time.
b) It requires more space.

Off season production of muskmelon

In vegetable crops off season produce fetches higher market rate as compare to regular. In offseason production temperature and light control is most important. Plastic tunnel is the important techniques for off season muskmelon production.

Plastic tunnel technology

Plastic tunnel have controlled atmosphere. The yield of vegetable cultivated in the tunnel was clearly higher than traditional farming. Walk-in plastic tunnel provide better yield in consideration to low plastic tunnel.In plastic tunnel higher quality hybrid seeds are used. For off-season muskmelon cultivation all the farmers were adopting low plastic tunnel. In the construction of low plastic tunnel the basic required material was wooden sticks for frame/ structure, string, black polythene sheet for weed control and transparent plastic sheets. (Latif, *et al.,* 2018) [13].

Mulching

Silver black polythene sheet is widely used for muskmelon crop mulching. Mulching increases the efficiency of water consumption. (Rashidi and Keshavarzpour, 2011) [24]. Mulching effectively control weeds, decreases nutrient leaching and conserves soil moisture by reducing soil evaporation (Kumar and Lal, 2012) [11], (Lamont, 2005) [12]. Muskmelons grown with polyethylene mulch resulted in high fruit yields and minimize nitrogen leaching. (George and Hanlon, 2010) [8]. Plastic mulch can improve plant microclimate conditions by conservingsoil moisture and increasing soil temperature which improve plant growth and decreased time to anthesis and harvest (Mahadeen, 2014) [15].

Integrated nutrient management:

Muskmelon is a short duration crop. It requires balance supply of nutrients at right crop growth stage. Different trials are conducted at various locations to study the effect of integrated nutrient management on muskmelon growthand yield.

- Organic fertilizers: Apply FYM 20 t/ha along with neem cake 100 kg before last ploughing, vermicompost also used.
- Falodun and Ogedegbe (2019) [6] reported that the soil application of swine manure 10 t/ha increases the yield and quality.
- The optimum requirement of N_2 O @ 60-120 kg, P_2 O_5 @ 9-18 kg, K_2 O @ 100-120 kg and organic manures 25-30 t ha^{-1} is sufficient. The full dose of P_2 O_5, K_2 O and half dose of N_2 O fertilizers should be applied before sowing. (Meena *et al*. 2018) [16]
- Muskmelon fruit yield increased with an increase in N fertilizer rate and the application of 150 kg N ha-1 gave the highest single fruit weight, fruit vine weight, fruit yield, and fruit yield. (Wahocho *et al.* 2017) [34]
- Biofertilizer**:** Apply Azospirillum and Phosphobacteria @ 2 kg/ha and Pseudomonas @ 2.5 kg/ha. 6.3) Chemical Fertilizers: Apply a recommended dose of 200:100:100 kg NPK/ha through split application.

Harvesting

Fruit is generally ready for harvesting 90 to 110 days after sowing, depending on variety and agro-climatic conditions. At the fruit ripening stage, the rind becomes soft, skin colour changes from green to yellow, yellow-green to brown, slight odour at blossom end and development of an abscission layer or crack at the stem attachment point. (Goutam *et al*. 2020) [9]. Full slip and half slip stage are the harvesting stages for muskmelon

1. **Full Slip stage:** The mature fruits separate/ slip easily from the stem leaving a complete scar. Fruit's shelf life is less than half at this point. This stage is appropriate for the local market or for eating at home.
2. **Half-slip stage:** Harvesting of fruits 1 to 2 days before full slip stage, only half of the stems separates leaving an incomplete. (Dhami, 2021) [5]. It is for distance market.

Yield

2000-5000 fruits per hectare can be harvested with proper cultural care when grown on bare field, while 6000-12000 fruits when using plastic mulch. (Meena, *et al.*, 2018) [16].

Post-harvest Handling

Postharvest handling is necessary to reduce postharvest loss. In India, major post harvest losses are due to improper handlings. Cleaning, sorting, pre-cooling, grading and storage operation play crucial role in quality retention and long term storage. Improper handling leads to bruising injury and decay. Delay in harvesting and loading may lead to rapid physiological processes resulting consequent loss. So harvesting at proper time enhances its aromatic compounds and sweetness (Meena *et al*. 2018) [16].

- **Sorting and Grading:** Fruits should be graded according to their size and colour. Infected, cracked, damaged, and overripe fruits should be separated.
- **Pre-cooling:** Muskmelon fruits need precooling just after harvest from the field. Pre-cooling helps in lowering down of respiration rate and transpiration rate. If this heat is not removed, fruits can degrade prematurely. Room cooling, icing and forced air cooling is ideal method of precooling of muskmelon. Force air cooling is more effective and commercial method of cooling which is done at 10-15 ºC.
- **Coating and Waxing:** Fruits of muskmelon can be coated with different coating agents like chitosan, aloe vera gel, natural bee wax, shellac wax etc. (with or without antimicrobial agents) by dipping into coating solutions for 10-20 minutes on the basis of type and nature of waxes for longer storage.
- **Storage:** Muskmelon fruit ripens during shipping and storage due to climatic conditions. The harvested fruits can be stored for 5-10 days at 5 ℃ and 95 percent relative humidity. (Dhami, 2021) [5].

Pest and diseases

Powdery mildew, Downy mildew, Fusarium wilt, Gummy Stem Blight are the important diseases of muskmelon. Crop rotation, soil fumigation, soil solarization, Seed treatment, soil-drenching with systemic fungicides give protection against these fungal diseases (Thamburaj and Singh, 2019) [33]. Avoid excess Nitrogen. Fungicides should be applied in every 7-10 days beginning very early in disease development.

Leaf miner, aphid, fruit fly are the important pests of muskmelon. Leaf miner attack at initial crop growth stage. Leaf miner maggots feed on leaf and make serpentine mines into leaf. Aphids damage the plants by sucking the leaf sap. Yellow sticky traps are effective for sucking pest control. Fruit fly is serious pest. Females lay their eggs beneath the skin of young fruits. Later, maggots feast on the pulp, and the fruits begin to decay. Use of of Neem seed Kernal extracts at a rate of 50 gm/Ltr of water found useful in fruit fly management.

Conclusion

Muskmelon (*Cucumis melo* L.) commonly known as Kharbooja is an important dessert fruit. Muskmellon is highly cross pollinated crop having monoecious or andro-monoecious vines. Muskmelon has worldwide and year round demand. Climate is the major constraint in offseason production. Plastic tunnel technology, mulching, drip irrigation technologies helps in off season production. Fusarium wilt severely reduces muskmelon production. Grafting of muskmelon on fusarium wilt resistance rootstock is effective the disease. Fruit fly incidence can be controlled by using pheromone traps. Different plant growth regulators viz. GA3, NAA and Ethrel can be used to improve germination, minimizing sex ratio and maximize fruit set. Muskmelon fruits are harvested according to variety, season and market conditions. Post harvest handling is important to reduce losses.

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