Basic melon (*Cucumis melo* L.) physiology and morphology

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Production Importance

Melons (*Cucumis melo* L.) are an important annual diploid plant belonging to the Cucurbitaceae family. Melons have many popular names that generate ambiguity when referring to this species, including muskmelon, cantaloupe, nutmeg melon, winter melon, Galia, piel de sapo, sweet melon, rock melon, Charentais, yellow canary, and snap melon. This confusion arises from the diversity of shapes and colors that different cultivar types produce, from fruits with either reticulate netting or smooth rind to a variety of sizes and shades of green, white, and yellow with or without stripes (Wehner et al., 2020).

The U.S. produced almost 1,134.7 million pounds of melons on approximately 41,000 acres in 2020. The average yield in the U.S. during the same year was 279.5 cwt/acre with an average price of $26.1/cwt, generating a commercial value of approximately $299 million (USDA-NASS, 2021). California and Arizona are the two largest producing states with a combined acreage of 35,100 acres in 2020 (USDA-NASS, 2021). Virginia's production of cucurbits concentrates mostly on squash, watermelon, and pumpkin. However, many small growers across the state have an interest in developing melons (primarily cantaloupes and honeydews, among others) as a potential summer crop. At this moment, there is little information available on the acreage of melons produced in Virginia.

History and origin

The origin of the modern melon is still under debate. The oldest known wild relatives originated in Africa, with records of its domestication of nearly 3000 bp, and its later evolution and separation into two subspecies *C. melo agrestis* and *C. melo inodorus*. (Kerje and Grum, 2000). Furthermore, there is evidence of archeological remains found in China dating back to 5000 bp, and in Egypt and Iran during the 2nd and 3rd millennia BC (Wehner et al., 2020). Recent molecular phylogenetic analysis suggests that *C. melo* likely originated in India. During the 1400's melon was brought from Armenia to the papal state of Cantaluppe, near Rome, and spread throughout Europe, giving origin to the common name when referring to the fruit. Melons arrived in the New World with Columbus and continued moving towards the west (California) with the Spaniards in 1683 (Wehner et al., 2020). The first commercial melon hybrid 'Burpee Hybrid' was introduced in 1955. Currently, hybrid cultivars are the predominant preference of growers and commercial breeding seed companies.

Cultivar Groups

There are 6 horticultural groupings based on fruit characteristics and uses (Table 1).

Table 1. *Cucumis melo* cultivar groups.

Group	Description
Cantalupensis (cantaloupe, muskmelon)	Very small to very large sized fruit (1.5 – 2.2 kg) with netted, warty, or scaly surface, flesh usually orange or green; fruit detaches from peduncle at maturity.
Inodorus (winter melon)	Fruit is usually larger than cantalupensis, later in maturity, and longer shelf life. Rind surface smooth, but not netted, flesh typically white or green. Fruit does not

	detach from the peduncle when mature.
Flexuosus (snake melon)	Fruit is very long, slender, and often ribbed. Used when immature as an alternative to cucumber.
Conomom (pickling melon)	Small fruit with smooth, tender skin, white flesh, early maturity, and usually with little sweetness or scent.
Dudaim (pomegranate melon)	Small, round to oval fruit with white flesh and thin rind.
Momordica (snap melon)	Fruit ovoid to cylindrical in shape, with flesh white or pale orange, low sugar content, and fruit disintegrates when barely ripe.

Modified from Wehner et al., 2020.

The cantalupensis group is the most economically important for commercial production around the world. Common types of this group include: 'Persian' (large fruit with heavy netting), 'Charentais' (thin rinds and only sparse netting, popular in Europe and Africa), 'Harper' (tolerant to detrimental conditions, light tan to green, firm, and tough rind, covered in a rough, raised, and light brown exterior) and 'Galia' (Green-fleshed netted melons).

Cultivars of the Inodorus group are called winter melons because the fruit generally stores well, with the most iconic members being the 'Honey Dew' and the 'Piel de Sapo' melons. The Inodorus group has traditionally been used as a parent to breed with the Cantalupensis group.

Morphology and Anatomy

Cucurbits generally possess a strong tap root and plenty of secondary roots. Lateral roots usually extend further than the above-ground biomass. Secondary roots are important during plant development as they serve as an assistance system to the primary root to increase nutrient and water uptake. The maximum root depth ranges between 2.6 and 5 ft, depending on the genotype, soil type, and growing conditions (Allen et al., 1998).

The main stem is almost round, with or without minor pubescence depending on genotype. Plants are typically trailing vines, but some cultivars can present compact structures and short internodes. Leaves are simple, either three- or five-lobed, and borne singly at the nodes, with a great variation of size, color, and shape among cultivars (Figure 1).

Figure 1 Melon plants 40 days after planting at the Eastern Shore AREC, Virginia Tech. Credit: E.A. Torres-Quezada, Eastern Shore AREC, Virginia Tech.

The plant develops single tendrils as an anchor system, borne in the leaf axis. Tendrils are plant organs specialized to anchor vining stems. Tendrils may originate from modified leaves, leaf tips, leaf stipules, and in some cases modified stem branches (Figure 2).

Figure 2 Melon plants on soilless media and vertical trellis system at the Eastern Shore AREC. Credit: E.A. Torres-Quezada, Eastern Shore AREC, Virginia Tech.

Melon plants can bear perfect flowers andromonoecy (self-pollinated and male flowers on the same plant) or imperfect flowers monoecy (female and male in separate flowers on the same plant) in several combinations. Flowers are yellow and small, usually 1 inch wide (Figure 3). In simple terms, melons are considered andromonoecious plants due to their ability to produce both male and perfect flowers in the same plant, although some cultivars can be classified as male and female, based on the predominant number of flowers that they produce.

Figure 3 Perfect flower on melon at 40 days after planting, at the Eastern Shore AREC. Credit: E.A. Torres-Quezada, Eastern Shore AREC, Virginia Tech.

Research showed that the number of pistillate flowers developed in the monoecious genotypes is almost two times lower than the number of perfect flowers developed in andromonoecious plants. Similarly, the number of staminate flowers per plant is close to 15% lower in monoecious genotypes than in andromonoecious genotypes (Girek et al., 2012). Given the lower number of flowers in monoecious plants, the number of fruits of andromonoecious is usually higher.

Regardless of the genotype, the time from emergence to the first flower is usually the same. Sex expression is controlled by genetic and environmental factors, such as light (both quality and duration), water supply, and temperature. Normally, conditions that promote carbohydrate accumulation and reduce respiration (low temperature, adequate moisture and nutrient availability, short photoperiod) promote female sex expression, while high temperature and conditions that increase plant respiration promote male flowers. Additionally, an increased concentration of gibberellins can promote male flower development, while auxins and ethylene induce female flowers.

Melons are considered indehiscent modified berries, with three ovary sections of locules. This means that the fruit is fleshy, with a leathery rind derived from an inferior ovary. The edible flesh is derived from the mesocarp tissue. There is a vast variability of shapes, sizes, and colors of fruits. Some fruits (depending on the cultivar) present an abscission layer at the attachment zone between the fruit and the stem (they detach from the stem when fully mature) (Figure 4), while others remain attached even after ripe.

Figure 4 Fully mature melon fruit, cantaloupe type, at the Eastern Shore AREC. Credit: E.A. Torres-Quezada, Eastern Shore AREC, Virginia Tech.

Seeds have a firm, multilayer testa (hard seed coat), with a thin perisperm, an endosperm, and a large embryo. The testa is composed of five zones: epidermis, hypodermis, sclerenchyma, aerenchyma, and inner epidermis. At the edge, there is a little small hole (the hilum), which marks where the seed was attached to the fruit. At maturity, the embryo consists of the hypocotyl, with two leafy cotyledons and a radicle.

Growth and Development

Germination starts with water imbibition to the seed. The initial increase in fresh weight (water uptake) is relatively fast (almost 50% increase) during the first 10 hours of imbibition (25ºC in the dark). The water update rate slows down after the seed absorbed 70% of its original weight in moisture. Temperature is perhaps the most important environmental factor affecting melon seed germination. The optimal temperature range is between 25ºC and 30ºC in most cases.

Temperatures below 20ºC will delay germination for most genotypes, while germination above 45ºC would almost completely inhibit it. Some genotypes can germinate in temperatures between 30ºC and 40ºC, but it is not the case for most commercial cultivars. Additionally, the optimal temperature for germination is different from the required temperature for optimal plant growth. Many other factors affecting melon seed germination are explained by Edelstein and Nerson, 2005. Most melon cultivars are indeterminate vines in some cases capable of growing up to 50ft long, although modern cultivars present shortened internodes, bushy structures, and concentrated yield. All cultivars are considered frost sensitive, with different levels of low and high-temperature tolerance (Nunez-Palenius et al., 2008). Low temperatures can cause growth abnormalities, and poor flower, and fruit set. Insects, in particular bees, are important to aid pollination and fruit set (Figure 5).

Figure 5 Bumblebee on melon flower at the Eastern Shore AREC. Credit: E.A. Torres-Quezada, Eastern Shore AREC, Virginia Tech.

Melon fruit development can be divided into four stages: young fruit, expanding, premature, and maturity. The open female flowers are ready for pollination only for about a day. Hence, the importance of adequate and numerous pollinators around the production areas. After pollination, cell division in the ovary increased. Ten days after flowering, ovarian epidermal cells stop division leading to the young fruit stage. Subsequently, following a rapid increase in the volume of young fruit, the cell diameters of the mesocarp, endocarp, and placenta increase quickly resulting in fruit enlargement.

Twenty days after flowering, the melon fruit enters the expanding stage, with still low fruit volume, and sugar content. Then, the fruit length is continuously increased, with rapidly increased sucrose content. Approximately thirty days after flowering, the melon fruit enters a premature stage, cell expansion stops with maximum fruit volume and flesh firmness. The sucrose content consistently increases and reaches the maximum (60% of total sugar), with the flesh turning soft in texture. Forty days after flowering, the melon fruit is considered fully mature. At this stage, the sucrose content reaches the highest level, along with other nutritional components (Zhang et al., 2016).

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2023 SPES-507NP