Cucurbit Crop Growth and Development

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Indiana produces more than 15,000 acres of cucurbits including watermelons, muskmelons (cantaloupes), pumpkins, cucumbers, and squash (Table 1). The state ranks among the top ten for production of watermelon, muskmelon, pickling cucumbers, and pumpkins (Table 1).

These crops are members of the Cucurbitaceae, or squash family. Genera most commonly grown include *Cucurbita* (squash and pumpkin); *Cucumis* (muskmelon and cucumber), and *Citrullus* (watermelon). Table 2 lists common species. This paper describes growth and reproductive development of these crops.

Germination and Emergence

Cucurbit seeds consist of an embryo and two cotyledons covered with a seed coat. Energy reserves are stored in the thick cotyledons. The processes of germination are typical of dicots with epigeal germination. Imbibition is followed by biochemical activity, and elongation and emergence of the radicle. The hypocotyl emerges from the seed coat and lengthens to push the hypocotyl hook above the soil surface. Exposed to light, the hook straightens, pulling the cotyledons out of the soil where they expand and begin photosynthesis. The seed coat may remain in the soil, or may adhere to one or both of the cotyledons, sometimes preventing their normal expansion.

The length of time required for germination in a moist environment depends on the temperature. Between 59°F and 77°F, cucumbers and muskmelons require 194 degree days above a base temperature of 54°F (Taylor, 1997). Table 3 shows the time to emergence for several cucurbit crops at different soil temperatures. Summer squash may germinate at temperatures as low as 40-50°F, and cucumber at 53°F, but muskmelon and watermelon require at least 60°F (Wien, 1997).

Seeds of triploid watermelon are more prone to germination problems than other cucurbits. Often, the seedcoat sticks to the cotyledons. Placing the seed horizontally, or with the radicle end pointed down at a 45° or 90° angle from horizontal reduces the number of seedcoats sticking to the cotyledons (Maynard, 1989). Germination can be increased by removing or clipping the seedcoat, treating with hydrogen peroxide, or providing a high-oxygen environment (Duval and Nesmith, 2000; Grange et al., 2003). Excessively wet media reduces germination (Grange et al., 2003).

Cucurbits may be direct-seeded in the field or transplanted. In Indiana, watermelons, muskmelons, fresh market cucumbers and summer squash are usually transplanted, and cucumbers for processing, pumpkins, and winter squash are usually direct seeded. The decision to direct seed or transplant should take into account desired harvest period, expected weather conditions, costs, weed control practices, potential for seed predation, equipment available, etc.

Vegetative Growth

Established seedlings rapidly produce new leaves as the main stem grows. At some point the main stem becomes too large to remain upright, and it falls over to grow along the ground unless supported by a trellis or other structure. Branches form at nodes and follow the same general pattern of growth as the main stem. The number and length of branches vary depending on species and cultivar. Tendrils and adventitious roots may also form at nodes. Genetic variations that lead to reduced internode length and shorter vines are present in all genera. Cultivars with this trait may be called “bush”, or “semi-bush”, or "“restricted vine.” In *Cucurbita* the trait is associated with a thicker stem, less branching, fewer tendrils, and greater tendency to produce female flowers (Loy, 2004). Many summer squash have a bush growth habit.

Flower Development

Flowers develop in leaf axils. Flower type varies depending on genetics and other factors. Plants may be monoecious (separate male and female flowers), andromonoecious (separate male and perfect flowers), gynoecious (female flowers only), or hermaphroditic (perfect flowers). The most common forms for various species are listed in Table 2. In monoecious and andromonoecious plants, several male flowers usually open before any pistillate (female or perfect) flowers open. At any one time there are usually several times more male flowers open than female flowers. Most typically, a stem develops a series of nodes with male flowers, one node with a pistillate flower, another series of nodes with male flowers, a second pistillate flower, and so on. Generally, as the plant develops, the proportion of nodes with female flowers increases. In older plants of cucumbers and summer squash, the distal portion of the stem may have pistillate flowers at every node. (Loy, 2004; Wien, 1997). In muskmelons, the pistillate flowers form on short lateral branches either on the main stem or on one of several large basal branches (McGlasson and Pratt, 1963). The first pistillate flower to open on muskmelon is usually on a short lateral of a branch near the base of the plant.

Whether a particular node initiates a male or pistillate flower and whether that flower develops fully to bloom is determined by genetics and environment. Cool temperatures promote development of pistillate flowers in cucumber, squash, and pumpkin. Under these conditions, the first pistillate flower forms at a node closer to the base of plant, and the ratio of male to pistillate flowers is reduced. For some summer squash, this means the first pistillate flower opens before any male flowers are open, and pollination and hence fruit set doesn’t occur. High temperatures promote male flowers, and delay female flower development. For instance, in pumpkins, temperatures of 90°F day/70°F night lead to abortion of female flower buds. Light levels are also important. High light levels promote female flower production, and shade can reduce the number of female flowers. Photoperiod doesn’t appear to play a major role in field production, but under controlled environments some cucumber cultivars produce more pistillate flowers under short days.

Plant nutritional status also plays a role; high nitrogen fertilization can delay production of pistillate flowers. (Loy, 2004; Wien, 1997.)

Sex expression in cucurbits is influenced by hormones produced within the plant as well as synthetic growth regulators applied to the plant. Gibberellins promote male flower development in *Cucumis* and *Cucurbita*. In these genera ethylene promotes pistillate flower development and suppresses male flowers. Natural and synthetic auxins promote pistillate flower development in cucumber. Very little work on watermelon has been done in this area, and whether it responds similarly to other genera isn't known. (Wien, 1997.)

Pollination and Fruit Set

Flowers open at temperatures above 50°F (pumpkins and squash), 60°F (cucumber and watermelon), or 65°F (muskmelon). They remain open for a day in the case of watermelons, muskmelons, and cucumbers, or half a day or less for *Cucurbita* spp. In most cases, fruit set requires the activity of pollinators, such as honeybees or native squash bees. Enough viable pollen must be delivered to the stigma so that there is one grain of pollen for each developing seed in the fruit. Once pollen is on the stigma, fertilization is still not guaranteed. The pollen must germinate and grow a pollen tube down the stigma to deliver sperm to the ovule. If there is not enough pollen, or conditions aren't suitable for pollen tube growth, only the ovules closest to the blossom may be successfully fertilized. Seeds developing close to the blossom end stimulate growth in that part of the fruit, but the rest of the fruit remains small. The result is a misshapen fruit.

In the case of triploid watermelon, pollination with viable pollen is necessary to stimulate fruit growth even though seeds do not develop. Triploid plants do not produce enough viable pollen themselves and so a pollenizer variety must be planted nearby. Traditionally, seeded varieties that produce fruit visually different from fruit of the seedless variety are used as pollenizers. More recently, some varieties have been developed that are marketed solely as pollenizers; they do not produce marketable fruit. For successful fruit set in triploid watermelons it is critical that pollenizer varieties produce viable pollen at the time female flowers are open on the triploid plant.

Some gynoecious cucumbers are parthenocarpic (able to set fruit without fertilization of ovules) and so do not require pollinators. Natural parthenocarpy is known to occur in other cucurbits as well, notably summer squash, but is generally not relied upon for commercial production. (Wien, 1997).

Environmental conditions and the condition of the plant can interfere with pollination and fruit set. Weather conditions influence pollinator activity. For example, honeybees are less active when it is hot and dry. Pesticide applications or residues can kill or deter bees. Fruit already developing on the plant hinder successful fruit set in younger flowers, especially those on the same branch or stem.

Fruit Development

Cucurbit fruit grows exponentially for a period after fruit set, and then the growth rate slows. The increase in fruit size after pollination is largely a result of cell expansion rather than an increase in the number of cells. Cucurbits can be divided into two major groups based on whether the fruit are harvested when immature – summer squash and cucumbers – or mature – all types of melons, winter squash, pumpkins, gourds. Cucumbers and summer squash are harvested during the period of rapid growth. They may be ready for harvest as soon as 3 days after pollination, depending on the market requirements. In the other crops, fruit typically reach their full size about 2 to 3 weeks after pollination, and take another 3 or more weeks to mature to a harvestable stage. During this time seeds develop to maturity and sweetness, flavor and color develop in the fruit. The rind toughens, becomes less permeable to water, and in the case of muskmelon, develops corky netting. A color change may occur, either subtle as in the change from pale green to yellowish in muskmelon; or just on the portion of the fruit near the ground, as in a yellow ground spot of a watermelon; or across the entire fruit surface, as in pumpkin. Watermelons and muskmelons typically mature 42 to 46 days after pollination, while winter squash and pumpkins take 50 to 90 days to reach harvest maturity. Developing fruit places heavy demands on the plant, reducing the growth of new leaves, roots, and any other fruit developing at the same time. (Loy, 2004; Wien, 1997)

Indicators of harvest maturity vary depending on the crop. Cucumbers and summer squash are usually harvested based on size. Muskmelons form an abscission layer between the peduncle and fruit so they “slip” from the vine when fully ripe; commercial harvest occurs after the layer begins to form but before the melon falls off the vine. Watermelon harvest maturity is identified by yellowing of the ground spot and wilting of tendril near the place of fruit attachment. Sugar levels do not increase in muskmelon or watermelon after harvest. (Wien, 1997.) In winter squash and pumpkin, hardening of the rind and change in rind color at the ground spot or over the entire rind indicate the earliest readiness for harvest. At this stage, seed development may not be complete, and leaving the fruit on the vine for another 10 to 20 days may improve postharvest quality. (Loy, 2004.)

The size of the mature fruit is influenced by genetics, environment, and plant conditions during development of the pistillate flower and fruit. Conditions that reduce the amount of assimilate available tend to decrease the size of individual fruit. Increased plant density, greater numbers of fruit per plant, and reduced water supply tend to decrease fruit size. In muskmelon and watermelon, the soluble solids content of the fruit is an important measure of quality. Like fruit size, soluble solids tend to be lower under conditions that reduce assimilate level. High night temperatures, reduced leaf area, increased numbers of fruit per plant and increased plant density can all reduce soluble solids. (Wien, 1997). In contrast to its affect on fruit size, reduced water supply can increase fruit soluble solids (e.g., Bhella, 1985; Fabeiro et al. 2002).

Temperature and Crop Growth

Optimum average temperatures for growth are 65°F-75°F for pumpkin squash, cucumber and muskmelon, and 75°F-85°F for watermelon. Maximum average temperatures are

95°F for watermelon and 90°F for the other crops. (Maynard and Hochmuth, 2007). Predictions of crop development based on growing degree-days have been developed for some of these crops in specific environments. Base temperatures of 45°F for squash, 50°F for muskmelon, and 55°F for cucumber and watermelon are reported for North Carolina (Maynard and Hochmuth, 2007). Predicting crop maturity can be difficult for those crops harvested more than a few days after pollination and when multiple fruit are present, possibly because of the fruit load effects on fruit growth rate (e.g., Perry and Wehner, 1990).

Cucurbit crops are susceptible to chilling injury at temperatures below 45°F to 50°F. The lower the temperature and the longer the duration, the greater the injury. Symptoms of chilling include watersoaked spots on leaves, wilting, and death of roots. Chilled plants can survive, but they are set back in development. The fruit of these plants also are susceptible to chilling injury. Symptoms include sunken spots that are often invaded by decay organisms. The injury may not be immediately apparent on fruit, but the fruit will not last as long.

Active research on cucurbits continues to expand understanding of these crops. In the United States, major areas of research include pest management, grafting, organic production, reduced tillage systems, fruit quality, optimizing nutrient and water management, and breeding and molecular genetics.

Table 1. Acreage of major cucurbit crops in Indiana.

Crop	Area Harvested			Rank in US
	2002	2006	Value 2006	
	acres		*million dollars*	
Cucumber*	1600	1600	2.2	9
Muskmelon	3000	2700	7.2	5
Pumpkin	4242	(no data)	(no data)	7
Squash	470	(no data)	(no data)	–
Watermelon	6700	7400	26.0	6

*Cucumbers for processing only.
Source: USDA Census of Agriculture, 2002, and Indiana Agricultural Statistics 2006-2007.

Table 2. Scientific names and typical sex expression of common cucurbit vegetables.

Crop	Scientific Name	Sex Expression
Cucumber	*Cucumis sativus*	monoecious*, gynoecious, hermaphroditic, andromonoecious
Muskmelon	*Cucumis melo*	andromonoecious*, monoecious
Pumpkin (most jack-o-lantern and fresh market pie	*Cucurbita pepo*	monoecious

types)		
Pumpkin (processing)	*Cucurbita moschata* or *Cucurbita maxima*	monoecious
Squash, summer	*Cucurbita pepo*	monoecious
Squash, winter		
Acorn, Sweet Dumpling	*Cucurbita pepo*	monoecious
Buttercup, Kabocha	*Cucurbita maxima*	monoecious
Butternut	*Cucurbita moschata*	monoecious
Watermelon	*Citrullus lanatus*	monoecious*, andromonoecious

*Most common
Source: Loy, 2004; Wien, 1997.

Table 3. Effect of temperature on time to emergence for 3 cucurbits.

Crop	Days required for seedling emergence at various soil temperatures from seed planted ½ in deep.				
	59°F	68°F	77°F	86°F	95°F
Cantaloupe	(no data)	8	4	3	(no data)
Cucumber	13	6	4	3	3
Watermelon	(no data)	12	5	4	3

Source: Maynard, D.N. and G.J. Hochmuth, 2007. *Knott's Handbook for Vegetable Growers*, 5th Ed. John Wiley and Sons, Hoboken, NJ. p. 112. Adapted from J.F. Harrington and P.A. Minges, "Vegetable Seed Germination," California Agricultural Extension Mimeo Leaflet (1954).

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