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Organic Sweet Corn Production

HORTICULTURE PRODUCTION GUIDE

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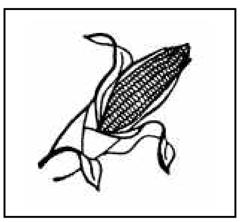
Abstract

Good markets exist for organic sweet corn. However, adequate weed and insect control can be difficult to achieve. This production guide addresses key aspects of organic sweet corn production, as well as post-harvest handling and economics. A list of web resources on sweet corn, especially those addressing ecological production practices, provides access to additional helpful information.

Although production guides on conventional sweet corn practices are readily available from the Extension Service, comprehensive information on organic cultivation practices is difficult to find. Organic sweet corn production differs from conventional production primarily in soil fertility and pest management practices. These issues are the primary focus of this discussion.



Organic Farming, Organic Certification, & the National Organic Program

Organic farmers rely heavily on crop rotations, crop residues, animal manures, legumes, green manures, composts, and mineral-bearing rock powders to feed the soil and supply plant nutrients. They manage insects, weeds, and other pests with mechanical cultivation and cultural, biological, and biorational controls. They do not use conventional commercial fertilizers, synthetic pesticides, or synthetic growth regulators.

A companion ATTRA publication—*Overview of Organic Crop Production*—is recommended to those seeking a better understanding of the history, philosophy, and practices of organic farming.

Organic certification emerged as a grassroots production and marketing

Contents

Table 1: Sweet Corn Genotypes				
Genotype	Sweetness	Conversion of sugars to starch	Isolate from	Comments
Normal sugary (su)	Moderately sweet	Rapid	(sh2) varieties	Early; germinates in cold soil
Sugary enhanced (se), (se+)	Sweeter than (su), less sweet than (sh2)	Not as rapid as (su)	(sh2) varieties	(se+) is sweeter than (se)
Super sweet or shrunken (sh2)	Very sweet	Very slow	(su), (se) & (se+) varieties	Longest shelf-life; germinates poorly in cold soils

tool during the 1970s and 1980s to ensure that foods labeled as "organic" met specified standards of production. The Organic Foods Production Act, a section of the 1990 Farm Bill, enabled the USDA to develop a national program of universal standards, certification accreditation, and food labeling.

In April 2001, the USDA released the Final Rule of the National Organic Program. This set of national regulations stipulates, in considerable detail, exactly what a grower can and cannot do to produce and market a product as organic. Application for certification must be made, paperwork completed, fees paid, and annual inspections undergone. To learn more about the details of the certification process, see ATTRA's *Organic Certification & National Organic Program* information packet.

When the national law goes into full effect in October 2002, any farmer selling produce labeled "organic" will have to be certified through a private or state-run certification agency accredited by the USDA. ATTRA maintains a comprehensive listing of these certification agencies; ask for the *Organic Certifiers Resource List*.

This publication focuses primarily on the certified organic growing of sweet corn, though some hard-to-find information of a more general nature is also included. For basic production information—planting dates, regionally adapted varieties, local market outlets—the Cooperative Extension Service is recommended. In addition, marketing assistance is often available through the Department of Agriculture in each state.

Sweet Corn Varieties

Variety selection is an important consideration in sweet corn production and includes factors such as sweetness, days to maturity, seed color, size, yield potential, and tolerance to pests. The Cooperative Extension Service can provide a list of varieties recommended for each region.

Modern sweet corn varieties are classified as: "normal sugary" (su); "sugary enhanced" (se) and (se+); and "shrunken" (sh2), also called "super sweet." These differ in flavor and tenderness, and in the rate at which starches are converted to sugar. In general, (se) lines yield the best, followed by (sh2), and finally (su).

Table 2. Commercial Organic Nitrogen Recommendations (4): Pounds of Organic Fertilizer Needed to Provide Variable Levels of Nitrogen (N)						
20 lbs N per acre	**40 lbs N per acre**	**60 lbs N per acre**	**80 lbs N per acre**	**100 lbs N per acre**	**Product**	**Percent N**
Pounds of product needed per acre:						
150	310	460	620	770	Blood meal	13%
330	670	1000	1330	1670	Cottonseed meal	6%
290	570	860	1140	1430	Soybean meal	7%
220	440	670	890	1100	Fish meal	9%
800	1600	2400	3200	4000	Alfalfa meal	2.4%

Cross-pollination of sweet corn with other kinds of corn or with some other sweet corn genotypes can result in starchy-tasting kernels. Generally, a minimal isolation distance of 250 feet between those varieties or types is recommended; 700 feet, however, is preferred for more complete isolation. Table 1 summarizes the general characteristics of sweet corn genotypes, including isolation requirements.

Soil Fertility

Nitrogen (N) is especially important in sweet corn production, not only for plant growth, but also for the production of amino acids that influence flavor and nutrition. Research at Michigan State University showed that 6% of the total nitrogen is taken up between germination and the 6th leaf stage, 25% from 7th leaf to tassel, 25% from tassel to silk, and 39% during ear development (1).

A common recommendation in conventional production is to apply 50 lbs N/acre prior to or at planting, followed by sidedressing with 60–80 lbs N/acre when the plants are 12–18 inches tall. The Pre-Sidedress Soil Nitrate Test (PSNT), also known as the Soil NO_3–N 'Quick Test', can be used to determine the need for any additional nitrogen fertilizer (2). It is now well established that if the nitrate-N level in the soil is above a threshold level of 25 ppm when the corn is six to twelve inches tall, additional N fertilizer will not increase yield (3).

Supplemental sidedress N fertilizers used in organic vegetable production include plant and animal by-products like blood meal, fishmeal, and soybean meal, as well as pelletized compost products.

Table 2, Commercial Organic Nitrogen Recommendations—modified from an information sheet produced by the University of Maine (4)—provides a handy guide to application rates for selected organic fertilizers to satisfy various levels of nitrogen need.

Research in Connecticut determined that 100 lbs N/acre (from commercial fertilizer) could produce optimum yields and economic returns for sweet corn (5). This research is significant because it found the standard rate used by Connecticut farmers, 160 lbs N per acre, was too high. In addition, it provides further support to the organic farming practice of raising sweet corn in rotation with forage legumes. For example, it is generally accepted that a healthy stand of hairy vetch can provide around 100–125 lbs N/acre to a subsequent crop. Recent research on cover crops in Maine—in which the authors state "*legume cover crops can supply all or most of the N required by a subsequent crop if legume biomass is of sufficient quantity and N mineralization is approximately synchronous with crop demand*"—substantiates this practice (6). When legume stands are poor and therefore nitrogen is estimated to be lacking, supplemental composts and organic fertilizers can be applied as necessary.

For additional information on estimating nitrogen production and release from cover crops, see ATTRA's *Overview of Cover Crops and Green Manures*.

Sweet corn does best with a pH of 6.0 to 6.5 and needs moderate to high levels of phosphorus (P) and potassium (K). Rate of application should be determined by soil testing. Rock phosphate, potassium sulfate (mined, untreated source), sulfate of potash-magnesia (K-Mag®), and a limited number of other rock powders may be used in certified organic programs.

One problem with rock phosphate is that P is very slowly available. In cold soils, P deficiencies (purple-tinged leaves) may become apparent. Thus, some growers drill a quickly available source of P—such as bone meal—at planting, to insure readily available P and a healthy crop stand. Other growers simply delay seeding until the weather and the soil warm up.

Rock mineral fertilizers, manures, and bulk composts can be applied and incorporated during field preparation and bedding operations; often application is made the previous fall to the preceding cover crop. Banding to the side of the row at planting is another option—primarily in combination with organic fertilizers or pelletized and fortified composts.

Foliar feeding, used in combination with a chlorophyll meter, is a yield-enhancing corn production practice advocated by the late eco-farming advisor, Don Schriefer. To illustrate the importance of photosynthate production in the early life of a corn plant, Schriefer emphasized the following facts relating growth phases of corn to yield potential (7):

- The number of rows of corn on the cob will be set five weeks after emergence. Rows will usually range from 14 to 18.
- Ear length and number of double ears per plant will be established nine weeks after emergence.

Foliar feeding, like many eco-farming methods, may be viewed as a sophisticated organic agriculture practice. To assist growers with technical details on crop manipulation through foliar feeding, ATTRA has compiled *Foliar Fertilization*, a resource packet in the Current Topics series.

While corn is relatively drought tolerant, yields are increased by irrigation, especially when applied during silking and when ears are filling. If irrigation is not an option and weed management is good, plants might be seeded further apart to reduce inter-plant competition.

Crop Rotations, Cover Crops, and Weed Control

An ideal rotation plan for organic sweet corn might look something like this:

- 2 years clover or legume pasture
- 1 year sweet corn
- 2 years other vegetables
- 1 year small-grain nurse crop mixed with clover

Corn typically follows pasture, hay, or a legume-based cover crop to take advantage of the nitrogen fixed by forage legumes, and because carry-over weed problems are more easily managed with a row crop like corn than with more narrowly spaced vegetable crops. Local organic growers can provide advice on rotations adapted to each region.

One efficient way to shift from vegetables to the small grain/clover mix is to plant a spring or summer vegetable crop in the last year of the vegetable rotation. After the vegetables are harvested, the field is seeded down to a cereal grain/clover mix. This usually occurs in early- to mid-autumn. When the cereal grain (e.g., rye, wheat, or oats) is harvested the following spring, the clover is already well established. Broadcasting cool-season cereal grains and legumes into standing vegetable crops is another way to establish these winter cover crops.

Long rotations like this are desirable because grass and legume sod crops are "soil builders," whereas row crops are "soil depleters." In addition to improving soil tilth, complex rotations are known to greatly enhance the non-chemical approach to weed control. According to Eliot Coleman, author of *The New Organic Grower*, a well-thought-out-rotation is worth 75% of everything else that might be done, including fertilization, tillage, and pest control (8).

On the other hand, short rotations and annual vegetable cropping is the norm for growers in many parts of the country. This is one of the reasons annual cover crops are used so prominently in organic farming.

A typical cover crop system for organic sweet corn is fall establishment of a winter annual legume, or cereal grain+legume mix. Pure stands of vetch or combinations of rye+hairy vetch or wheat+crimson clover are common. The cereal grains provide a fast soil cover and a significant amount of root biomass; the legumes fix nitrogen. The cover crop is then plowed down a couple weeks in advance of next season's crop—usually in mid-to-late spring, thus providing a green manure. The cost of the cover-crop seed and a legume inoculant may be viewed as an organic fertilizer cost.

Cover-crop and tillage systems adapted to sweet corn crops include clean-till, low-till, no-till, mulch-till, strip-till, living mulches, and relay intercropping. ATTRA's *Overview of Cover Crops and Green Manures* is recommended for a review of the benefits and uses of cover crops, and to gain access to important cover crop resources such as *Managing Cover Crops Profitably*, Sustainable Agriculture Network (SAN) Handbook No. 3, and the *UC-SAREP Cover Crops Database*.

Weed control in organic sweet corn is based on a good rotation and timely mechanical cultivation. Two rotary hoeings followed by two to three cultivations with sweeps and hillers is a common means of non-chemical weed control. Flame weeding and living mulches are complementary non-chemical weed suppression techniques used in commercial production, usually as an adjunct to mechanical tillage practices.

A midwestern organic vegetable grower explained, "We typically rotary hoe seven days and 14 days after planting corn, before weeds have emerged. We cultivate anywhere from 20 to 34 days after planting, when corn is 6 to 12 inches tall. Second cultivation is 35 to 50 days after planting, when corn is 18 to 20 inches tall" (9).

On larger farms, specialized weeding equipment may be an affordable option. State-of-the-art cultivating implements include rolling cultivators, finger tine weeders, finger weeders, basket weeders, spyders, torsion weeders, and spring hoe weeders. *Steel in the Field* (10), SAN Handbook No. 2, provides illustrations, descriptions, and practical examples of 37 specialized tools used to control weeds. It features profiles of farmers using reduced- or non-chemical weed control strategies, and contains a list of equipment manufacturers and distributors.

Research and Field Experience in Weed Control and Cover Crops

- A New York study showed improved production in sweet corn fields intercropped with white clover as a living mulch (11). White clover was multivated or rototilled with the middle tines removed, leaving strips of live clover growing between the corn rows—a procedure called "partial rototilling." To suppress excessive re-growth of the living mulch, white clover was partially rototilled two weeks after corn emergence. Waiting until the fourth or sixth week after sweet corn emergence to perform partial rototilling was less effective.

- Several Massachusetts farmers used propane flame weeders to control weeds in organic sweet corn. A stale seedbed was created by preparing the soil and then letting it sit for a couple of weeks to encourage weeds to sprout. The objective of the stale seedbed strategy is to kill these emerging weeds without further soil disturbance to avoid bringing new weed seeds to the surface. After the weeds emerge the field is "flamed" and then immediately planted. Flaming may be repeated prior to crop emergence (12).

- Economic thresholds for weeds in corn and soybeans were developed by University of Illinois. The fact sheet contains a chart that shows percentage of corn yield reduction in relation to number of weeds (e.g., pigweed, lambsquarters, Johnsongrass) per 100 feet of row (13).

- Whereas herbicides are commonly used in association with no-till production to chemically kill cover crops, a series of research reports and farm trials show that mow-down and roll-down methods can be used to knock down cover crops and provide a no-till mulch in vegetable production.

- Flail mowers are viewed as an ideal piece of mow-down equipment, but small-scale farmers are known to employ rotary mowers (brush hogs) and even string weeders (weed eaters) to chop down cover crops. Timing is important; hairy vetch should be mowed when the legume has already begun flowering; mowing of rye should also be delayed until flowering (when the anthers are shedding pollen).

- Researchers in Connecticut direct-seeded sweet corn into flail-mowed legume cover crops (hairy vetch, crimson clover, and field peas) mixed with oats as a nurse crop. Peas were winter-killed, leaving inadequate mulch cover. Vetch was the easiest cover crop to sow into, while crimson clover was the only cover crop to reseed itself. Yields were highest with hairy vetch, at 2.6+ tons fresh weight per acre (14).

- Mechanical roller-crimpers and rolling stalk-choppers are gaining increased attention as an effective kill method. These are heavy-duty drum rollers (similar to a cultipacker) with horizontal, welded, blunt-steel strips. When they are pulled through the field, they crush and crimp the cover crop, which leaves residue lying flat on the soil surface, discouraging regrowth. Research in Alabama showed that rolling down cereal grains like rye, wheat, and black oats was most effective after flowering (anthesis) and prior to soft dough (grain formation) (15).

- Overseeding cover crops into standing sweet corn—a technique known as relay intercropping—is one way to achieve cover crop establishment, usually with a goal to increase nutrient cycling (i.e., as a catch crop), suppress weeds (i.e., as a living mulch), or to enhance cropping-system diversity. Researchers in New Mexico broadcast forage brassicas, rape, and turnips into sweet corn at last cultivation ('early' intersowing) and blister stage of the sweet corn crop ('late' intersowing). Sweet corn yields were not depressed by intercropping. Sweet corn ears and stover were harvested in early September, while brassicas were harvested in November (16).

Insect Pest Management

Sweet corn can be attacked by a large number of insect pests. Among the most widespread and damaging are corn earworm, European corn borer, corn rootworm, and cutworm.

Corn Earworm

The corn earworm (*Helicoverpa zea)* is the larval stage of a moth that lays eggs in the corn silk. Corn earworm is also known as tomato fruitworm, cotton bollworm, and soybean podworm. In

Table 3. **Sweet Corn Cultivars with Some Resistance to Corn Earworm** (19, 20)		
Stowell's Evergreen	Hastings GB	Burpee HP
Silver Queen	Hastings CGS	Burpee PL
Viking RB	Hastings MER	Burpee HC
Supersweet JRB	Hastings KK	Burpee ST
Golden Bantam	Hastings IOC	Burpee ST
Jubilee	Hastings CAL	Burpee IXS
Texas Honey June	Hastings SWE	
Bodacious		

most of the country, the corn earworm (CEW) is the most destructive pest of sweet corn. CEW is particularly difficult to control because it is protected by the husk while feeding. Organic pest control strategies focus on variety selection and planting dates, cultural practices to increase natural biological control (parasitism and predation), and the use of microbial pesticides.

Management options begin with resistant varieties. Sweet corn varieties that mature early, that possess long tight husks extending beyond the tips of the ears, or contain naturally occurring earworm-repelling chemicals in the silks, show the most resistance to earworm attack (17, 18). Table 3 lists sweet corn varieties known to possess some level of resistance to CEW.

Northern growers can reduce the length of time sweet corn ears are exposed to CEW by using a short-season variety and planting early in the season (21). Early seeding is more effective as a cultural practice in northern states where the corn earworm moth is migratory, than in growing regions close to where the moth overwinters (e.g., South Texas and Mexico).

Naturally occurring biological control agents that prey on CEW eggs and larvae include lady beetles, lacewings, syrphid fly larvae, big-eyed bug, parasitic wasps and parasitic tachinid flies (22). Farmscaping—developing insect refugia through establishment of flowering plants grown in strips and field borders—may be used to encourage these beneficial insects on the farm. One farmscaping strategy entails the establishment of sweet alyssum (*Lobularia maritima*), a short-lived flowering annual, in occasional pest habitat strips or field borders (23). This flower is particularly attractive to parasitic wasps that prey on CEW (as well as caterpillar pests of cabbage-family vegetable crops). See ATTRA's *Farmscaping to Enhance Biological Control* for details and resources on this topic.

In addition to habitat manipulation through farmscaping, inundative release of the tiny parasitic *Trichogramma* wasps can enhance biological control. Levels of control achieved with *Trichogramma* release have varied from 20 to 100% (24). Favorable environmental conditions are important. For instance, when *Trichogramma* wasps are released, the cards bearing parasite eggs should be covered with a small tent to protect them from rain and sun (25). Commercial insectaries can provide additional information about timing, release rates, and the preferred *Trichogramma* species for specific regions.

Bacillus thuringiensis or Bt (trade names include Javelin, Dipel, Condor, and Lepinox), is a well-known microbial pesticide commonly used to control lepidopterous pests. However, aerial sprays of Bt are usually only "somewhat effective" against the CEW. This is because Bt must be ingested to be effective, and most larval feeding is done underneath the husk where foliar sprays do not reach.

In contrast, direct application of Bt mixed with vegetable oil to individual corn ears, applied two to three days after silks have extended to their maximum length (full brush), works "exceptionally well" as an organic approach to CEW control. However, direct application means application by hand, and this is time-consuming. Use of a machinery oiling can to inject the mineral oil increases the efficiency of this procedure. According to a USDA circular published in 1942, *Mineral-Oil Treatment of Sweet Corn for Earworm Control*, one worker is capable of treating one acre, or 12,000 ears, in an eight-hour day using one of these mineral oil injectors (26).

Although mineral oil treatment for corn earworm originated in the 1940s, on-farm research trials in the 1990s in both Oklahoma (27) and New England (28) have verified the utility of this approach, with recent research proving that a vegetable oil + Bt mix provides outstanding control. Ruth Hazzard, IPM specialist with the University of Massachusetts, has written several informative leaflets that describe a biointensive approach to sweet corn pest control, with detailed notes on vegetable oil + Bt mixtures. Several of these are listed in the web resources section below. To facilitate the farm-scale adoption of this approach, University of Massachusetts Extension developed and released a hand-held, gun-style applicator known as the Zea-Later™, available in 2001 from Johnny's Selected Seeds for a cost of $214 (29).

Two other microbial pest control strategies that show promise for CEW control include parasitic nematodes in the genera *Steinernema* and *Heterorhabditis*, and the entomopathogenic fungus *Beauveria bassiana* (trade names include Mycotrol, Naturalis, and BotaniGard). However, recommendations for their use are not well developed. The *Insect Parasitic Nematodes* (30) website, a SARE-funded project hosted by Ohio State University, is a good place to find details on biology and ecology of parasitic nematodes, retail suppliers, and fact sheets on application and use.

The efficacy of natural pesticide sprays and augmentative release of biocontrol agents like *Trichogramma* is dependent on timing. Pheromone traps are a common tool for monitoring the presence of adult CEW moths, telling the grower when egg-laying is likely to begin. They also provide an estimate of CEW population pressure.

Scouting and sampling for CEW eggs is a complementary monitoring technique. Earworm eggs are laid singly, usually on the corn silks. Newly laid eggs are white, but develop a reddish-brown ring after 24 hours. Eggs that have been parasitized by *Trichogramma* turn completely black within the eggshell. Scouting for eggs and monitoring egg maturation can help increase CEW pest control, as optimum timing for spraying can be determined within 12–24 hours. Despite the best intentions and the greatest of care, some CEW damage may occur. If so, worm-infested ears can be shucked and the damaged ends simply cut off at the tip. Consumers probably won't even know the difference, since shucked and cut corn has become a ready-packaged grocery item in recent years.

European Corn Borer

The European corn borer (*Ostrinia nubilalis)* overwinters as a fully-grown larva in the stems and ears of corn plants, usually just above the ground surface. As the weather warms in the spring, the larvae pupate, emerging later as adult moths. These adults mate, and the females lay eggs on the underside of the corn leaves. The smallest larval stages of the first generation feed on leaves and on other exposed plant tissues. After the larvae are half-grown, they bore into the stalk, the ear, or the thicker parts of the leaf stem. Once inside the plant, European corn borers (ECB) are difficult to control, so most management efforts are directed toward the egg and early larval stages.

It is interesting to note that ECB is one pest problem directly affected by soil management and fertilization. Researchers at Ohio State University collected soils from three sets of neighboring farms that had a history of conventional (inorganic fertilizers, pesticide inputs, and corn-soybean rotations) and organic (animal manures and forage-based, long-term rotations) management. The soil samples were placed in pots and each soil type was amended for nitrogen using [1] ammonium nitrate [2] fresh dairy-cow manure, or [3] no amendment. The potted corn plants were raised in a greenhouse, where ECP adults were released twice per week. The researchers observed preferential egg-laying: ECB adults laid 18 times as many eggs on potted plants with soils from conventionally managed farms, as on potted plants with soils from organically managed farms (31). This study confirms similar observations made in the late 1970s during research comparing organic and conventional farms in the western Corn Belt (32).

Pest management options for ECB include the use of resistant varieties, cultural controls (such as adjusting planting dates to avoid infestations), sanitation (the destruction of overwintering sites such as cornstalks), biocontrol agents, and microbial insecticides. Please note that making the best use of these tools requires field monitoring. Monitoring for ECB also includes the inspection of areas adjacent to the field, in addition to scouting of the field itself.

Release of parasitic *Trichogramma* wasps into sweet corn looks promising as a biological control method, but this technique is highly dependent on favorable environmental conditions. For release, the wasp eggs are attached to cards, each bearing between 100,000 and 140,000 eggs. Cards should be placed three to five acres apart, and covered with a small tent to protect them from rain and sun (33). Optimal timing for card placement is when tassels are in the whorl stage. After the wasps emerge, they parasitize ECB eggs. Insectaries have additional information about timing, release rates, and the preferred *Trichogramma* species for a specific area. Research reports show parasitism rates ranging from 60 to 97% using *T. ostriniae*, an Asian *Trichogramma* wasp (34). Cost for these releases are about $13 per acre for 60,000 wasps.

Bt var. *kurstaki,* the microbial pesticide, is an effective control for ECB. However, in order to be effective, the Bt must be ingested before the larva bores into the plant. Monitoring techniques are commonly employed to enhance accuracy and timing of Bt applications. Foliar sprays should be applied just before or after tassel emergence, but before silking and before larvae bore into the ear or stalk. *Biointensive Insect Management in Sweet Corn*, a factsheet by Ruth Hazzard and Pam Westgate of University of Massachusetts Extension, provides guidelines for Bt control of ECB and CEW (35).

USDA researchers working in association with Iowa State University state that *Beauveria bassiana,* the entomopathogenic fungus, applied in granular form during whorl-stage of corn development, can provide season-long control of corn borer populations (36). However, recommendations for commercial use are not well developed.

Destruction of ECB overwintering sites—that is, all crop residues and plant refuse in which the borers may spend the winter—is another control option. Stalks should be well shredded prior to plowing or disking for this method to be truly effective.

<u>Corn Rootworm</u>

The corn rootworm (*Diabrotica* spp.) is a beetle that feeds on corn leaves and clips corn silks, thus inhibiting pollination. The females lay eggs in late summer. These eggs hatch the following May or June. The larvae attack corn roots, reducing yield and causing stalks to blow over easily in high winds.

There are three common species of corn rootworm: the northern, western, and southern rootworms. Crop rotation is one of the most effective means of controlling the northern and western species, under most circumstances. In the late 1980s there were reports in several upper midwestern states of northern corn rootworm emergence in cornfields that followed soybeans in rotation. This was the result of extended diapause in which eggs spent two years in the soil before hatching, rather than the usual one year. This delayed hatch defeated common corn-soybean-corn rotations (37).

The Western corn rootworm has also developed means to overcome this simple rotation scheme. A new strain of the species, which some scientists are calling the "eastern phenotype," thrives in soybean fields as well as in the pest's traditional host, corn. One factor seems to be the presence of early-maturing corn varieties that the adult western corn rootworm finds less attractive than still-succulent soybean plants (38). As a result, longer rotations, featuring greater crop diversity, are becoming necessary to control these pests.

The Southern corn rootworm, also known as the spotted cucumber beetle, is controlled by late planting, and by fall and early spring plowing. Populations of all three species are suppressed by predatory ground beetles, tachinid flies, and beneficial nematodes.

<u>Cutworm</u>

Cutworms cut seedling corn stems at or near the soil surface. They feed at night and spend the day hidden in the soil. Normally considered a minor pest, cutworms can become a significant problem in sweet corn following sod, in no-till culture, and in fields adjacent to grassy areas. There are several species of cutworms that may become pests in corn, but the black cutworm is perhaps the most common.

Cultural measures are the traditional means of cutworm control. Fall plowing of sod, early spring plowing with delayed planting, control of adjacent vegetation, and crop rotation are commonly recommended. Land kept "clean-tilled" during the late summer is rarely infested.

Under conditions where infestations may occur, monitoring is encouraged to determine if additional control is advisable. Among the organic options for cutworm control are parasitic nematodes and Bt. Bt is more effective when mixed with bran and molasses, and applied as a bait. Another option is placing baits of corn meal or bran meal around the plant. When consumed, they swell inside the worm and kill it. Similarly, a molasses bait can be made from hardwood sawdust, bran, molasses, and water. Once ingested, the molasses hardens and renders the pest helpless. Organically acceptable sprays of pyrethrum and/or rotenone can also be used if applied late in the evening. Because these pesticides have short residual activity, several applications may be necessary.

<u>Insect Pest Monitoring</u>

Commercial pheromone traps and other monitoring devices such as black lights, strategically placed in sweet corn fields and border areas, provide an excellent means to determine the time of arrival and the level of infestation for several major pests, most notably the corn earworm and European corn borer. This information can improve control, and in many cases save on spray applications.

The Cooperative Extension Service has developed several excellent publications and resources to assist growers in learning how to trap, scout, and interpret results appropriately for their locale. *Sweet Corn IPM: Insect Pest Management* is a 30–minute video available through the University of Massachusetts (39). The video demonstrates the use of pheromone traps, field monitoring, pest action thresholds, and pesticide application for sweet corn pests in the Northeast.

Also recommended is the *Northeast Sweet Corn Production and Integrated Pest Management Manual*, a regional IPM publication produced by the University of Connecticut. Filled with handy tables, color photos, and illustrations, it includes helpful sections on cultural practices, cover crops, sidedress nitrogen recommendations, sweet corn pests, IPM monitoring, and IPM action thresholds (40).

The Internet has revolutionized the way agricultural information is distributed and obtained, and quite a few IPM materials are located on the world wide web. In fact, many of the Extension Service fact sheets and IPM newsletters are now available only in electronic format. A selection of web resources is provided at the end of this publication.

Sources of pheromone traps and IPM monitoring supplies include Gemplers IPM (42), Great Lakes IPM (43), and BioQuip Entomology Products (41).

✔ For additional background on trapping, scouting and similar IPM methodologies, request ATTRA's *Biointensive Integrated Pest Management*

Additional Research and Field Experience in Pest Control

- Soil application of the parasitic nematode *Steinernema riobravis* demonstrated a high degree of parasitism on the overwintering corn earworm population in a Texas study (44).

- An Ohio farmer achieved good control of corn earworm on 30 acres by treating individual ears with mineral oil, using eye droppers. His experience confirms previous research findings that eight person-hours per acre are required for "oiling," and that a single application is sufficient to be effective (45).

- Plant breeders at the University of Minnesota have made significant advances in recent years, developing sweet corn strains resistant to European corn borer. In 1992 they made this germplasm available to commercial breeders (46).

- A Massachusetts farmer achieved an exceptional level of European corn borer control on 70 acres of sweet corn by using *Trichogramma* wasps. He employed a new species, *T. ostriniae*, introduced from China and bred for release by the USDA (24).

- Oklahoma researchers had good results applying both vegetable- and petroleum-based oils as an over-the-top spray to control corn earworm. Some toxicity to plants, however, was observed with a petroleum-based oil (47).

- Field trials at Cornell University indicate that soil-applied formulations of pathogenic fungi such as *Metarhizium anisopliae* and *Beauveria bassiana* appear promising as a control for corn rootworm species (48).

- A Georgia farmer planted sweet corn in April along with a field border of dill, sweet basil, and tarragon. *Trichogramma* wasps were released in May. Earworm damage was reduced to one ear in ten. The previous year's damage was six ears in ten (49).

- *Handbook of Corn Insects*, a pest management handbook published by Entomological Society of America in 1999, provides a comprehensive guide to major and minor insect pests of corn. It addresses insect identification, life-history data, and management options, and includes a section on predators and parasites. It contains 158 color photographs, 132 illustrations, a directory of local information resources, and a glossary (50).

Diseases

Smut

Smut is a fungal disease contracted while the corn plant is a seedling. White or gray swellings on any part of the plant are indications of smut. Crop rotation and resistant varieties are the primary means of controlling this problem. Sulfur and copper fungicides can also be used. Badly affected plants should be removed and destroyed before the galls open and infect other plants.

Rust

Rust is another fungal disease. Infected plants have orange-brown raised spots on the leaves, which gradually enlarge and turn black before dying. Rust-tolerant cultivars should be used.

Stewart's Wilt

Stewart's bacterial wilt is a disease caused by a bacterium that affects sweet corn, especially early-maturing varieties. This disease can reduce yields and stunt (or kill) entire plantings. Some plants are killed in the seedling stage while others may not show symptoms until tasseling or later. Leaves develop long whitish streaks, and bacterial slime oozes from any cut plant part. Infected plants should be destroyed, and populations of flea beetles—the vector for this disease—should be kept low. Some hybrid varieties are resistant.

Maize Dwarf Mosaic

Mosaic is a viral disease that typically attacks late-planted corn. It is best controlled by resistant varieties. If susceptible varieties are planted, it's important to remove Johnsongrass, an alternate host, from adjacent areas, and keep aphids—the vectoring agent—in check.

Postharvest Handling

Since sweet corn is a highly perishable crop, postharvest handling is important. Proper treatment at harvest will help ensure good quality. For example, trimming the flag leaves off the ears at harvest reduces kernel denting, as the leaves draw moisture from the kernels.

Rapid removal of field heat via pre-cooling will help delay deterioration. Pre-cool the corn to 32° F within one hour after harvest and hold it steady at the same temperature (51). At optimum conditions of 32° F and 95% relative humidity, sweet corn has a storage life of 5–8 days. After 2–3 days, the product declines in flavor and tenderness. Sugar levels decrease less rapidly at 32° F. At 86° F, 60% of the sugars may convert to starch in a single day, versus only a 6% loss at 32° F.

Even at 50° F, sugar is converted four times more quickly than at 32° F (52).

Don Schlimme, a professor at the University of Maryland, recommends the following strategy for refrigerated storage of sweet corn (52). He uses enhanced or super sweet cultivars, harvested at optimum maturity. After husking and de-silking, cut the stem end close to the cob and remove insect damage on the tip end. Put the ears in ice water until the cob temperatures reach at least 40° F (15–30 minutes). Add 1 teaspoon of common household bleach per gallon of cold water to kill microbes. Add 1 teaspoon of white vinegar per gallon of water to lower the pH. Remove the ears from the water, drain for only a minute or two to avoid letting the corn warm up, and place in a gallon-size plastic bag. Then refrigerate the corn at 40° F (usually colder than the average home refrigerator). Sweet corn held in this way will last two weeks; holding the corn at 31° F will increase holding time to three weeks.

Several methods are available for pre-cooling sweet corn after harvest. Vacuum coolers are widely used by larger commercial operations. Hydrocooling (by spraying or immersing in water at 32–38° F), is the next best method and more easily accessible on a moderate scale, though it takes longer.

Crated corn needs to be left for over one hour in a hydrocooler to cool the corn to 41° F. Many growers, especially at small and medium scales of production, prefer mesh or burlap bags to crates because the same container used for field harvest can be easily dunked into the tank for cooling. Once cooled, the bags are ready for shipping or short-term cold storage.

After hydrocooling, the corn should be iced during transport and holding. If pre-cooling facilities are unavailable, top icing is absolutely necessary. The standard pack for sweet corn is 42–50 lb. cartons, wirebound crates, or sacks. Standard packs should be used, because sweet corn tends to heat when kept in a pile.

For growers selling to local markets, harvesting during the cool morning hours and selling as soon as possible are techniques that make hydrocooling unnecessary. U-pick marketing is another means of avoiding postharvest handling. For additional information, see ATTRA's *Postharvest Handling of Fruits & Vegetables*.

Table 4: Net Dollar Returns per Acre of Sweet Corn: Central California Coast †

	Wholesale Price Received per 48-ear box (unhusked)							
Yield	**$5**	**$6**	**$7**	**$8**	**$9**	**$10**	**$11**	**$12**
200	-814	-614	-414	-214	-14	+186	+386	+586
250	-699	-449	-199	+51	+301	+551	+801	+1051
300	-583	-283	+17	+317	+617	+917	+1217	+1517
350	-468	-118	+232	+582	+932	+1282	+1632	+1982
400	-352	+48	+448	+848	+1248	+1648	+2048	+2448

† Adjusted for changes in harvest costs due to yield

Table 5: Net Dollar Returns per Acre of Sweet Corn: Maryland †			
	Retail Price Received per Dozen Ears		
Yield	*$1.50*	*$2.50*	*$3.50*
250 doz	-854.40	-604.40	-479.40
500 doz	-479.40	+20.61	+270.61
750 doz	-104.40	+645.61	+1010.61
† The total variable and fixed costs developed in this budget was $1229.40/acre			

Marketing and Economics

An attractive feature of growing sweet corn, especially for the small farmer, is its marketability. Sweet corn sells quite well at farmers' markets and other direct-to-consumer venues, and a good-quality product is easily and rapidly sold out in most communities.

ATTRA has a number of marketing publications that can be of particular use to sweet corn growers. These include *Direct Marketing*, *Farmers' Markets*, and *Entertainment Farming and Agri-Tourism*.

Marketability is no guarantee of profitability, however. While sweet corn sells readily, it does not have a reputation as a money maker among small producers, though many use it to "bait" customers.

Table 4 was developed from budget information on California organic production in 1994 (53). It shows the influence of yield and market price on net returns. The range of yields and prices shown are realistic for that state. It should be noted that even with high yields and an optimal market, per-acre profitability is less than $2,500. Growers with limited acreage would be wise to consider alternative crops having higher potential net returns per acre.

A 1999 production budget for organic sweet corn in Maryland (54) produced a similar but more modest projection of profitability. The data is presented in Table 5.

Organic production budgets for many specialty crops can vary widely. It should be noted that the Maryland production budget used to create Table 5 found total variable and fixed costs per acre of $1,229.40. A 1996 budget for organic sweet corn in nearby New Jersey (55) found total variable and fixed costs of $1,901.13.

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Foss Hill Road
Albion, ME 04910
207-437-4395 (Commercial Department)
http://www.johnnyseeds.com
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http://www.gemplers.com

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By Ruth Hazzard, John C. Howell, A. Richard Bonanno, David N. Ferro, and Craig S. Hollingsworth, University of Massachusetts Extension
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Shelby's Sweet Corn Pest Alert Network
PennState Online Vegetable Resources
http://www.ento.psu.edu/vegetable/sweetcorn/default.html

Pests of Sweet Corn
PennState Online Vegetable Resources
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Corn Insect Pests collection of web links
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"Sweet Corn" links in Publications Database
http://www.agry.purdue.edu/ext/corn/

Relay Intercropping Brassicas into Chile and Sweet Corn
New Mexico State University, Guide A-609
http://cahe.nmsu.edu/pubs/_a/A-609.html

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New (Summer 2001) 42-minute **video** on ecological sweet corn production practices. The video was produced by Vern Grubinger, University of Vermont, and Ruth Hazzard, University of Massachusetts Extension, with funding from Northeast SARE. It features ten different farmers and the ecological farming practices they employ such as: hairy vetch cover crop; organic soil fertility; pre-sidedress nitrate test; mechanical weed control; spraying B.t. for European corn borer; Zea-Later oil application for corn earworm; etc. Cost, $15 through:

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**By Steve Diver, George Kuepper,
and Preston Sullivan
NCAT Agriculture Specialist
September 2001**

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