



# Sweet Corn: Organic Production

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Organic sweet corn may be grown for direct sale, the fresh market or processing. This publication discusses key aspects of producing organic sweet corn including varieties, soil fertility, crop rotations, weed control, insect pest management, diseases, harvesting, postharvest handling, marketing and production economics.

## Introduction

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 postharvest handling and economics. A list of Internet resources on sweet corn

provides access to helpful information on ecological production practices. ATTRA publications mentioned in this production guide are available online at [www.attra.ncat.org](http://www.attra.ncat.org) or by calling 800-346-9140.

Although production guides on conventional sweet corn practices are readily available from the U.S. Department of Agriculture Cooperative 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 publication.

## Organic farming and certification

Organic farmers rely heavily on crop rotations, crop residues, animal manures,



Photo courtesy of USDA/ARS.

legumes, green manures, composts and mineral-bearing rock powders to feed the soil and supply plant nutrients. Organic farmers manage insects, weeds and other pests with mechanical cultivation and cultural, biological and biorational controls. Biorational methods aim to manage the pest species with the minimum amount of disturbance to beneficial insects.

Organic farmers do not use conventional commercial fertilizers, synthetic pesticides or synthetic growth regulators. Organic farmers do not use genetic engineering, as defined in the excluded methods of the National Organic Program.

ATTRA’s *Organic Crop Production Overview* provides information on the history, philosophy and practices of organic farming.

## Related ATTRA Publications

Organic Crop Production Overview

Organic Farm Certification and the National Organic Program

Seed Production and Variety Development for Organic Systems

Overview of Cover Crops and Green Manures

Foliar Fertilization

Farmscaping to Enhance Biological Control

Cucumber Beetles: Organic and Biorational IPM

Biointensive Integrated Pest Management

NCAT's Organic Crops Workbook

Postharvest Handling of Fruits and Vegetables

Direct Marketing

Farmers' Markets: Marketing and Business Guide

Entertainment Farming and Agri-Tourism

Organic certification emerged as a grassroots production and marketing 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. Growers must be certified, complete paperwork, pay fees and undergo annual inspection. To learn more about the details of the certification process, see ATTRA's *Organic Farm Certification and the National Organic Program*.

The national law that took effect in October 2002 essentially requires farmers selling produce labeled organic to be certified through a private or state-run certification agency accredited by the USDA.

Section 205.204 of the NOP states that seed must be organically grown. Farmers may use untreated, non-organic seed when an equivalent organically produced variety is not commercially available. Most certifiers require that certified organic sweet corn be produced from certified organic seed. Although breeding efforts are underway, varieties bred specifically for organic production are not available at this time. Only seed of the usual commercial varieties produced under organic management

is available. For more information, see ATTRA's *Seed Production and Variety Development for Organic Systems*.

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 including planting dates, regionally adapted varieties and local market outlets, contact the Cooperative Extension Service in your area. In addition, marketing assistance is often available through each state's department of agriculture.

## 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.

Cross-pollination of sweet corn with other kinds of corn or with some other sweet corn genotypes can result in starchy-tasting kernels. Sweet corn will cross with field corn, including genetically engineered varieties, but not with popcorns. Generally, a minimal isolation distance of 250 feet between those varieties or types is recommended; 700 feet is preferred for more complete isolation. Some authorities recommend a quarter mile, or 1,320 feet. *Table 1* summarizes the general characteristics of sweet corn genotypes, including isolation requirements.

**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

### Seedling establishment

- Plant seed 1.5 to 2 inches deep.
- Plot rows no closer than 30 to 36 inches. Rows planted closer together may cause nutrient stress, be difficult to cultivate and cause shaded conditions for overseeding in the fall.
- Consider planting later than conventional growers. With the use of untreated seed, organic sweet corn growers often plant later, hoping that warmer soil temperatures will encourage quick germination, leading to better management of annual weeds (Michalak, 2002).

For suggestions on dealing with seed rots, see Cornell University's *Resource Guide for Organic Insect and Disease Management*. It is available online at [www.nysaes.cornell.edu/pp/resourceguide](http://www.nysaes.cornell.edu/pp/resourceguide). For information on finding this publication, see the *Sweet corn integrated pest management* portion of the **Resources** section at the end of this publication.

### 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 percent of the total nitrogen is taken up between germination and the sixth leaf stage, 25 percent from seventh leaf to tassel, 25 percent from tassel to silk and 39 percent during ear development (Evans, 1995).

A common recommendation in conventional production is to apply 50 pounds of nitrogen per acre prior to or at planting, followed by side dressing with 60 to 80 pounds of nitrogen per acre when the plants are 12 to 18 inches tall.

The Pre-Sidedress Soil Nitrate Test, also known as the Soil NO<sub>3</sub>-N Quick Test, can determine the need for any additional nitrogen fertilizer (Heckman et al., 1997). It is now well established that if the nitrate-nitrogen level in the soil is above a threshold level of 25 ppm when the corn is 6 to 12

inches tall, additional nitrogen fertilizer will not increase yield (Howell, 1998).

Supplemental sidedress nitrogen 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: Pounds of organic fertilizer needed to provide variable levels of nitrogen (N)**

(*Commercial Organic Nutrient Recommendations*, <http://anlab.umesci.maine.edu/handout/organ01.htm>)

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
<b>Pounds of product needed per acre:</b>						
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%

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

Research in Connecticut determined that 100 pounds of nitrogen per acre from commercial fertilizer could produce optimum yields and economic returns for sweet corn (Bravo-Ureta et al., 1995). This research is significant because it found the standard rate used by Connecticut farmers, 160 pounds of nitrogen per acre, was too high.

In addition, it provides further support for 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 to 125 pounds of nitrogen per acre to a subsequent crop.

Recent research on cover crops in Maine substantiates this practice. In the *Agronomy*



**S**weet corn does best with a pH of 6.0 to 6.5 and needs moderate to high levels of phosphorus and potassium.

*Journal*, authors of an article about cover crops for sweet corn 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” (Griffin et al., 2000).

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 (commercially available K-Mag) and a limited number of other rock powders may be used in certified organic programs.

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

Growers can apply and incorporate rock mineral fertilizers, manures and bulk composts during field preparation and bedding operations. Growers often make applications in the fall before planting the 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.

The late eco-farming adviser Don Schriefer advocated foliar feeding, used in combination with a chlorophyll meter, as a yield-enhancing corn production practice. 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:

- The number of rows of corn on the cob will be set five weeks after emergence. Rows usually range from 14 to 18.
- Ear length and number of double ears per plant will be established nine weeks after emergence (2000).

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 the publication *Foliar Fertilization*.

While corn is relatively drought tolerant, irrigation increases yields, 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 farther apart to reduce interplant competition.

## Crop rotations, cover crops and weed control

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

- Two years clover or legume pasture
- One year sweet corn
- Two years other vegetables
- One 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. This is because carry-over weed problems are more easily managed with a row crop like corn than with more narrowly spaced vegetable crops. Many farmers see an increase in corn yields of 5 to 7 percent following soybeans, and 10 to 15 percent following hay (Michalak, 2002). Local organic

growers can provide advice on rotations adapted to each region.

One efficient way to shift from vegetables to the small grain and 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 and clover mix. This usually occurs in early to mid autumn. When the cereal grain such as 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 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 percent of everything else that might be done, including fertilization, tillage and pest control (Davis, 2005).

On the other hand, short rotations and annual vegetable cropping are 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 and legume mix. Pure stands of vetch or combinations of rye and hairy vetch or wheat and 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 the 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 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 or three cultivations with sweeps and hillers are 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.

Crow Miller, a Midwestern organic vegetable grower, explained his weed control technique like this:

"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" (2001).

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*, a handbook from the Sustainable Agriculture Network, 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 (Bowman, 1997). Updated information on equipment suppliers can usually be easily obtained through an Internet search. ATTRA can help with specific requests about finding appropriate equipment.

### ***Research and field experience in weed control and cover crops***

A New York study showed improved production in sweet corn fields intercropped with

**M**ow-down and roll-down methods can knock down cover crops and provide a no-till mulch in vegetable production.

white clover as a living mulch (Grubinger and Minoti, 1990). White clover was mulched or rototilled with the middle tines removed, leaving strips of live clover growing between the corn rows. This procedure is called partial rototilling. To suppress excessive regrowth of the living mulch, researchers partially rototilled white clover 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. The farmers created a stale seedbed 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, farmers flamed and immediately planted the field. Flaming may be repeated prior to crop emergence (Hazzard, 1994).

The University of Illinois developed a fact sheet with economic thresholds for weeds in corn and soybeans. The fact sheet contains a chart that shows percentage of corn yield reduction in relation to number of weeds such as pigweed, lambsquarters and Johnsongrass per 100 feet of row (Pike).

Growers commonly use herbicides 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 knock down cover crops and provide a no-till mulch in vegetable production.

Flail mowers are an ideal piece of mow-down equipment, but small-scale farmers also 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 is already flowering. Delay mowing of rye 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. Researchers winter-killed peas, leaving inadequate mulch cover. Vetch was the easiest cover crop to sow into, while crimson clover was the only cover crop that reseeded itself. Yields were highest with hairy vetch, at 2.6-plus tons fresh weight per acre (DeGregorio et al., 1991).

Mechanical roller-crimpers and rolling stalk-choppers are gaining increased attention as effective kill methods. These are heavy-duty drum rollers similar to a cultipacker with horizontal, welded, blunt-steel strips. When pulled through the field, these drum rollers crush and crimp the cover crop and leave residue lying flat on the soil surface, discouraging regrowth. By having the roller-crimper placed on the front of the tractor, a seeder can be pulled at the same time, allowing for only one pass through the field. This not only reduces soil compaction, but also reduces energy and labor costs. Research in Alabama showed that rolling down cereal grains like rye, wheat and black oats was most effective after flowering, or anthesis, and prior to soft dough, or grain formation (Ashford et al., 2000).

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 as a catch crop, suppress weeds as a living mulch or to enhance cropping system diversity.

Researchers in New Mexico broadcasted forage brassicas, rape and turnips into sweet corn at last cultivation, known as early intersowing, and blister stage of the sweet corn crop, known as late intersowing. Intercropping did not depress sweet corn yields. Researchers harvested sweet corn ears and stover in early September and brassicas in November (Guldan et al., 1998).

## **Insect pest management**

A large number of insect pests can attack sweet corn. The American Phytopathological Society's 1999 *Handbook of Corn Insects* is the standard reference (Steffey et al., 1999).

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 most of the country, the corn earworm is the most destructive pest of sweet corn. Corn earworm 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 such as parasitism and predation, and the use of microbial pesticides.

Management options begin with resistant varieties. Sweet corn varieties that mature early, 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 (Davidson and Lyon, 1987 and Williams and Williams, 1994). *Table 3* lists sweet corn varieties known to possess some level of resistance to corn earworm.

Northern growers can reduce the time sweet corn ears are exposed to corn earworm by using a short-season variety and planting early in the season (Wiseman and Isenhour, 1994). Early seeding is more effective as a cultural practice in northern states where the corn earworm moth is migratory. The moth overwinters in



Corn earworm. Photo by R.L. Croissant, Bugwood.org.

some growing regions, such as south Texas and Mexico.

Naturally occurring biological control agents that prey on corn earworm eggs and larvae include lady beetles, lacewings, syrphid fly larvae, big-eyed bug, parasitic wasps and parasitic tachinid flies (Straub and Emmett, 1992). Farmscaping by developing insect refugia through establishment of flowering plants grown in strips and field borders may encourage these beneficial insects to stay 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 (Grossman and Quarles, 1993). This flower is particularly attractive to parasitic wasps that prey on corn earworm, as well as caterpillar pests of cabbage-family vegetable crops. See ATTRA's *Farmscaping to*

**Table 3. Sweet corn cultivars with some resistance to corn earworm**

(Wiseman and Isenhour, 1994; Pleasant, 1994)

Stowell's Evergreen	Bodacious	Hastings SWE
Silver Queen	Hastings GB	Burpee HP
Viking RB	Hastings CGS	Burpee PL
Supersweet JRB	Hastings MER	Burpee HC
Golden Bantam	Hastings KK	Burpee ST
Jubilee	Hastings IOC	Burpee ST
Texas Honey June	Hastings CAL	Burpee IXS



*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 varied from 20 to 100 percent (Miles, 1995). 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 (Shirley, 1992). Commercial insectaries can provide additional information about timing, release rates and the preferred *Trichogramma* species for specific regions.

**M**ost larval feeding is done underneath the husk where foliar sprays do not reach.

*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 corn earworm. 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 extend to their maximum length, or full brush, works exceptionally well as an organic approach to corn earworm 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 *Mineral-Oil Treatment of Sweet Corn for Earworm Control*, a USDA circular published in 1942, one worker is capable of treating one acre, or 12,000 ears, in an eight-hour day using one of these mineral oil injectors (Barber).

Although mineral oil treatment for corn earworm originated in the 1940s, on-farm research trials in the 1990s in both Oklahoma (Kuepper et al., 1991), and New England (Hazzard and Westgate, 2001), verified the utility of this approach, with

recent research proving that a vegetable oil and Bt mix provides outstanding control. Ruth Hazzard, an integrated pest management specialist with the University of Massachusetts, wrote several informative leaflets that describe a bio-intensive approach to sweet corn pest control, with detailed notes on vegetable oil and Bt mixtures. Several of these are listed in the **Resources** section below.

To facilitate the farm-scale adoption of this approach, UMass Extension developed and released a hand-held, gun-style applicator known as the Zea-Later. The Zea-Later II and the spray mixture for corn earworm control, made up of emulsified soybean oil mixed with Bt, are available from Johnny's Selected Seeds. See the *Sweet corn integrated pest management* portion of the **Resources** section for purchasing information.

Two other microbial pest control strategies that show promise for corn earworm control include parasitic nematodes in the genera *Steinernema* and *Heterorhabditis* and the entomopathogenic fungus *Beauveria bassiana*. Trade names include Mycotrol, Naturalis and BotaniGard. In 2007 the University of Maryland's annual *IPM Activities Report* stated that use of *B. bassiana* had become commonplace in certified organic vegetable production. The report, available at [www.mdipm.umd.edu/reports/index.cfm](http://www.mdipm.umd.edu/reports/index.cfm), said:

There are specific formulations developed for the organic market that have carriers ... acceptable to OMRI. *Beauveria bassiana* (Bb) has been very effective for us in controlling whiteflies and green peach aphid. We found it could suppress thrips if you started [applications] early.... We have worked with brand name BotaniGard, which is one of the more popular formulations of Bb. In most cases, it is best to apply *Beauveria bassiana* using a high-volume sprayer and penetrate the plant canopy to make contact with the pest ... Unfortunately, in our field tests with growers we found that the available formulations of Bb tended to clog commercial low-volume sprayers and we could not get even spore distribution [in greenhouse use] (Maryland Cooperative Extension, 2007).

The Insect Parasitic Nematodes Web site, a SARE-funded project hosted by The Ohio



State University, is a good place to find details on the biology and ecology of parasitic nematodes, retail suppliers and fact sheets on application and use. The Web site is available at [www.oardc.ohio-state.edu/nematodes](http://www.oardc.ohio-state.edu/nematodes). The University of Nebraska-Lincoln hosts a similar site, Plant and Insect Parasitic Nematodes, available at <http://nematode.unl.edu>.

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

Scouting and sampling for corn earworm 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 corn earworm pest control, as optimum timing for spraying can be determined within 12 to 24 hours.

Despite the best intentions and the greatest of care, some corn earworm damage may occur. If so, growers can shuck worm-infested ears and cut the damaged ends 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 and emerge 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



*European corn borer.* Photo by Frank Peairs, Colorado State University, Bugwood.org

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 are difficult to control, so most management efforts are directed toward the egg and early larval stages.

It is interesting to note that the European corn borer is one pest problem directly affected by soil management and fertilization. Researchers at The 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. Researchers placed the soil samples in pots and amended each soil type for nitrogen using ammonium nitrate, fresh dairy cow manure or no amendment. Researchers raised the potted corn plants in a greenhouse and released European corn borer adults twice a week.

The researchers observed preferential egg-laying. European corn borer 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 (Phelan et al., 1995). This study confirms similar observations made in the late 1970s during research comparing organic and conventional farms in the western Corn Belt (Kuepper, 2001).

Pest management options for European corn borer include the use of resistant varieties, cultural controls such as adjusting planting dates to avoid infestations, sanitation including the destruction of overwintering sites such as cornstalks, and biocontrol agents and microbial insecticides. Please note that making the best use of these tools requires field monitoring. Monitoring for European corn borer also includes inspecting 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 card bearing between 100,000 and 140,000 eggs. Cards should be placed from three to five acres apart and covered with a small tent to protect them from rain and sun (Shirley, 1992).

Optimal timing for card placement is when tassels are in the whorl stage. After the wasps emerge, they parasitize European corn borer 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 percent using *T. ostrinae*, an Asian *Trichogramma* wasp (Hoffmann et al., no date). Cost for these releases are about \$13 per acre for 60,000 wasps.



Corn rootworm. Photo by Scott Bauer, USDA Agricultural Research Service, Bugwood.org

Bt var. *kurstaki*, the microbial pesticide, is an effective control for European corn borer. 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 fact sheet by Ruth Hazzard and Pam Westgate of UMass Extension, provides guidelines for Bt control of European corn borer and corn earworm (Hazzard and Westgate, 2001).

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 (Leopold Center, 2001). However, recommendations for commercial use are not well developed. New research findings are assisting in development of non-Bt corn refugia planted within a measurable distance to Bt corn stands to allow the survival of susceptible moths to mate with resistant moths (USDA ARS, 2004).

Destruction of European corn borer overwintering sites, or 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 effective.

## Corn rootworm

The corn rootworm (*Diabrotica*) 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. Under most circumstances, crop rotation is one of the most effective means of controlling the Northern and Western

species. 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 (Swoboda, 1988). Geo-referenced grid samples for Northern corn rootworm, taken from 1995 to 2000 from two study sites in eastern South Dakota, show increased incidence of extended diapause in Northern corn rootworm (Ellsbury et al., 2002).

The Western corn rootworm 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 (Holmberg, 1996). 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. See the ATTRA publication *Cucumber Beetles: Organic and Biorational IPM* for more information.

## **Cutworm**

Cutworms cut seedling corn stems at or near the soil surface. Cutworms feed at night and spend the day hidden in the soil. Normally considered a minor pest, cutworms can be 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.



*Cutworm. Photo courtesy of Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org.*

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, corn meal and bran meal 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 or rotenone can also be used if applied late in the evening. Because these pesticides have short residual activity, several applications may be necessary.

## ***Insect pest monitoring***

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 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 UMass Extension. See the *Sweet corn integrated pest management* portion of the **Resources** section for information on obtaining the video. 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 integrated pest management 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, integrated pest management monitoring and action thresholds. See the *Sweet corn integrated pest management* portion of the **Resources** section for ordering information. Also, see the University of Connecticut Web site at [www.hort.uconn.edu/ipm](http://www.hort.uconn.edu/ipm) for updated sweet corn integrated pest management topics for the Northeast.

For additional background on trapping, scouting and similar integrated pest management methodologies, request ATTRA's *Biointensive Integrated Pest Management*.

The Internet revolutionized the way agricultural information is distributed and obtained, and quite a few integrated pest management materials are available online. Many of the Cooperative Extension Service fact sheets and integrated pest management newsletters are now available only in electronic format. A selection of Internet resources is provided at the end of this publication.

Sources of pheromone traps and integrated pest management monitoring supplies include Great Lakes IPM and BioQuip Entomology Products. See the *Sweet corn integrated pest management* portion of the **Resources** section at the end of this publication for ordering information.

## 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. Growers should remove and destroy infected 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. Use rust-tolerant cultivars.

### Stewart's bacterial 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 is important to remove Johnsongrass, an alternate host, from adjacent areas and keep aphids, the vectoring agent, in check.

**T**he Internet revolutionized the way agricultural information is distributed and obtained, and quite a few integrated pest management materials are available online.

## Harvest

The following are general guidelines for organic sweet corn harvest.

- The same techniques as conventional sweet corn are appropriate.
- Sweet corn should be handled differently and more carefully than animal feed, or dent corn.
- Organic corn must be kept separate from conventional corn in order to maintain its value and identity. Any equipment used for both organic and conventional crop harvest must be thoroughly cleaned before harvesting an organic crop.
- Although mechanical sweet corn harvesters are available, most harvest is still done by hand labor.
- Trimming the flag leaves off the ears at harvest reduces kernel denting since the leaves draw moisture from the kernels.
- For more information on organic regulations, see *NCAT's Organic Crops Workbook*.

## Postharvest handling

Since sweet corn is a highly perishable crop, postharvest handling is important. Proper treatment at harvest will help ensure good quality.

Rapid removal of field heat via precooling will help delay deterioration. Precool the corn to 32 degrees Fahrenheit within one hour after harvest and hold it steady at the same temperature (USDA, 1986). At optimum conditions of 32 degrees and 95 percent relative humidity, sweet corn has a storage life of five to eight days. After two to three days, the product declines in flavor and tenderness. Sugar levels decrease less rapidly at 32 degrees. At 86 degrees, 60 percent of the sugars may convert to starch in a single day versus only a 6-percent loss at 32 degrees. Even at 50 degrees, sugar is converted four times more quickly than at 32 degrees (Aylsworth, 1995).

Don Schlimme, a professor at the University of Maryland, recommends the following strategy for refrigerated storage of sweet corn. 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 degrees. This will take from 15 to 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 degrees; usually colder than the average home refrigerator. Sweet corn held in this way will last two weeks; holding the corn at 31 degrees will increase holding time to three weeks (Aylsworth, 1995).

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

Crated corn needs to be left for more than one hour in a hydrocooler to cool the corn to 41 degrees. 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 precooling facilities are unavailable, top icing is absolutely necessary. The standard pack for sweet corn is 42- to 50-pound cartons, wire-bound 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. You-pick marketing is another means of avoiding postharvest handling. For additional information, see ATTRA's *Postharvest Handling of Fruits and Vegetables*.

## Marketing and economics

In different parts of the United States organic sweet corn may be raised for shipping, for processing or for sale through alternative marketing channels such as farm stands, farmers' markets or community-supported agriculture systems.

Farmgate or wholesale prices for organic sweet corn are difficult to determine. Sample crop budgets and economic information differ widely from region to region and year to year. See **Appendix** for a crop budget template. Sweet corn yields vary widely depending upon the stand, growing conditions, weather and marketing channels, according to the University of California-Davis.

### Local markets: Fayetteville, Ark.

The Fayetteville (Ark.) Farmers' Market did not have certified organic sweet corn in 2008, but vendors marketed premium-quality conventional sweet corn at prices ranging from 50 cents per ear to six ears for \$5 toward the end of the marketing window in late August. That was up from 20 to 40 cents per ear in 2007. The produce manager of Ozark Natural Food Co-op in Fayetteville said organic produce prices are up 3 percent across the board this year, but he has discretion in marking up individual items. Although the co-op's policy is to buy local "when available," just about all the store's sweet corn is shipped in. In 2008, corn sold at retail for \$1.19 per ear; in 2007 the manager was able to offer it few times at 99 cents per ear. The customary markup is 100 percent (Freeman, 2008).

A 2001 survey done by the Organic Farming Research Foundation reported that 82 percent of organic sweet corn is grown for commercial processing such as canning and freezing.

The survey found farmgate prices for organic sweet corn range from \$1 to \$3.50 per dozen ears. A Colorado grower complained that "cheap prices through local supermarkets and a local economy in recession" made it "difficult to obtain the organic price premium." The window of availability for fresh market sweet corn is small compared with that of vegetables produced over a longer season or more amenable to storage, so it is not surprising that fresh market conventional competes with fresh market organic. Of 68 U.S. organic sweet corn producers surveyed, 16 percent direct marketed. The producers reported weather fluctuations as the No. 1 factor affecting returns to organic vegetable growers (Walz, 2004).

See the **Resources** section for a variety of crop budgets for sweet corn.

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 sells out easily and rapidly in most communities.

### Standards for sweet corn

#### Weights and measures

**Crate** = 4 to 6 dozen ears (North Carolina Extension, Organic Sweet Corn Production)

**50-pound waxed cardboard box** = 4 dozen ears (California Standards, Corn picked for shipping)

**Bushel** = minimum of 35 pounds of ears in the husk with minimum 8-inch ears with full kernel development (U.S. Bureau of Standards)

**Bushel of sweet corn** = From 35 to 40 pounds (University of Nebraska Weights and Measures, [www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationID=603](http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationID=603))

**Sweet corn** = From 6 to 8 pounds per dozen (University of Georgia, <http://caes.uga.edu>)

#### Per acre yields

##### Organic

826 to 1,240 dozen ears, or 248 crates (North Carolina Extension, Organic Sweet Corn Production) (Davis, 1997)

560 to 720 dozen ears, or 4.2 to 4.5 tons (OFRF 2001 survey) (Walz, 2004)

##### Conventional

1,400 to 2,000 dozen ears, or 350 to 500 48-count boxes per acre. This is about 17,500 pounds to 25,000 pounds, or 8.75 tons to 12.5 tons per acre (UC Davis figures for conventional sweet corn production)

1,000 dozen ears average (Oklahoma Extension figures for conventional sweet corn production)



**Table 4: Net dollar returns per acre of sweet corn: Central California coast †**  
(Klonsky et al., 1994)

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	+\$1,051
300	-\$583	-\$283	+\$17	+\$317	+\$617	+\$917	+\$1,217	+\$1,517
350	-\$468	-\$118	+\$232	+\$582	+\$932	+\$1,282	+\$1,632	+\$1,982
400	-\$352	+\$48	+\$448	+\$848	+\$1,248	+\$1,648	+\$2,048	+\$2,448

† Adjusted for changes in harvest costs due to yield.

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 attract customers.

*Table 4* was developed from budget information on California organic production in 1994 (Klonsky et al., 1994). 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 that have higher potential net returns per acre.

**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	+\$1,010.61

† The total variable and fixed costs developed in this budget were \$1229.40/acre

A 1999 production budget for organic sweet corn in Maryland produced a similar but more modest projection of profitability (Anon., 1999). 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 found total variable and fixed costs of \$1,901.13 (Anon., 1996).

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### Sweet corn integrated pest management

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*This guide is intended for organic farmers and farmers in transition to organic production, extension professionals and farm advisors. It includes crop management practices and fact sheets for materials accepted in organic production.*

- Johnny's Selected Seeds  
Foss Hill Road  
Albion, ME 04910  
(207) 437-4395 (commercial department)  
[www.johnnyseeds.com](http://www.johnnyseeds.com)
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- Sweet Corn IPM: Insect Pest Management  
[www.umass.edu/umext/imp/publications/other\\_pubs.html](http://www.umass.edu/umext/imp/publications/other_pubs.html)  
*30-minute video available for \$15 postage paid from:*  
*UMass Extension Bookstore*  
*Draper Hall, 40 Campus Center Way*  
*University of Massachusetts*  
*Amherst, MA 01003-9244*  
*(413) 545-2717*
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*Available for \$22.50 postage paid from: University of Connecticut Communication & Information Technology, U-35*  
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(517) 268-5911 fax  
[glipm@nethawk.com](mailto:glipm@nethawk.com)
- BioQuip Entomology Products  
17803 LaSalle Avenue  
Gardena, CA 90248-3602  
(310) 324-0620  
(310) 324-7931 fax  
[bqinfo@bioquip.com](mailto:bqinfo@bioquip.com)
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- Sweet Corn Pest Alert Network/Pests of Sweet Corn. PennState Online Vegetable Resources. <http://PestWatch.cas.psu.edu>
- Sweet Corn Pest Thresholds. PennState Entomological Notes. [www.ento.psu.edu/extension/factsheets/cornthresholds.htm](http://www.ento.psu.edu/extension/factsheets/cornthresholds.htm)
- IPM centers (Southern, North Central, Northeastern, Western Regions)  
IPM Web Resources for Sweet Corn  
IPM Crop Profiles—Sweet Corn  
[www.ipmcenters.org/index.cfm](http://www.ipmcenters.org/index.cfm)

The Sweet Corn Pheromone Trap Network for Western New York. [www.nysipm.cornell.edu/scouting](http://www.nysipm.cornell.edu/scouting)

Vegetable fact sheets—Pests, Diseases. Cornell University IPM. [www.nysipm.cornell.edu/factsheets/vegetables/](http://www.nysipm.cornell.edu/factsheets/vegetables/)

Corn Borer Killed By Beauveria Fungus. Iowa State University. [www.ent.iastate.edu/imagegal/lepidoptera/ecb/0164.8beauveria.html](http://www.ent.iastate.edu/imagegal/lepidoptera/ecb/0164.8beauveria.html)

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KingCorn.org: The Corn Grower's Guidebook. "Sweet Corn" links in publications database. [www.agry.purdue.edu/ext/corn](http://www.agry.purdue.edu/ext/corn)

Corn: Field and Organic. [www.kansassustainableag.org/Library/C.htm](http://www.kansassustainableag.org/Library/C.htm)

Growing Sweet Corn in Missouri. <http://extension.missouri.edu/explore/agguides/hort/g06390.htm>

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*A 42-minute video, **Farmers and Their Ecological Sweet Corn Production Practices**, was produced in 2001 by Vern Grubinger of the University of Vermont and Ruth Hazzard of UMass Extension with funding from Northeast SARE. It features 10 different farmers and the ecological farming practices they employ such as hairy vetch cover crop, organic soil fertility, pre-sidress nitrate test, mechanical weed control, spraying Bt for European corn borer, Zea-Later oil application for corn earworm and more. It is available in DVD or VHS format for \$15 through:*

*Center for Sustainable Agriculture  
University of Vermont*

*590 Main Street*

*Burlington, VT 05405-0059*

*(802) 656-5459*

*[www.uvm.edu/vtvegandberry/Videos/cornvideo.html](http://www.uvm.edu/vtvegandberry/Videos/cornvideo.html)*

# Appendix: Crop Budget Worksheet for Organic Sweet Corn

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(Klonsky et al., 1994)

**Yield** (1,000 doz. ears/# crates/tons) \_\_\_\_\_

**Price** (crate) \_\_\_\_\_

**Total costs** (sum of fixed and variable expense) \_\_\_\_\_

## Variable expenses

Soil amendments

    Compost with Gypsum (\$35/ton/ 6 tons/A) \_\_\_\_\_

Pest Management

    Trichogramma Wasps (\$00.00/card/2 cards) \_\_\_\_\_

    Pheromone (whole farm # units@\$\_\_\_\_\_) \_\_\_\_\_

Seed/A \_\_\_\_\_

Fuel/A \_\_\_\_\_

Repairs \_\_\_\_\_

Labor (hired) \_\_\_\_\_

Labor (operator) \_\_\_\_\_

Irrigation \_\_\_\_\_

Marketing costs (crates, etc.) \_\_\_\_\_

or

Marketing fee (\_\_\_%/sales) \_\_\_\_\_

## Fixed expenses

Interest on Operating Capital \_\_\_\_\_

Land use value \_\_\_\_\_

Machinery use value \_\_\_\_\_

Management fee \_\_\_\_\_





# Notes

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**Sweet Corn: Organic Production**

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