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SMALL GRAIN PRODUCTION MANUAL PART 13

Harvesting and Storage

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This publication, *Harvesting and Storage,* is the thirteenth in a fourteen-part series of University of California Cooperative Extension online publications that comprise the *Small Grain Production Manual*. The other parts cover specific aspects of small grain production practices in California:

- *Part 1: Importance of Small Grain Crops in California Agriculture*, Publication 8164
- *Part 2: Growth and Development*, Publication 8165
- *Part 3: Seedbed Preparation, Sowing, and Residue Management*, Publication 8166
- *Part 4: Fertilization*, Publication 8167
- *Part 5: Irrigation and Water Relations*, Publication 8168
- *Part 6: Pest Management—Diseases*, Publication 8169
- *Part 7: Pest Management—Insects*, Publication 8170
- *Part 8: Pest Management*—Vertebrates, Publication 8171
- *Part 9: Pest Management—Weeds*, Publication 8172
- *Part 10: Small Grain Forages*, Publication 8173
- *Part 11: Small Grain Cover Crops*, Publication 8174
- *Part 12: Small Grains in Crop Rotations*, Publication 8175
- *Part 14: Troubleshooting Small Grain Production*, Publication 8177

HARVESTING

Direct Combining

Most small grain crops in California are harvested when the moisture content of the grain is 8 to 12 percent. Grain is fully developed when its moisture content drops below 35 percent, but it cannot be stored safely until the moisture is below 14 percent. A simple test to determine whether grain is dry enough for harvest is to rub a grain head between the palms of your hands. If the kernels do not separate readily from the chaff or if the kernels separate but are easily dented with your thumbnail, the grain is too moist to harvest. Grain can be harvested at higher moisture content and artificially dried to below 14 percent before storage, but this is usually not cost-effective. Harvesting early and drying the grain may be justified in some cases by the time gained for planting a high-value crop that follows the small grain crop. If green weeds are present when the crop is ready for harvest, herbicides are available to desiccate the weeds so that normal combining can proceed.

Follow the manufacturer's recommendations for adjusting the combine when you prepare for harvest. Attachments can be added to measure the amount of grain

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being lost as unthreshed seed or as free seed over the shoe and straw walkers at the rear of the machine. Frequent adjustments are necessary during harvest as conditions change. Use a slower cylinder speed and less air as grain becomes drier; very dry grain kernels crack easily.

Windrowing

Windrowing (swathing) instead of direct combining is sometimes done to hasten drying, to dry out late-spring or summer weed growth, or to avoid grain yield losses by cultivars susceptible to grain shattering at maturity. Shattering is the loss of grain when kernels are knocked from the spikes (or panicles in oat) as the spikes move against each other or are whipped about by wind. Losses can vary greatly between cultivars. Cultivars of wheat with the tight glume characteristic do not shatter much but are more difficult to combine than those with loose glumes. Swathing should be done after the grain moisture level is less than about 35 percent (late dough stage) to avoid losses in grain yield due to underdeveloped (immature) kernels. Windrows can be combined after sufficient drying time (1 to 3 days).

STORAGE

Since prehistoric times grain has been stored to save seed, provide food between harvest seasons, and supply feed for livestock. Today, grain is harvested over a relatively short period of time during the year and is stored for a variable period (from a few weeks or less to several years) before being distributed to the final destinations as food, feed, seed, or other uses. An extensive system of grain handling and storage has been developed.

Handling and Storage Facilities

Today, much of the grain supply is stored in farm silos. Grain is also stored in bulk bins, bagged and stored in warehouses, and in commercial grain elevators.

- Farm silos store grain grown on the farm.
- Country silos store grain from surrounding farms for distribution to local mills and for transfer to larger regional silos.
- Regional or inland silos are located in heavy grain-growing and high-population areas and receive grain from country silos and import terminals.
- Export silos store grain in preparation for loading onto oceangoing vessels.
- Import silos store grain discharged from oceangoing vessels.

Grain Quality in Storage

Storage conditions should maintain the quality of the grain. The value of grain depends not only on the market situation but also on the condition of the grain. Grain quality is judged on characteristics including grain cleanness, shininess, plumpness, color, odor, and test weight; insect-damaged kernels; presence of live insects and foreign material; and proportion of germinated and broken kernels.

Length of time in storage and seed viability

The length of time that seed grain can be stored without loss of viability depends on the storage environment. The main factors are the moisture content of the seed while in storage and the storage temperature. Grain that contains 11 to 13 percent moisture or less can be stored in weatherproof bins or silos for many years in most climates without deterioration, provided it is protected from insects, rodents, external moisture, and high humidity. The composition of sound dry grain remains almost unchanged except for some increase in fatty acids and a slight loss of energy content from respiration. At average air temperatures weight loss in dry matter is about 1 percent over 20 years of storage. Prolonged storage results in a slight loss in protein. Under proper storage conditions, seed germination after 20-year storage is about 45 to 50 percent.

Grain moisture

Most small grain crops in California have a relatively low moisture content at harvest (8 to 12 percent). In other parts of the United States, the average moisture content at harvest ranges from 18 to 26 percent. Grain can be stored safely at a moisture content of below 14 percent; grain with a higher moisture content should be dried. The most economical method to dry grain is delay harvest until the grain reaches the desired moisture content. Low humidity, solar radiation, and windy conditions decrease grain moisture content. Forced unheated air can lower grain moisture if relative humidity is below 70 percent after the grain has dried to 15 to 17 percent moisture. The drying of grain requires airflow of 1 to 6 cubic feet per minute per bushel of grain (0.8 to 4.8 liters of air per minute per liter of grain). Using heated air to dry grain is costly, but it is rapid and dependable. Drying should start promptly after harvest and proceed continuously at a rate fast enough to avoid heat damage. For grain intended for seed, 110°F (43°C) is generally the upper temperature limit; for grain intended for milling, temperatures should not exceed 130°F (54°C); for grain intended for feed, temperatures from 145° to 160°F (62° to 71°C) are permissible.

Insect pests

Insects destroy as much as 30 percent of the world's supply of stored grain each year; however, in developed countries, losses are usually about 10 percent. More than 50 species of insects are found in stored grain and grain products in the United States. The most common and destructive stored-grain insect pests include

- granary weevil *(Sitophilus granarius)*
- rice weevil *(Sitophilus oryzae)*
- maize weevil *(Sitophilus zeamais)*
- saw-toothed grain beetle *(Oryzaephilus surinamensis)*
- red flour beetle *(Tribolium castaneum)*
- lesser grain borer *(Rhyzopertha dominica)*
- rusty grain beetle *(Cryptolestes ferrugineus)*

These insects are widely distributed in all grains, cereal products, and animal feeds, and are very common where grain is stored (silos, warehouses, storage bins, barns, and houses). Because most insect infestations originate after grain is placed in storage, sanitation offers the most practical means of preventing insect infestations. Grain should be free of infestation before being placed in storage. New grain should not be placed on top of old grain; bins should be completely emptied and cleaned before they are refilled. Extra care should be given to areas of potential insect contamination such as broken sacks and small piles of grain around machinery, grain bins, warehouses, and silos.

The temperature and moisture of the storage environment can be manipulated to prevent insect problems. As temperature and moisture become lower, the rates of insect activity, feeding, development, and reproduction are reduced. Grain temperature can be lowered by aeration with ambient air or refrigerated air. The goal is to reduce grain temperature to about 58° to 65°F (14° to 18°C), a level at which most insects either cannot complete development or grow very slowly. Simple temperature aeration controllers can be used to lower air temperatures to cool the grain at night. Insects such as weevils are long-lived at a temperature of about 58°F (14°C), and only prolonged exposure to temperatures below 50°F (10°C) significantly increases mortality; cooling with refrigerated air is an option in such cases. Secondary benefits of aeration include control of moisture migration, preservation of grain quality, and distribution of volatile toxicants.

The lower the moisture content of grain, the less susceptible it is to spoilage by insects and mites, as well as by fungi (see below). Mites and fungi are a problem only at moisture contents above 14 percent, and insects cannot reproduce in grain of moisture content below about 9 percent. To help prevent losses to insects, mites, and fungi, grain with a high moisture content must be dried either in the field or in storage after it is received using either ambient or heated air.

Corrective treatments are required when grain becomes infested; these treatments can include fumigation and heated air. The role of chemical grain protectants for insect control is in question because of the decreasing tolerances of chemical residues in grain and food products and the increasing incidence of insecticide resistance. Consult with your local UCCE Farm Advisor or pest control adviser for correct application materials and rates.

Monitoring is essential for protecting stored grain. Infestations can be detected in bulk grain by taking grain samples, usually with a spatial sampling program, at regular intervals of between 2 and 4 weeks. An alternative is the use of trapping procedures, such as probe traps and sex pheromone–baited flight traps, to detect insects in bulk grain and empty storage structures.

Fungal (mold) pests

Various fungi (molds) are an important part of the natural microflora of grain, both in field crops and in stored grain. The term "field fungi" is used to describe fungi growing on grains before harvest. Common field fungi include *Alternaria alternata, Cladosporium cladosporiodes, C. herbarum, Epicoccum nigrum, Fusarium* spp., and others. The term "storage fungi" is used to describe fungi involved in the deterioration of grains during storage. *Aspergillus* and *Penicillium* are the most important genera in this group, which includes *Aspergillus candidus, A. fumigatus, A. nidulans, A. repens, Penicillium brevicompactum, P. verrucosum, P. hordei, P. roquefortii,* and others.

The original source of both groups of fungi is the field. Invasion by fungi before harvest is governed primarily by the interaction between the plant host and the fungus, while growth by fungi after harvest is governed by crop nutrients, temperature and moisture, and competition by insects. Field fungi generally do not grow in grain with a moisture content less than 20 percent, and their growth is severely inhibited by low oxygen and high carbon dioxide concentrations. Clean and dry storage conditions combined with low storage temperatures are the best line of defense against fungi (and bacteria) that cause moldy grain. The best ways to prevent mold damage are to avoid storing grain with high moisture content and to cool the grain with aeration (temperatures that limit insect growth also reduce mold growth).

Fungal growth and mycotoxin production can be important causes of loss of quality in stored grain, especially in grain held at a high moisture content. Mycotoxins are produced by both field fungi and storage fungi. There are four basic types of toxigenic fungi:

- plant pathogens such as *Fusarium graminearum*, which causes scab, an important disease in the northern plains states but not currently in California
- fungi such as *Fusarium moniliforme* and *Aspergillus flavus* that grow and produce mycotoxins on senescent or stressed plants

- fungi that initially colonize the plant and predispose the grain to mycotoxin contamination after harvest, such as by *A. flavus*
- fungi that occur in the soil or in decaying plant material on the developing kernels in the field and later proliferate in storage, such as *Penicillium verrucosum* and *Aspergillus ochraceous*

The five agriculturally important fungal toxins include deoxynivalenol, zearalenone, ochratoxin A, fumonisin, and aflatoxin. Worldwide, aflatoxins produced by storage fungi have caused the most severe mycotoxicoses. Factors that affect mycotoxin formation in storage include moisture, temperature, time, mechanical damage to grain, oxygen and carbon dioxide levels, composition of substrate, fungal abundance, prevalence of toxigenic strains, spore load, microbiological interactions, and invertebrate vectors. *Eurotium* spp. (*Penicillium* spp.) xerophilic fungi are often the primary invaders of stored grains; once established, their metabolic activity raises the moisture content of the grain, allowing establishment and growth of fungi such as *Aspergillus flavus* and *A. parasiticus*. Mycotoxin production is maximized from about 77º to 96ºF (25º to 35ºC).

Vertebrate pests

Rodents, birds, and other wildlife can infest or damage stored grain. Rodent-proofing buildings and other storage areas is the best method of managing these pests. Secure any opening larger than ¼ inch (6 mm) in foundations, walls, floors, roofs, and eaves. Inspect grain storage facilities frequently for new infestations.

Safety of Grain Storage

Storage structures such as warehouses, storage bins, barns, silos, and granaries present significant hazards because the majority of time these facilities are enclosed and develop a toxic or oxygen-depleted atmosphere. Human exposure to reduced oxygen levels causes anoxia, which affects judgment, causes rapid fatigue or nausea, and can be fatal. Other toxic gases in grain storages include nitric oxide, nitrogen dioxide, nitrogen tetroxide, ammonia, and hydrogen sulfide. These gases can cause symptoms ranging from mild respiratory irritation to death, depending on the exposure. Respiratory hazards associated with grain storage structures include dust, mold, fungal toxins, and residual fumigants. Exposure to these hazards presents both long- and short-term health risks.

When working in grain storage facilities, always use the correct respiratory equipment and never enter a confined space alone. Falls from grain storage structures are a leading cause of injury. Safety cages should be installed around permanent ladders 20 feet (6 m) high or higher. When handling grain always remember the potential for grain dust explosion or fire. Be aware of potential ignition sources, such as electric shorts, hot engines, and open flames. Moving grain puts a large amount of highly flammable dust in the air. Proper safety procedures must be followed when operating grain handling equipment such as augers, sweepers, conveyers, and elevators. The grain itself can pose a serious safety threat. Moving grain cannot support the weight of a person; someone can sink very rapidly and become trapped or buried and suffocated by falling grain.

REFERENCES

Abramson, D., J. T. Mills, and R. N. Sinha. 1990. Mycotoxin production in amber durum wheat stored at 15 and 19% moisture. Food Additives and Contaminants 7:617–627.

Athie, I., R. Gomes, S. Bolonhezi, S. Valentini, and M. De Castro. 1998. Effects of carbon dioxide and phosphine mixtures on resistant populations of stored-grain insects. Journal of Stored Product Research 34:27–32.

Clement, L. D., L. F. Jackson, T. E. Kearney, J. P. Orr, R. L. Sailsbery, and J. F. Williams. 1982. Wheat production in the Sacramento Valley. University of California Division of Agricultural Sciences Leaflet 21323.

Cook, R. J., and R. J. Veseth. 1991. Wheat health management. St. Paul, MN: APS Press.

Flint, M. L., ed. 1990. Integrated pest management for small grains. University of California Division of Agriculture and Natural Resources Publication 3333.

———. 2002. UC IPM pest management guidelines: Small grains. University of California Division of Agriculture and Natural Resources Publication 3466. UC Statewide IPM Program Web site, http://www.ipm.ucdavis.edu/PMG/selectnewpest.small-grains.html.

Hocking, A.D., and H. J. Banks. 1991. Effects of phosphine fumigation on survival and growth of storage fungi in wheat. Journal of Stored Product Research 27:115–120.

Langseth, W., H. Stenwig, L. Sogn, and E. Mo. 1993. Growth of moulds and production of mycotoxins in wheat during drying and storage. Acta Agriculturae Scandinavica, Section B, Soil and Plant Science 43:32–37.

Magan, N., and J. Lacey. 1985. Interactions between field and storage fungi on wheat grain. Transactions of the British Mycological Society 85:29–37.

Miller, J. D. 1995. Fungi and mycotoxins in grain: Implications for stored product research. Journal of Stored Product Research 31:1–16.

Reed, C., and J. Harner. 1998. Cooling of stored wheat in multiple or single cycles using automatic aeration controllers. Applied Engineering in Agriculture 14:497–500.

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