UNIVERSITY OF CALIFORNIA
Division of Agriculture and Natural Resources
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PUBLICATION 8165

SMALL GRAIN PRODUCTION MANUAL PART 2

Growth and Development of Small Grains

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

- *Part 1: Importance of Small Grains in California Agriculture*, Publication 8164
- *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 13: Harvesting and Storage*, Publication 8176
- *Part 14: Troubleshooting Small Grain Production*, Publication 8177

The growth and development of the small grains—wheat, triticale, barley, and oat—follow very similar patterns (fig. 1). Plant development is divided into several stages: germination and early seedling growth, tillering and vegetative growth, elongation and heading, flowering, and kernel development. Numerical scales have been devised for quantifying the growth stages of small grains. Those most commonly used are the Zadoks, Feekes, and Haun growth scales (table 1). The Zadoks system uses a 2-digit code to refer to the principal stages of growth from germination (stage 0) through kernel ripening (stage 9). The second digit subdivides each principal growth stage. For instance, "13" indicates that in principal stage 1 (seedling growth) subdivision 3, leaves are at least 50 percent emerged from the main stem; "75" indicates that in principal stage 7 (kernel development) subdivision 5, the grain is at the medium milk stage. The Feekes scale (1 to 11.4) numerically identifies stages from emergence through ripening. The Haun scale deals mainly with the pattern of leaf production, in which the length of each emerging leaf is expressed as a fraction of the preceding leaf. For more information on these scales, see Simmons, Oelke, and Anderson 1995.

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Table 1. Comparison of Zadoks, Feekes, and Haun growth scales for small grains

Growth stage	Scale		
	Zadoks	**Feekes**	**Haun***
planting	00	—	—
emergence	10	1	0.0
first leaf	11	1	0.0–1.0
second leaf	12	1	1.1–2.0
third leaf	13	1	2.1–3.0
tillering	21–29	2–4	3.1–6.0
jointing	31	6	6.1–10.0
flag leaf	37–39	8	8.1–9.0
boot	40–47	9–10	9.1–10.0
heading	51–59	10.1–10.5	10.1–11.0
flowering	61–69	10.5.1–10.5.3	—
grain formation	71	10.5.4	—
milk	71–79	11.1	—
soft dough	85	11.2	—
hard dough	87	11.3	—
harvest ripe	92	11.4	—

Source: Flint 1990, p. 12.
Note: * Values are for Yecora Rojo wheat

GERMINATION AND EARLY SEEDLING GROWTH

The kernel (seed), or caryopsis, consists of a seed coat surrounding an embryo and endosperm. The embryo contains the seedling root (radicle), stem, and growing points of the new grain plant. The endosperm provides nutrients for growth until the first true leaves emerge and the root system is established. When moisture conditions are favorable, the seed germinates with the emergence of the radicle and the coleoptile, the first leaf that forms a protective sheath around the first four leaves.

The primary root system includes the radicle and roots that develop from stem tissue near the kernel (see fig. 1). It may penetrate the soil up to 12 inches (30 cm) and provides the developing seedling with water and nutrients. The primary root system supports plant growth until tillering, when the secondary root system becomes the main root system of the plant. The primary roots may persist for the life of the plant and can support some plant growth through the heading stage. The first secondary roots appear at the tillering node about 1 inch (2.5 cm) below the soil line at the two- or three-leaf stage. These roots are always produced at about the same distance below the soil's surface, regardless of the depth at which the seed is planted. The secondary root system makes up the major part of the fully developed plant's root system. Root growth may continue at ½ inch (12.5 mm) per day for 60 to 70 days. With no competition, roots may spread 4 feet (1.2 m) horizontally and 6 feet (1.8 m) vertically, with most roots in the top 2 feet (60 cm) of soil. Horizontal root growth is less than 1 foot (30 cm) in wheat fields with normal plant

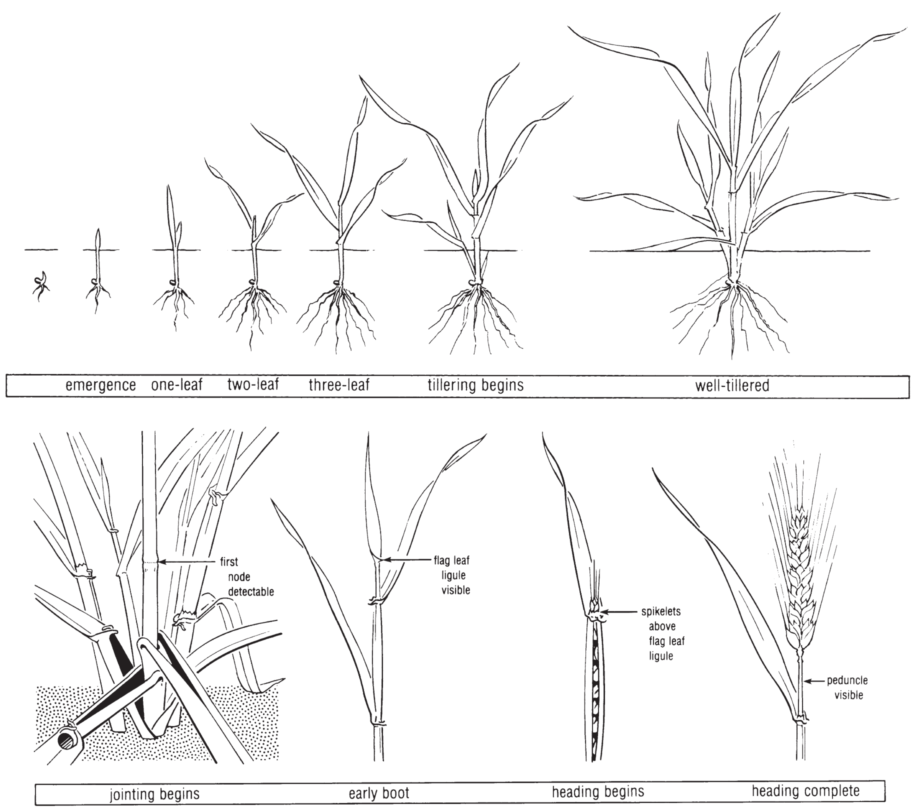

Figure 1. Small grain developmental stages. *Source:* Flint 2002.

population density. Root development approaches the maximum at about the boot stage. The "boot" represents the swollen flag leaf sheath within which the developing spike is located after being pushed up as the stem has elongated.

As the seedling root system is forming, the coleoptile grows upward and ruptures, allowing the first leaf to begin unfolding as soon as the coleoptile tip breaks the soil surface. Emergence usually occurs 6 to 20 days after sowing, depending on temperature and moisture. Emergence can be later than 20 days after sowing under prolonged cold or dry conditions. Initial formation of leaves and stems occurs at the shoot apex, which is located just below the soil surface.

TILLERING AND VEGETATIVE GROWTH

Branching in small grains is called tillering or stooling. Individual branches are called tillers, and the mass of tillers is the stool. Two to four primary tillers develop from buds in the crown area of the main stem. Secondary tillers develop from buds in the axils of leaves at the base of the primary tillers. Tertiary tillers may develop from buds in the axils of leaves at the base of the secondary tillers. Each plant has the potential to produce more than 50 tillers. Usually only two to four tillers survive to produce fertile spikes at normal seeding rates and growing conditions. The number of tillers that form is influenced by plant density (more with low plant density), soil moisture and nutrient supply (more with high supply), sowing date (more with early sowing), temperature (more under cooler temperatures), and cultivar. Water stress, nutrient deficiency, low temperatures, weed competition, and pest damage during early development reduce the number of tillers.

The emergence of primary tillers is synchronous with the emergence of leaves on the main stem of the plant. The first primary tiller begins developing as leaf 4 of the main stem emerges; the second primary tiller begins developing as leaf 5 emerges. Subsequent primary tillers begin developing when subsequent leaves emerge. Successive tillers develop fewer leaves; flowering and grain development is only slightly delayed on later-developing tillers. Before the main stem and tillers begin to elongate, the spikes (panicles in oat) differentiate. The precursors (primordia) of all florets (flowers with lemma and palea, the outer bracts) or spikelets (units consisting of several florets on a thin axis, subtended at the base by two bracts, or glumes) develop at this time. In wheat and oat, formation of new spikelets ends with the formation of the terminal spikelet, which usually occurs when leaf 6 appears. A terminal spikelet is not formed in barley.

Wheat, barley, and oat appear very similar in the vegetative stage. However, they can usually be easily distinguished based on auricle (a pair of clawlike projections at the junction of the leaf sheath and blade) characteristics. On barley, the auricles are long and clasping; on wheat, the auricles are short; on oat, auricles are absent.

STEM ELONGATION AND HEADING

Stem elongation, or jointing, occurs when stem internodes increase in length and bring the nodes above ground. The uppermost five or six internodes elongate, beginning with the lowest of these. The appearance of the first node above ground marks the beginning of jointing. Jointing begins about the time all spikelet primordia have formed. The flowering structure (inflorescence) of wheat, triticale, and barley is called a spike; that of oat is called a panicle. Inflorescences are composed of spikelets, each consisting of one or more flowers, called florets, at nodes along the spike or panicle. In barley, three spikelets form at each node, and each spikelet has a single floret. All three spikelets are fertile in 6-row barley; only the middle spikelet is fertile in 2-row barley. One spikelet forms at each node of the wheat and triticale spike, but each spikelet consists of three to six potentially fertile florets. In the highly branched panicle of oat, individual spikelets form at the end of branches.

During stem elongation the spike or panicle increases in length from about 0.1 inch (3 mm) to its final size, and individual florets mature. All stages of spikelet development in wheat, triticale, and barley begin near the middle of the spike and proceed toward the base and tip. Development of oat florets begins at the tip of the panicle branches and proceeds toward the base. The last leaf of the small grain plant to emerge is called the flag leaf. When the flag leaf blade has completely emerged, the appearance of its ligule (a short membrane on the inside of the leaf at the junction of the blade and sheath) marks the beginning of the boot stage. During boot stage the enlarging spike swells and splits the sheath of the flag leaf. Heading begins when the spike begins emerging through the flag leaf collar and is complete when the base of the spike is visible.

Figure 2. Stages of grain ripening in wheat. *Source:* Flint 1990, p. 14.

FLOWERING AND GRAIN FILLING

The flowers of wheat, triticale, barley, and oat are self-pollinated; most of the pollen is shed before the anthers emerge from the florets. Flowering (anthesis, or pollen shed) usually occurs within 2 to 4 days after spikes have completely emerged from the boot (barley often flowers prior to emerging from the boot). If emergence occurs during hot weather, flowering may occur while spikes are still in the boot. Most cells of the grain endosperm are formed during a period of rapid cell division following pollination. These cells enlarge and accumulate starch during grain filling. Most of the carbohydrate used for grain filling comes from the photosynthetic output of the flag leaf. Developing spikelets compete for limited supplies of photosynthate and nitrogen. The smallest, slowest-growing florets, which occur at the tip of the barley spike and at the tip of each wheat spikelet, are often unable to obtain enough nutrients to keep growing. Some spikelets at the base of the wheat or barley spike also may fail to develop.

The stages of grain ripening are called milk, soft dough, hard dough, hard kernel, and harvest ripe (for wheat, see fig. 2). Dry matter begins accumulating in the kernel during the milk stage. During early milk stage, a clear fluid can be squeezed from the kernel. During late milk stage, milky fluid can be squeezed from the kernel. Most of the dry matter accumulates during the soft dough stage. Loss of water gives the kernel a doughy or mealy consistency. At the end of the hard dough stage the kernel reaches physiological maturity, water content drops to about 30 percent, and the plant loses most of its green color. The kernel contents can be divided with a thumbnail. At the hard kernel stage the plant is completely yellow and water content of the kernel is 20 to 25 percent. The contents of the kernel are difficult to divide with a thumbnail, but its surface can be dented. When kernel moisture content has dropped to 13 to 14 percent, the grain is harvest ripe. The surface of the kernel cannot be dented with a thumbnail.

GROWTH HABIT

Wheat, triticale, barley, and oat are classified as having either a spring or a winter growth habit. Plants with a winter habit require a period of chilling, or vernalization, to induce the formation of reproductive structures. Without proper vernalization, winter-habit plants either fail to head or head much later than normal. Plants with a spring habit do not require vernalization. Most California production consists of fall-sown spring-habit small grain crops. However, since market classifications sometime refer to the season of production, not growth habit, California's production is often referred to as winter-type cereals (e.g., hard red winter wheat). True winter wheat and winter barley are produced on limited acreage in the intermountain area of north-central and northeastern California.

YIELD COMPONENTS

Grain yield is the product of plant density, tiller number, number of spikes per plant, number of spikelets per spike, number of kernels per spikelet, and kernel weight. Plant density is determined by seeding rate, germination percentage, and the number of seedlings that emerge and survive. Tiller number per plant depends on plant density, cultivar, sowing date, availability of moisture and nutrients, and temperature. The number of spikelets that can form is determined by when stem elongation is initiated; stress (weed competition, heat, cold, drought, nutrient deficiency, diseases) during this period reduces the number of spikelets that are formed. Florets are initiated during the stem elongation stage. The small grain plant is not able to produce enough photosynthate to allow development of all florets. The fastest-growing florets have first access to the available carbohydrate, nitrogen, and other nutrients and are the most likely to produce mature seed. Good growing conditions during stem elongation favor development of the maximum number of florets. The cells of the endosperm accumulate starch and protein during grain filling. Any stress or damage that reduces photosynthetic output or interferes with the transport of carbohydrate between flowering and hard dough stage will reduce kernel weight.

Timing of Field Activities

Table 2 gives approximate dates when important crop growth stages occur for wheat produced in key growing regions of California. The dates and corresponding growth stages are for common wheat cultivars sown at optimal planting dates with sufficient soil moisture to initiate germination. Seasonal weather conditions are considered average. Depending on the cultivar selected, crop development may vary 7 days on either side of the dates specified. Similarly, even under the most variable weather conditions, crop development will be within about 7 days of the dates specified. For barley, heading and grain-fill dates will be advanced by about 2 weeks. Herbicides for early-season weed control should be applied prior to the onset of tillering, when weeds are small (follow

Table 2. Approximate dates of selected wheat growth stages in key growing regions of California

	Date growth stage attained for region and approximate sowing date					
Growth stage	**Intermountain Area (winter) mid Oct. to early Nov.**	**Intermountain Area (spring) mid April**	**Sacramento Valley mid Nov.**	**San Joaquin Valley late Nov. to Mid Dec.**	**Central Coast early Nov.**	**Imperial Valley mid Dec.**
emergence	Nov. 10	May 1	Dec. 1	Dec. 30	Dec. 1	Dec. 30
tillering	Jan. 15	May 15	Jan. 1	Feb. 5	Jan. 1	Jan. 15
jointing	April 1	June 10	Feb. 15	Mar. 10	Feb. 18	Feb. 15
boot	May 15	June 20	April 1	April 1	April 10	March 15
heading/flowering	June 1	July 15	April 15	April 10	April 30	April 1
milk	June 15	July 20	May 1	April 25	May 15	April 10
soft dough	June 25	Aug. 1	May 15	May 10	May 30	April 20
hard dough	July 10	Aug. 15	June 1	May 25	June 15	May 1

the label). Herbicide applications for later-season weed control should be made when the crop is fully tillered. Fertilizer top-dressing should be made at the mid-tillering stage. Nitrogen top dressing to improve grain protein should be made at heading or flowering in conjunction with an irrigation. If fungicide applications to control foliar diseases are planned, they should be applied to protect the flagleaf and penultimate leaf (the leaf that emerges prior to the flagleaf), and thus should be made just prior to boot stage.

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Publication 8165

ISBN-13: 978-1-60107-405-8
ISBN-10: 1-60107-405-0

UC PEER REVIEWED

This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by the ANR Associate Editor for Agronomy and Range Sciences.

pr-09/06-SB/CM