GROWTH AND DEVELOPMENT GUIDE FOR Spring Barley

P.M. ANDERSON, E.A. OELKE
AND S.R. SIMMONS

Agricultural Extension Service • University of Minnesota • AG-FO-2548

GROWTH AND DEVELOPMENT GUIDE FOR

Spring Barley

P.M. Anderson, E.A. Oelke, and S.R. Simmons*

Introduction

Barley (*Hordeum vulgare* L.) originated in the Eastern Mediterranean region. Barley can be distinguished by differences in head type and growth habits. In a six-rowed barley, three kernels are formed at each node of the head while in a two-rowed type, only a single kernel forms at each node (figure 2).

Barley is also classed by its requirement for cold temperatures. Winter barley must be planted so that seedlings will be exposed to cold (vernalized), which enables it to later produce heads and grain normally. Winter barley is usually sown in the fall for exposure to low temperatures during the winter and then development is completed during the following spring and summer. Spring barley does not require exposure to winter temperatures and can be sown in spring. Winter types usually mature somewhat earlier than spring types. Growth and development of the six-rowed spring barley commonly grown in Minnesota will be considered here. Figure 1 shows major developmental stages in spring barley with the approximate time and heat units required to reach each stage. Differences in maturity exist among varieties.

Barley production has become more intense and complex in recent years. Crop managers must understand barley development and be able to recognize growth stages because of the increased use of growth stage sensitive production inputs such as chemical fertilizers, pesticides, and growth regulators.

* P.M. Anderson is a former graduate research assistant and E.A. Oelke is a professor in the Department of Agronomy and Plant Genetics and an agronomist with the University's Agricultural Extension Service. S.R. Simmons is an associate professor in Agronomy and Plant Genetics.

Growth staging

A number of staging systems have evolved for describing the development of cereal crops such as barley. The Zadoks system is becoming the most universally accepted and is described here. It is applicable to any small grain, and its stages are easy to identify in the field. The Haun and the Feekes-Large staging systems will be briefly introduced.

The Zadoks system is a two-digit code where the first digit refers to the principal stage of development beginning with germination and ending with kernel ripening. Table 1 gives the nine principal growth stages. The second digit (also between 0 and 9) subdivides each principal growth stage. A second digit value of 5 usually indicates the midpoint of that stage. For example, a 75 refers to the medium milk stage of kernel development. In seedling growth (principal growth stage 1) the second digit refers to the number of emerged leaves. To be counted, a leaf must be at least 50 percent emerged. A code of 13 indicates that three leaves on the main shoot are at least 50 percent emerged. Tiller leaves are not counted. For tillering (principal stage 2), the second digit indicates the number of emerged tillers present on the plant.

Since stages may overlap, it is possible to combine Zadoks indexes to provide a more complete description of a plant's appearance. For example, a plant with one tiller and three leaves could be described by either or both of the Zadoks stages 13 and 21. To time herbicide applications, the seedling stage (stage 1) identifying the leaf numbers is useful. As the plant matures, the Zadoks stages describing kernel development are usually used alone. A more complete description of the Zadoks system is available in the reference by Zadoks, Chang and Konzak (5) cited at the end of this publication.

Figure 1. Timetable with approximate days after emergence and growing degree days (base 40°F) required to attain various growth stages. Data are for an intermediate maturing variety grown in St. Paul, Minnesota. For simplicity, tillers are not shown after "advanced tillering."

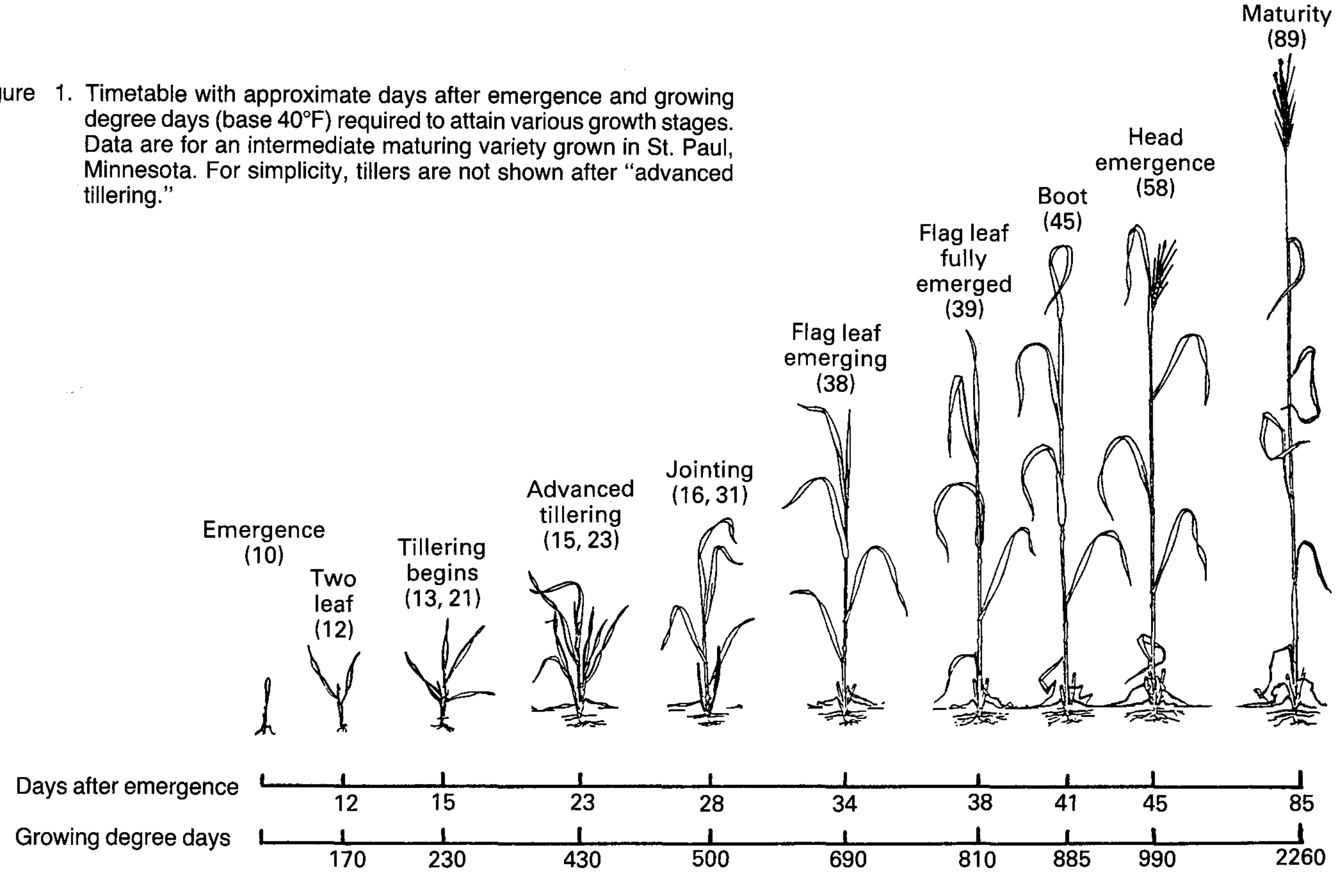
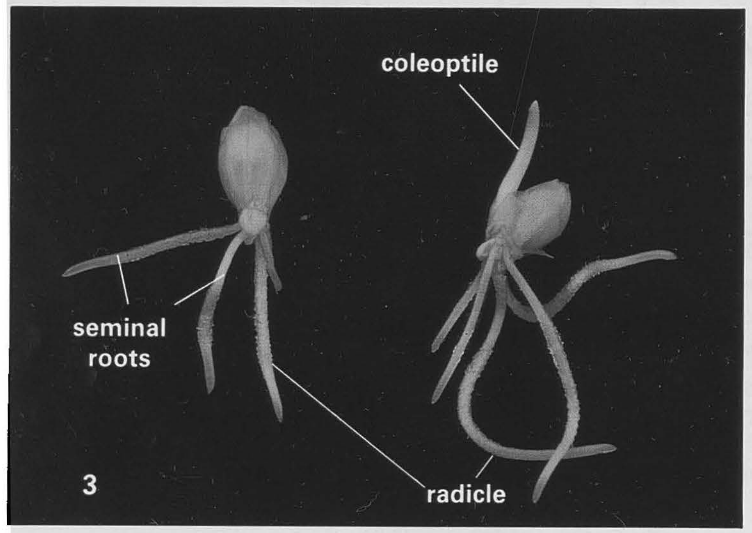


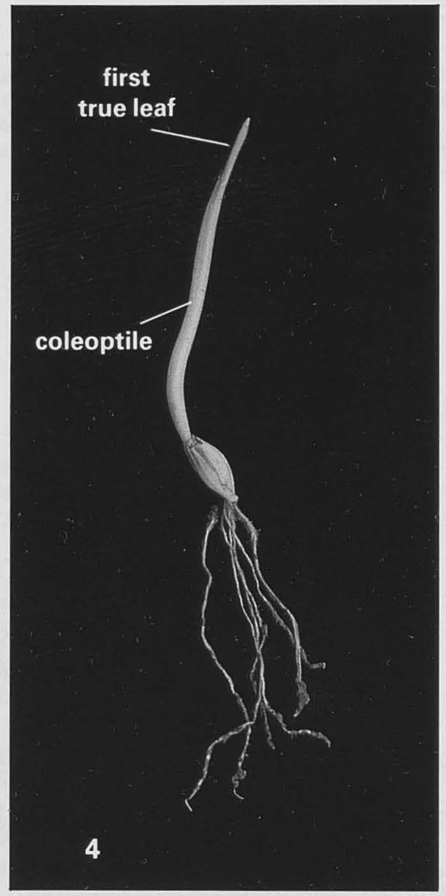
Table 1. Condensed summary of the Zadoks two-digit code system for growth staging in barley with corresponding Feekes scale

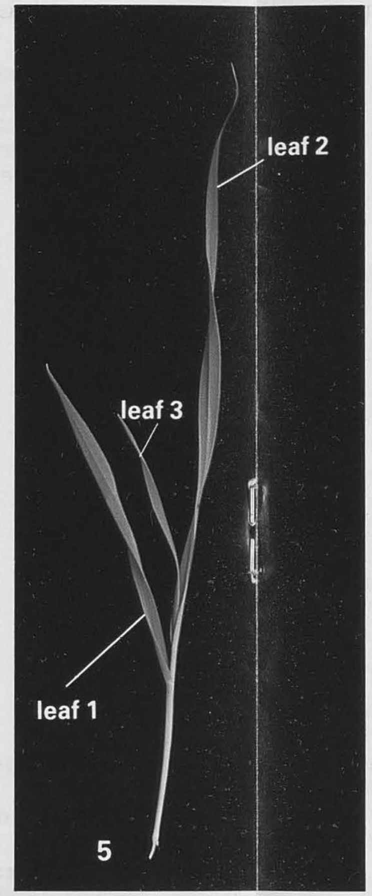
Zadoks code: Principal stage	Zadoks code: Secondary stage	Description	Corresponding Feekes code
0		Germination	
	0	Dry kernel	
	1	Start of imbibition (water absorption)	
	5	Radicle emerged	
	7	Coleoptile emerged	
	9	Leaf just at coleoptile tip	
1		Seedling development	1
	0	First leaf through coleoptile	
	1	First leaf at least 50% emerged	
	2	Second leaf at least 50% emerged	
	3	Third leaf at least 50% emerged	
	4	Fourth leaf at least 50% emerged	
	5	Fifth leaf at least 50% emerged	
2		Tillering	
	0	Main shoot only	
	1	Main shoot plus 1 tiller visible	2
	2	Main shoot plus 2 tillers	
	3	Main shoot plus 3 tillers	
	4	Main shoot plus 4 tillers	
	5	Main shoot plus 5 tillers	3
3		Stem elongation	
	1	First node detectable	6
	2	Second node detectable	7
	3	Third node detectable	
	7	Flag leaf just visible	8
	9	Flag leaf collar just visible	9
4		Boot	
	1	Flag leaf sheath extending	
	3	Boot just beginning to swell	

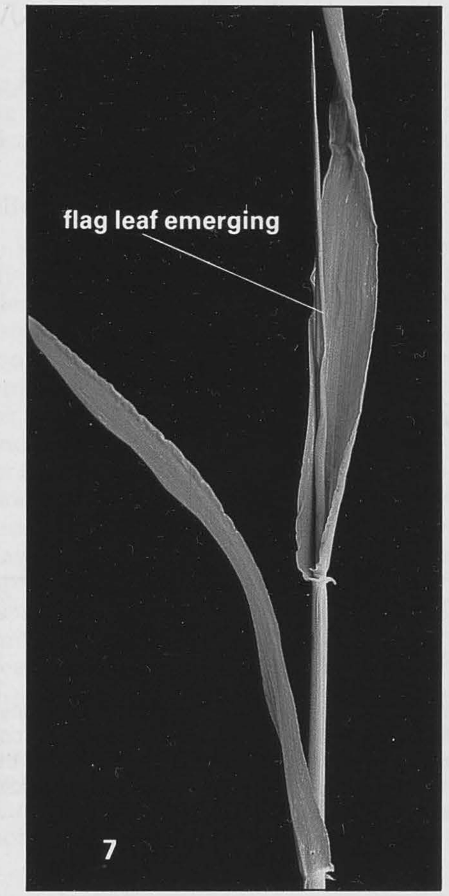
Table 1 (continued).

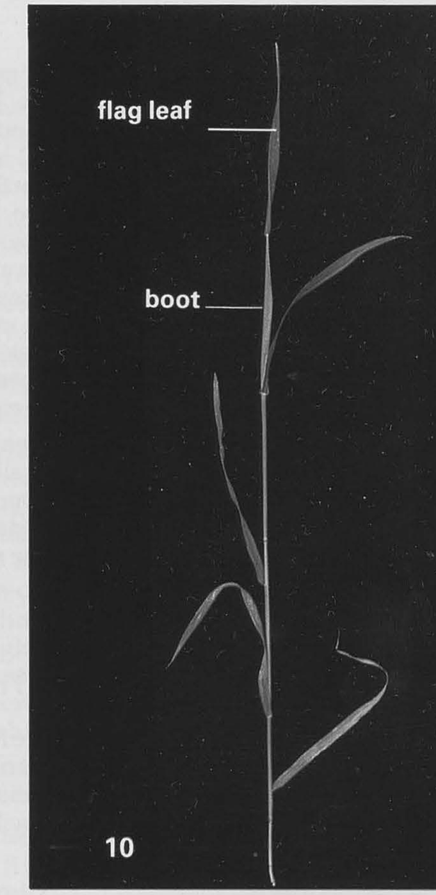
Zadoks code: Principal stage	Zadoks code: Secondary stage	Description	Corresponding Feekes code
	5	Boot swollen	10
	7	Flag leaf sheath opening	
	9	First awns visible	
5		Head emergence	
	1	First spikelet of head just visible	10.1
	3	One-fourth of head emerged	10.2
	5	One-half of head emerged	10.3
	7	Three-fourths of head emerged	10.4
	9	Head emergence complete	10.5
6		Flowering (not readily visible in barley)	
	1	Beginning of flowering	10.5.1
	5	Half of florets have flowered	10.5.2
	9	Flowering complete	10.5.3
7		Milk development in kernel	
	1	Kernel watery ripe	10.5.4
	3	Early milk	
	5	Medium milk	11.1
	7	Late milk	
8		Dough development in kernel	
	3	Early dough	
	5	Soft dough	11.2
	7	Hard dough, head losing green color	
	9	Approximate physiological maturity	
9		Ripening	
	1	Kernel hard (difficult to divide with thumbnail)	11.3
	2	Kernel cannot be dented by thumbnail—harvest ripe	11.4











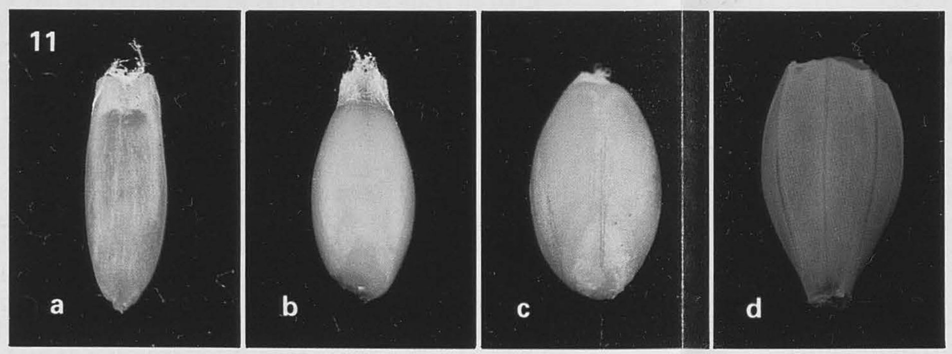


Figure 2. Six-rowed (left) and two-rowed (right) barley heads.

Figure 3. Germinating barley kernels with radicle emergence (Zadoks stage 05) at left, and coleoptile emergence (Zadoks stage 07) at right.

Figure 4. First true leaf emerging through the coleoptile tip (Zadoks stage 10).

Figure 5. Seedling at two-leaf stage (Zadoks stage 12).

Figure 7. The upper third of a plant at flag leaf emergence (Zadoks stage 38).

Figure 8. The lower half of a barley plant at early tillering showing a tiller emerging from the axil of the first leaf (Zadoks stage 21).

Figure 10. Boot stage in barley (Zadoks stage 45).

Figure 11. Kernel development: a) watery ripe (Zadoks stage 71), b) late milk (Zadoks stage 77), c) hard dough (Zadoks stage 87), and d) harvest ripe with lemma and palea attached (Zadoks stage 92).

Figure 12. Physiological maturity indicator in barley. Note that all green color is gone from the glumes [a] (appendages surrounding each kernel in barley) and peduncle [b]. Kernels have been removed from the lower node to more easily show glumes [a].

The Haun system is concerned mainly with the leaf production stages of development. The length of each emerging leaf is expressed as a fraction of the length of the preceding fully emerged leaf: a 3.2 indicates that three leaves are fully emerged, and a fourth leaf has emerged two-tenths of the length of the third. Although this system can be modified, it is not as useful where decisions are made using developmental indicators other than leaf numbers. Yet, agronomists and weed scientists concerned with seedling development staging and particularly leaf numbers may find the system useful. A recent publication by Bauer et al (1) describes early wheat development in relation to the Haun system.

The Feekes-Large system has been widely used, but is becoming less popular. It numerically identifies stages such as tillering, jointing, and ripening, but lacks the more detailed attributes of the Zadoks and Haun systems. For further information see the references by Haun (2) and Large (3).

Growth and development

The growth cycle of barley has the following divisions: germination, seedling establishment and leaf production, tillering, stem elongation, pollination, and kernel development and maturity. Each will be considered in greater detail.

Germination

The minimum temperature for germination of barley is 34° to 36° F (1° – 2° C). After the seed takes up moisture, the primary root (radicle) emerges. The radicle grows downward, providing anchorage and absorbing water and nutrients, and eventually develops lateral branches. Other roots formed at the level of the seed make up the seminal root system (figure 3). These roots become highly branched and remain active throughout the growing season.

After the radicle emerges from the seed, the first main shoot leaf emerges. It is enclosed within the coleoptile for protection as it penetrates the soil. As a result, the seeding depth should not exceed the length that the coleoptile can grow, usually no more than 3 inches (7.6 cm).

Seedling establishment and leaf production

Once the seedling has emerged, the coleoptile ceases elongating and the first true leaf appears (figure 4). Then leaves appear about every 3 to 5 days depending on the variety and conditions. Figure 5 shows a seedling at the two-leaf stage. Another way of quantifying leaf appearance is in terms of accumulated heat units calculated by summing the number of degrees above 40° F for each day.[1] About 100 heat units accumulate between the appearance of successive leaves in a medium maturing barley (figure 6). Eight or nine leaves are usually formed on the main stem, with later maturing varieties usually form-

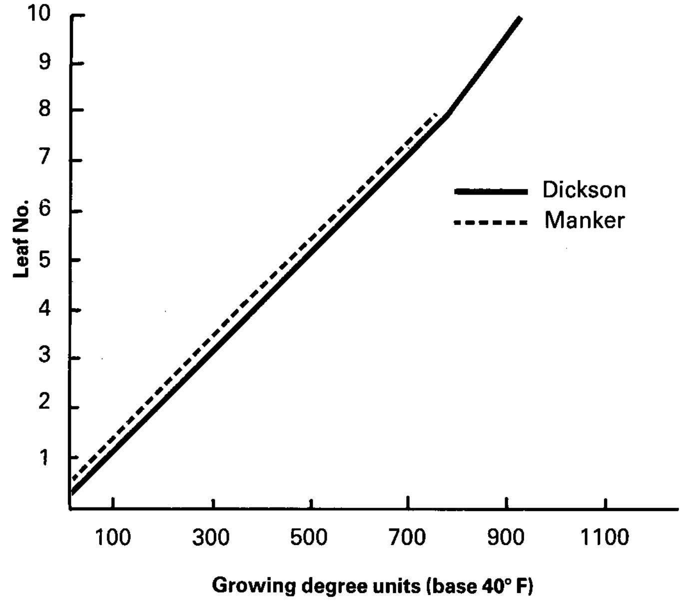


Figure 6. Main shoot leaf production for the varieties Manker and Dickson in the field. These varieties exhibit contrasting leaf production characteristics. Note that while their leaf production rates are similar, Dickson produces more total leaves.

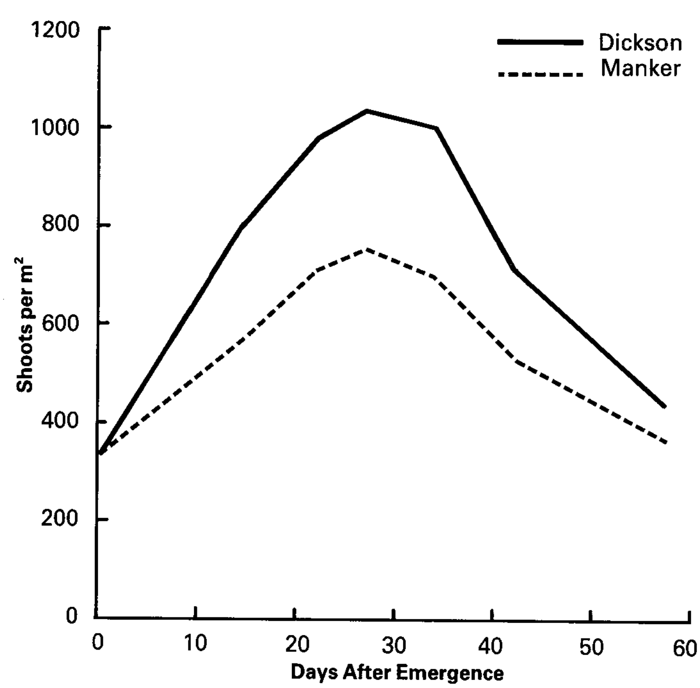


Figure 9. Shoot production for a low-tillering (Manker) and high-tillering (Dickson) variety. Production increases through the tillering phase, then decreases as tiller abortion occurs. ($1m^2 = 10.8$ ft.^{2})

[1] Heat units for each day are calculated with the following equation:

$$\text{Growing degree units} = \frac{(\text{Max. temp} + \text{min. temp})}{2} - 40° \text{F}$$

ing more leaves. Emergence of the final leaf, termed the flag leaf, is an important growth stage for timing the application of certain growth regulators (figure 7).

Tillering

When the seedling has about three leaves, tillers usually begin to emerge (figure 8). Ability of barley plants to tiller is an important method of adapting to changing environmental conditions. When environmental conditions are favorable or if the plant density is reduced, compensation is possible by producing more tillers. Under typical cultural conditions for spring barley, tillers emerge during about a 2-week span with the total number formed depending on the variety and environmental conditions. Deep seeding and high seeding rates usually decrease the number of tillers formed per plant. There may be more tillers formed when early season temperatures are low, when the plant population is low, or when the soil nitrogen level is high. Some tillers initiate roots, contributing to the "nodal" root system. About four weeks following crop emergence, some of the previously formed tillers begin to die without forming a head (figure 9). The extent to which this premature tiller death occurs varies depending on the environmental conditions and the variety. Under poor or stressed growing conditions, plants respond by forming fewer tillers or by displaying more premature tiller death.

Stem elongation

Until jointing, the plant apex or growing point is below the soil surface where it is protected somewhat from frost, hail, or other mechanical damage. Between 3 and 4 weeks after plant emergence, the upper internodes of the stem begins to elongate, moving the growing point above the soil surface. The head also begins to grow rapidly, although it is still too small to readily detect through the surrounding leaf sheaths. During the "boot" stage, the head becomes prominent within the flag leaf sheath (figure 10).

Pollination flowering

Pollination usually takes place in barley just before or during head emergence from the boot. Pollination begins in the central portion of the head and proceeds toward the tip and base. This event occurs 6 to 7 weeks after crop emergence. Since pollen formation is sensitive to stress, water deficits and high temperatures at this time will decrease the number of kernels that form and may reduce yields. These yield reductions can be diminished by planting early so that pollination and early grain filling is completed before late season stresses occur.

Kernel development and maturity

Once head emergence and pollination have occurred, kernels begin to develop (figure 11). The length of the barley kernel is established first, followed by its width. This helps explain why "thin barley" developed under stress conditions is usually as long as normal grain, but is narrower. Figure 11 shows the physical changes as a kernel develops. The first period of kernel development, designated the "watery ripe" and "milk" stages, lasts about 10 days. Although the kernels do not gain much weight during this phase, it is extremely important because it determines the number of cells that will subsequently be used for storing starch. Kernels crushed in this stage initially yield a watery substance which later becomes milky. Kernels that are storing starch and growing rapidly are characterized by a white semi-solid consistency termed "soft dough." This period usually lasts about 10 days following the milk stage. Finally, as the kernel approaches maturity and begins losing water rapidly, its consistency becomes more solid, termed "hard dough." This is when the kernel also loses its green color (figure 11).

When kernel moisture has decreased to about 30 to 40 percent, it has reached physiological maturity and will not accumulate additional dry matter. The final yield potential has been established at this time. An easily identified field indicator of physiological maturity is 100 percent loss of green color from the glumes and peduncle. (figure 12). Although the moisture content of the grain is still too high for direct combining, it can be swathed and windrowed. When kernel moisture has decreased to 13 to 14 percent, the barley kernel is ready for combining and threshing.

Leaf area establishment and duration

Since photosynthesis provides energy for growth and dry matter for yield, it is important that leaf area be established rapidly and protected throughout the growing season. Early in the plant's growth, the leaf blades are the major photosynthetic organs. The rate of leaf area establishment depends on temperature, but can be increased by high nitrogen fertilization and seeding rates.

The duration of leaf function is also important for maximum grain yield. The maximum leaf area is usually reached about heading, then declines during grain growth when the demand is great for photosynthate (products of photosynthesis). As the lower leaves die, the upper leaf blades, leaf sheaths, and heads, become very important as photosynthetic sources for grain filling. For maximum yields, the last two leaf blades and sheaths, as well as the head and awns, are particularly important. Barley also has a limited capacity to mobilize substances that were produced and stored earlier in the growing season if conditions reduce the capacity of the plants to produce current photosynthate.

Summary

Although a number of growth staging systems are available, the Zadoks system is the most comprehensive and may serve as the most helpful guide when making management decisions. Recognizing barley growth stages is important to the producer because many of today's agricultural chemicals must be applied at critical times. By using the physiological maturity indicators, harvest decisions can also be made that will maximize crop yield potential. Basing management decisions on an understanding of barley growth and development is essential to profitable production.

Glossary

Anther: The part of the flower that produces the pollen.

Coleoptile: The sheath that encloses the first main shoot leaf and provides protection as it emerges from the soil.

Flag leaf: The leaf immediately below the head.

Floret: An individual flower within the head.

Glumes: The pair of bracts located at the base of a spikelet in the head.

Internode: The part of a stem between two nodes.

Jointing: Stage of barley development when stem nodes are first detected above the soil; Zadoks stage 31.

Leaf blade: The flattened portion of a leaf above the sheath.

Leaf sheath: The lower part of a leaf enclosing the stem.

Lemma and palea: Bracts (hulls) enclosing the kernel. After threshing, the lemma and palea usually adhere to the kernels.

Main shoot: The primary shoot which emerges first from the soil and from which tillers originate.

Node (Joint): A region on the stem where leaves are attached.

Peduncle: The top section of the stem between the flag leaf and the head.

Seminal roots: Roots arising at the level of the seed.

Spikelet: The flower of a grass consisting of a pair of glumes and one or more enclosed florets.

Tiller: A shoot originating from the base of the plant.

For further information

1. Bauer, A., C. Fanning, J.W. Enz, and C.V. Eberlein. 1984. Use of growing-degree days to determine spring wheat growth stages. North Dakota State University Extension Bulletin 37.
2. Haun, J.R. 1973. Visual quantification of wheat development. Agron J. 65:116-119.
3. Large, E.C. 1954. Growth stages in cereals. Illustration of the Feekes scale. Plant Path. 3:128-129.
4. Simmons, S.R., E.A. Oelke, and P.M. Anderson. 1985. Growth and development guide for spring wheat. University of Minnesota Agricultural Extension Folder AG-FO-2547.
5. Zadoks, J.C., T.T. Chang, and C.F. Konzak. 1974. A decimal code for the growth stages of cereals. Weed Research 14:415-421.

Designer: Dianne C. Swanson

Photographer: Dave Hansen

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Patrick J. Borich, Dean and Director of Agricultural Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Agricultural Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, religion, color, sex, national origin, handicap, age, or veteran status.