Chapter 4

Rice Growth and Development

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First (Main) Crop

Growth and development of the rice plant involve continuous change. This means important growth events occur in the rice plant at all times. Therefore, the overall daily health of the rice plant is important. If the plant is unhealthy during any state of growth, the overall growth, development and grain yield of the plant are limited. It is important to understand the growth and development of the plant.

The ability to identify growth stages is important for proper management of the rice crop. Because management practices are tied to the growth and development of the rice plant, an understanding of the growth of rice is essential for management of a healthy crop. Timing of agronomic practices associated with water management, fertility, pest control and plant growth regulation is the most important aspect of rice management. Understanding the growth and development of the rice plant enables the grower to properly time recommended practices.

Growth and Development

Growth and development of rice grown as an annual from seed begin with the germination of seed and ends with the formation of grain. During that period, growth and development of the rice plant can be divided into two phases: vegetative and reproductive. These two phases deal with growth and development of different plant parts. It is important to remember growth and development of rice are a continuous process rather than a series of distinct events. They are discussed as separate events for convenience.

The vegetative phase deals primarily with the growth and development of the plant from germination to the beginning of panicle development inside the main stem. The reproductive phase deals mainly with the growth and development of the plant from the end of the vegetative phase to grain maturity. Both phases are important in the life of the rice plant. They complement each other to produce a plant that can absorb sunlight and convert that energy into food in the form of grain.

The vegetative and reproductive phases of growth are subdivided into groups of growth stages. In the vegetative phase of growth there are four stages: (1) emergence, (2) seedling development, (3) tillering and (4) internode elongation. Similarly, the reproductive phase of growth is subdivided into five stages: (1) prebooting, (2) booting, (3) heading, (4) grain filling and (5) maturity.

Growth Stages in the Vegetative Phase

Emergence

When the seed is exposed to moisture, oxygen and temperatures above 50 degrees F, the process of germination begins. The seed is mostly carbohydrates stored in the tissue called the endosperm. The embryo makes up most of the rest of the seed. Germination begins with imbibition of water. The seed swells, gains weight, conversion of carbohydrates to sugars begins and the embryo is activated.

Nutrition from the endosperm can supply the growing embryo for about 3 weeks. In the embryo, two primary structures grow and elongate: the radicle (first root) and coleoptile (protective covering enveloping the shoot). As the radicle and coleoptile grow, they apply pressure to the inside of the hull. Eventually, the hull weakens under the pressure, and the pointed, slender radicle and coleoptile emerge. Appearance of the radicle and coleoptile loosely defines the completion of germination.

After germination, the radicle and coleoptile continue to grow and develop primarily by elongation (or lengthening) (Fig. 4-1). The coleoptile elongates until

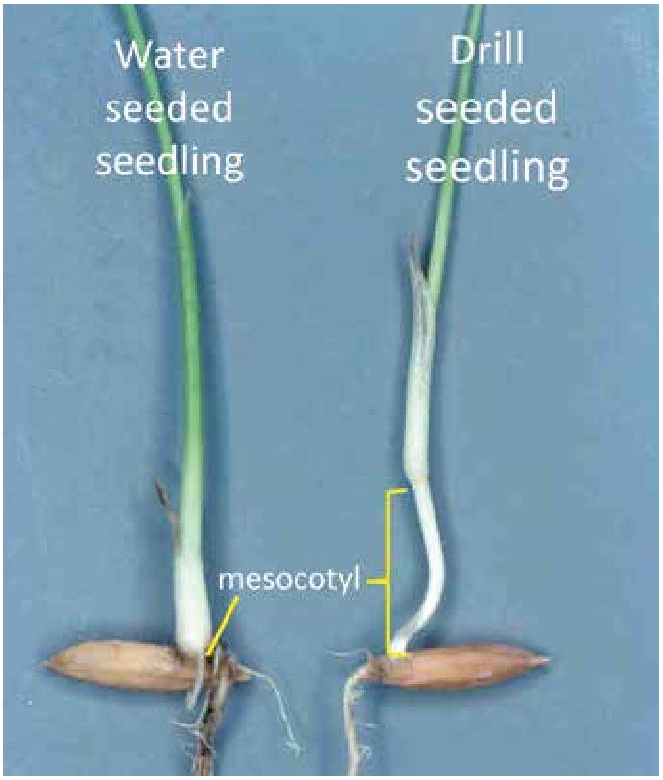

Fig. 4-1. Left, water-seeded seedling. Right, drill-seeded seedling.

it encounters light. If further elongation is required (for example, if the seeds are planted or covered too deeply), the region of the shoot below the coleoptile begins to elongate. This region is called the mesocotyl. Usually, it does not develop in water-seeded rice. The mesocotyl originates from the embryo area and merges with the coleoptile. The mesocotyl and coleoptile can elongate at the same time. They are sometimes difficult to tell apart. Usually, the mesocotyl is white, and the coleoptile is off-white and slightly yellowish. Shortly after the coleoptile is exposed to light, usually at the soil surface, it stops elongation. The appearance of the coleoptile signals emergence. From a production perspective (and in the DD50 program), emergence is called when 8 to 10 seedlings 3/4 inch tall are visible per square foot in water-seeded rice or 4 to 7 plants per foot for drill-seeded rice, depending on drill spacing (Fig. 4-2)

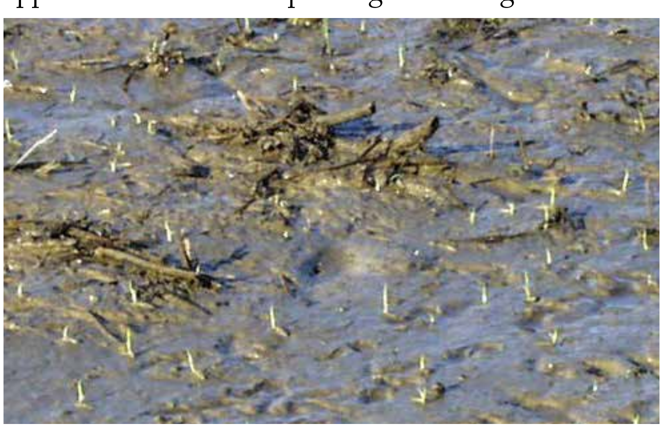
Fig. 4-2. Emergence, water-seeded rice.

Seedling Development

Seedling development begins when the primary leaf appears shortly after the coleoptile is exposed to light and splits open at the end. The primary leaf elongates through and above the coleoptile (Fig. 4-3). The primary leaf is not a typical leaf blade and is usually 1 inch or less in length. The primary leaf acts as a protective covering for the next developing leaf. As the seedling grows, the next leaf elongates through and past the tip of the primary leaf. Continuing to grow and develop, the leaf differentiates into three distinct parts: the sheath, collar and blade (Fig. 4-4). A leaf that is differentiated into a sheath, collar and blade is considered complete; thus, the first leaf to develop after the primary leaf is the first complete leaf. The

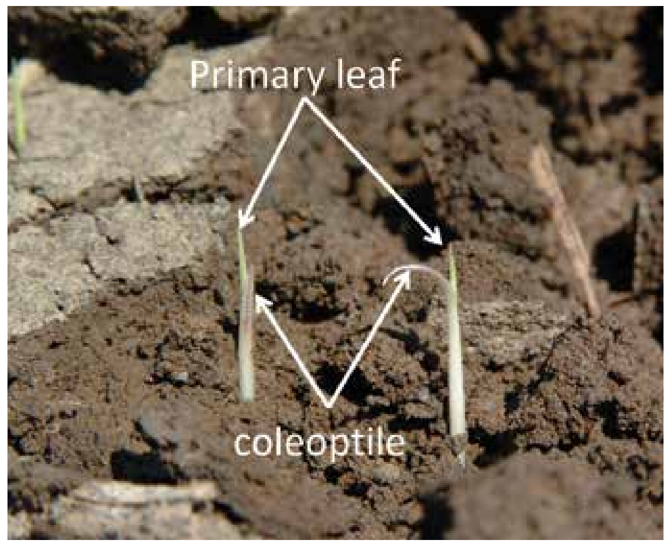

Fig. 4-3. Emergence, drill seeded rice.


Fig. 4-4. One leaf seedling.

one-leaf stage of growth rice has a primary leaf and a completely developed leaf.

All subsequent leaves after the first leaf are complete leaves. The sheath is the bottom-most part of a complete leaf. Initially, all leaves appear to originate from a common point. The area is actually a compressed stem with each leaf originating from a separate node. Throughout the vegetative growth period, there is no true stem (culm) development. The stem of rice, as with all grasses, is called the culm. Leaf blades are held up by the tightly wrapped leaf sheaths. This provides support much like tightly rolling up several sheets of paper to form a column. Without this mechanism, the leaves would lay flat on the soil surface.

The collar is the part of the leaf where the sheath and blade join (Fig. 4-5). It is composed of strong cells that form a semicircle that clasps the leaf sheath during vegetative development and the stem during reproductive development. It is marked by the presence of membranous tissue on its inner surface called the ligule. Rice also has two slender, hairy structures on each end of the collar called auricles.

The blade or lamina is the part of the leaf where most photosynthesis occurs. Photosynthesis is the process by which plants in the presence of light and chlorophyll convert sunlight, water and carbon dioxide into glucose (a sugar), water and oxygen. It contains more chlorophyll than any other part of the leaf. Chlorophyll is the green pigment in leaves that absorbs sunlight. The absence of chlorophyll is called chlorosis. The blade is the first part of a complete leaf to appear as a leaf grows and develops. It is followed in order by the appearance of the collar at the base of the blade then the sheath below the collar. During the vegetative phase of growth, the collar and blade of each complete leaf become fully visible. Only the oldest leaf sheath is completely visible, since the younger leaf sheaths remain covered by sheaths of leaves whose development preceded them. Each new leaf originates from within the previous leaf so that the oldest leaves are both the outermost leaves and have the lowest point of origin.

Since growth and development are continuous, by the time the first complete leaf blade has expanded, the tip of the second complete leaf blade is usually already protruding through the top of the sheath of the first complete leaf. The second leaf grows and develops in the same manner as the first. When the second collar is visible above the collar of the first leaf, it is called two- leaf rice (Fig. 4-6). Subsequent leaves develop in the same manner, with the number of fully developed leaves being used to describe the seedling stage of growth.

Fig. 4-5. Collar of rice leaf.

Fig. 4-6. Two leaf seedlings.

When the second complete leaf matures, the sheath and blade are each longer and wider than their counterparts on the first complete leaf. This trend is noted for each subsequent leaf until about the ninth complete leaf, after which leaf size either remains constant or decreases.   Although a rice plant can produce many (about 15) leaves, as new leaves are produced, older leaves senesce (die and drop off), resulting in a somewhat constant four to five green leaves per shoot at nearly all times in the life of the plant. Each additional leaf develops higher on the shoot and on the opposite side of the previous leaf producing an arrangement referred to as alternate, two-ranked and in a single plane. Seedling growth continues in this manner through the third to fourth leaf, clearly denoting plant establishment.

Root system development is simultaneous to shoot development. In addition to the radicle, other fibrous roots develop from the seed area and, with the radicle, form the primary root system (Fig. 4-7). The primary root system grows into a shallow, highly branched mass limited in its growth to the immediate environment of the seed. The primary root system is temporary, serving mainly to provide nutrients and moisture to the emerging plant and young seedling. In contrast, the secondary root system is more permanent and originates from the base of the coleoptile.

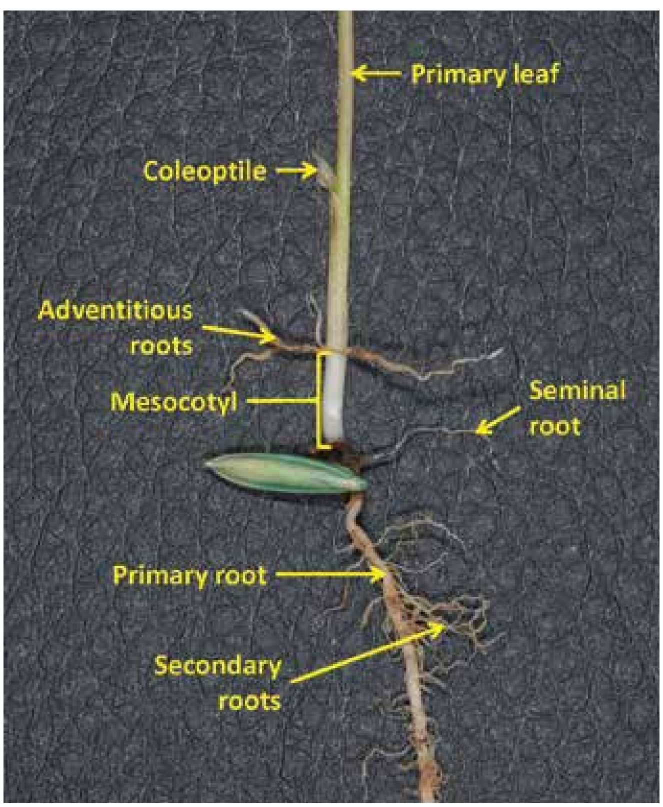

Fig. 4-7. Rice seedling root system.

In water-seeded rice (or any time seeds are left on the soil surface), the primary and secondary root systems appear to originate from a common point. When seed are covered with soil as in drill seeding, the primary root system originates at or near the seed, while the secondary root system starts in a zone above the seed originating from the base of the coleoptile. These differences can have an impact on some management practices.

During the seedling stages, the secondary root system, composed of adventitious roots, is not highly developed and appears primarily as several nonbranched roots spreading in all directions from the base of the coleoptile in a plane roughly parallel to the soil surface. The secondary root system provides the bulk of the water and nutrient requirements of the plant for the remainder of the vegetative phase and into the reproductive phase.

During the seedling stages, the plant has clearly defined shoot and root parts. Above the soil surface, the shoot is composed of one or more completely developed leaves at the base of which are the primary leaf and upper portions of the coleoptile. Below the soil surface, the root system is composed of the primary root system originating from the seed and the secondary root system originating from the base of the coleoptile. Plants originating from seed placed deep below the soil surface will have extensive mesocotyl and coleoptile elongation compared with plants originating from seed placed on or near the soil surface (Fig. 4-1). Seed placement on the soil surface usually results in no mesocotyl development and little coleoptile elongation. In general, the presence of primary and secondary roots and a shoot, which consists of leaf parts from several leaves, is the basic structure of the rice plant during the seedling stages of growth.

Tillering

Tillers (stools) first appear as the tips of leaf blades emerging from the tops of sheaths of completely developed leaves on the main shoot. This gives the appearance of a complete leaf that is producing more than one blade (Fig. 4-8). This occurs because tillers originate inside the sheath of a leaf just above the point where the sheath attaches at the base of the plant. If the leaf sheath is removed, the bud of a beginning tiller will appear as a small green triangular growth at the base of the leaf. This bud is called an axillary bud. Tillers that originate on the main shoot in this manner are primary tillers. When the first complete leaf of the first primary tiller is visually fully differentiated (blade, collar and sheath apparent), the seedling is in the first tiller stage of growth.

The first primary tiller usually emerges from the sheath of the first complete leaf before the fifth leaf. If a second tiller appears, it usually emerges from the sheath of the second complete leaf and so on. Consequently, tillers develop on the main shoot in an alternate fashion like the leaves. When the second primary tiller appears, it is called two-tiller rice. The appearance of tillers in this manner usually continues through about fourth or fifth primary tiller. If plant populations are very low (fewer than 10 plants per square foot), tillers may originate from primary tillers much in the same manner as primary tillers originate from the main shoot. Tillers originating from primary tillers are considered secondary tillers. When this occurs, the stage of growth of the plant is secondary tillering.

Fig. 4-8. One tiller rice seedling.

Tillers grow and develop in much the same manner as the main shoot, but they lag behind the main shoot in their development. This lag is directly related to the time a tiller first appears. It usually results in tillers producing fewer leaves and having less height and maturing slightly later than the main shoot.

During tillering (stooling), at the base of the main shoot, crown development becomes noticeable. The crown is the region of a plant where shoots and secondary roots join. Inside a crown, nodes form at the same time as the development of each leaf. The nodes appear as white bands about 1⁄16 inch thick and running across the crown, usually parallel with the soil surface. Initially, the plant tissue between nodes is solid, but with age, the tissue disintegrates, leaving a hollow cavity between nodes. With time, the nodes become separate and distinct, with spaces (internodes) about ¼ inch or less in length between them.

In addition to crown development, leaf and root development continue on the main shoot. An additional five to six complete leaves form with as many additional nodes forming above the older nodes in the main shoot crown. On the main shoot, some of the older leaves turn yellow and brown. The changes in color begin at the tip of a leaf blade and gradually move to the base. This process is called senescence. The lowest leaves senesce first with the process continuing from the bottom up or from oldest to youngest leaves. From this point on, there is simultaneous senescence of older leaves and production of new leaves. The result is that there are never more than four or five fully functional leaves on a shoot at one time.

In addition to changes in leaves, the main shoot crown area expands. Some of the older internodes at the base of the crown crowd together and become indiscernible by the unaided eye. Usually, no more than seven or eight crown internodes are clearly observable in a dissected crown. Sometimes, the uppermost internode in a crown elongates ½ to 1 inch. This can occur if depth of planting, depth of flood, plant population, N fertility and other factors that tend to promote elongation in rice are excessive. During tillering, tiller crowns develop. Along with growth of the main shoot and tiller shoot crowns, more secondary roots form, arising from the expanding surface of the crowns. These roots grow larger than those that formed during the seedling stages. They are wider and longer as they mature. A vegetatively mature rice plant will be composed of a fully developed main shoot, several tillers in varying degrees of maturity, healthy green leaves, yellow senescing leaves and an actively developing secondary root system.

Internode Elongation and Stem Development

Each stem or culm is composed of nodes and internodes. The node is the swollen area of the stem where the base of the leaf sheath is attached. It is also an area where a great deal of growth activity occurs. This area is one of several meristematic regions. Growth of the stem is the consequence of the production of new cells along with the increase in size, especially length, of these cells. The area between each node is the internode. The combination of node and internode is commonly called a "joint."

The formation and expansion of hollow internodes above a crown are the process that produces a stem, determines stem length and contributes to a marked increase in plant height. Internode formation above a crown begins with the formation of a stem node similar to that of the crown nodes (Fig. 4-9). The stem node forms above the uppermost crown node, and a stem internode begins to form between the two nodes. As the stem internode begins to form, chlorophyll accumulates in the tissue below the stem node. This produces green color in that tissue. Cutting the stem lengthwise usually reveals this chlorophyll accumulation as a band or ring. This is commonly called "green ring" and indicates the onset of internode elongation (Fig. 4-10). It also signals a change

Fig. 4-9. Plant with three distinct crown nodes and a fourth developing.

Fig. 4-10. Green ring-internode elongation.

Fig. 4-11. Half-inch internode.

in the plant from vegetative to the reproductive stage of development (Fig. 4-11).

Subsequent nodes and internodes develop above each other. Growth of the stem can be compared to the extension of a telescope with the basal sections extending first and the top last. As the newly formed nodes on the main stem become clearly separated by internodes, the stages of growth of the plant progress from first internode, to second internode, to third internode et cetera. With the formation and elongation of each stem internode, the length of the stem and the height of the plant increase. Internode elongation occurs in all stems. The main stem is usually the first to form an internode and is also the first stem in which internode formation ends. In tillers, internode formation lags behind the main stem and usually begins in the older tillers first.

During the internode formation stages, each newly formed internode on a stem is longer and slenderer than the preceding one. The first internode formed is the basal most internode. It is the shortest and thickest internode of a stem. The basal internode is located directly above the crown. Sometimes, if the uppermost crown internode is elongated, it can be confused with the first internode of the main stem. One difference between these two internodes is the presence of roots. Sometimes, especially late in the development of the plant, the node at the top of the uppermost crown internode will have secondary roots associated with it. The upper node of the first stem internode will usually have no roots at that time. If roots are present, they will be short and fibrous. The last or uppermost internode that forms is the longest and slenderest internode and is directly connected to the base of the panicle. The elongation of the uppermost internodes causes the panicle to be exserted from the sheath of the uppermost or "flag leaf." This constitutes heading. This process is covered in detail in the booting and heading sections.

Internode length varies, depending on variety and management practices. In general, internode lengths vary from 1 inch (basal internode) to 10 (uppermost internode) inches in semidwarf varieties and from 2 inches to 15 inches in tall varieties. These values, as well as internode elongation in general, can be influenced by planting date, plant population, soil fertility, depth of flood, weed competition and so on.

The number of internodes that forms in the main stem is relatively constant for a variety. Varieties now being grown have five to six internodes above the crown in the main stem. In tillers, fewer internodes may form than in the main stem. The number is highly variable and depends on how much the tiller lags behind the main stem in growth and development.

The time between seeding and internode formation depends primarily on the maturity of the variety, which is normally controlled by heat unit exposure (see DD-50 Rice Management Program section). It also can be influenced by planting date, plant population, soil fertility, flood depth and weed competition. In general, varieties classified as very early season maturity (head 75 to 79 days after planting) reach first internode about 6 weeks after planting. Varieties classified as early season maturity (head 80 to 84 days after planting) reach first internode about 7 weeks after planting, and varieties classified as midseason maturity (head 85 to 90 days after planting) reach first internode about 8 weeks after planting.

The appearance of nodes above the crown marks a change in the role of the node as the point of origin of several plant parts. Before stem internode formation begins above the crown, all leaves, tillers and secondary roots formed during that time originate from crown nodes. But after internode formation begins above the crown, the stem nodes serve mainly as the point of origin of all subsequent leaves.

Because stem nodes become separated significantly by internode development, the leaves that originate at these nodes are more separate and distinct than leaves formed before internode formation. The separation of these leaves increases as the length of the internodes increases. More complete leaf structure does not become apparent until the last two leaves to form have all or most of all three parts (sheath, collar and blade) completely visible. In varieties now in use, no more than six new complete leaves are produced on the main shoot after stem internode elongation begins. The last of these leaves to form is the flag leaf. It is the uppermost leaf on a mature stem. The sheath of the flag leaf, the boot, encloses the panicle during the elongation of the last two internodes. Not only is the flag leaf the last formed and uppermost leaf on a mature stem, it is also considered to be the most important leaf because the products of photosynthesis from it are most responsible for grain development.

Root growth approaches a maximum as internode formation above the crown begins. At this time, the secondary root system has developed extensively in all directions below the crown and has become highly branched. Newly formed roots are white; older roots are brown and black. A matted root system forms in addition to the secondary root system. It is composed of fibrous roots, which interweave and form a mat of roots near the soil surface.

Tiller formation usually ceases and tiller senescence begins during internode elongation. With adequate soil fertility, more tillers are produced during tillering than will survive to maturity. Tiller senescence begins as the crown becomes fully differentiated and continues until the last internode forms above the crown of the main stem.

Tiller senescence can be recognized by the smaller size of a tiller in comparison to other tillers on a plant. It appears significantly shorter than other tillers, has fewer complete leaves and fails to have significant internode development above the crown. Eventually, most leaves on a senescing tiller lose coloration while most leaves on other tillers remain green. The leaves and stems of senescing tillers turn brown and gray and, in most instances, disappear before the plant reaches maturity.

Internode elongation signals the end of vegetative growth. As stem internodes develop, reproductive growth begins.

Growth Stages During the Reproductive Phase

Prebooting

Prebooting refers to the interval after the onset of internode elongation and before flag leaf formation is complete. During prebooting, the remaining leaves of the plant develop, internode elongation and stem formation continue, and panicle formation begins.

When cells first begin actively dividing in the growing point or apical meristem, the process is called panicle initiation (PI). This occurs during the fifth week before heading. Although it can be positively identified only by microscopic techniques, it is closely associated with certain vegetative stages of growth. The growth stages that coincide closely with PI differ depending on the maturity of a variety. In very early season varieties, PI and internode elongation (green ring) occur at about the same time. In early season varieties, PI and second internode elongation occur almost simultaneously, and in midseason varieties, PI and third internode elongation are closely concurrent.

About 7 to 10 days after the beginning of active cell division at the growing point, an immature panicle about ⅛ inch long and 1⁄16 inch in diameter can be seen. At this point, the panicle can be seen inside the stem, resembling a small tuft of fuzz. This is referred to as panicle differentiation (PD) or panicle 2-mm (Fig. 4-12). The panicle, although small, already has begun to differentiate into distinct parts. Under a microscope or good hand lens, the beginnings of panicle branches and florets are recognizable. As the panicle develops, structures differentiate into a main axis and panicle branches (Fig. 4-13). The growing points of these branches differentiate into florets. Florets form at the

Fig. 4-12. Immature panicle, PD or panicle 2-mm.

Fig. 4-13. Half inch panicle.

uppermost branches first and progress downward. Because there are several panicle branches, development of florets within the panicle as a whole overlaps. Florets at the tip of a lower branch might be more advanced in their development than florets near the base of an upper panicle branch.

From a management stand point, panicle length defines plant development during this phase. A fungicide label, for example, might prescribe its application "from a 2- to 4-inch panicle." By the time the panicle is about 4 inches long, individual florets can be easily recognized on the most mature panicle branches.

Booting

Booting is the period during which growth and development of a panicle and its constituent parts are completed inside the sheath of the flag leaf. The sheath of the flag leaf is the boot. Booting stages are classified according to visible development of the panicle without dissection. For convenience, it is divided into three stages: early, middle and late boot. It is based on the amount of flag leaf sheath exposed above the collar of the leaf from which it emerges, the penultimate (second to last) leaf. Early boot (Fig. 4-14) is recognized when the collar of the flag leaf first appears above the collar of the penultimate leaf on the main stem and lasts until the collar of the flag leaf is about 2 inches above the collar of the penultimate leaf. Middle boot occurs when the collar of the flag leaf is 2 to 5 inches above the collar of the penultimate leaf and late boot when the collar of the flag leaf is 5 or more inches above the collar of the penultimate leaf. By late boot, the increasing panicle development causes the boot to swell, giving rise to the term "swollen boot." The boot becomes spindle shaped; it is wider in the middle tapering to a smaller diameter at each end.

Heading

Heading refers to the extension of the panicle through the sheath of the flag leaf on the main stem. This process is brought about mainly by the gradual and continuous elongation of the uppermost internode. When elongation of the uppermost internode of a main stem pushes the panicle out of the sheath of the flag leaf exposing the tip of the panicle, that stem has headed. The uppermost internode continues

Fig. 4-14. Early boot, flag leaf first appears above collar.

to elongate, revealing more of the panicle above the sheath of the flag leaf. Once the uppermost internode completes elongation, the full length of the panicle and a portion of the uppermost internode are exposed above the collar of the flag leaf. This stem is now fully headed.

The main stem of each plant heads before its tillers. In a field of rice, there is considerable variation in the heading stage of growth. For example, some main stems, as well as tillers of other plants, may be fully headed while other plants may have just begun to head. Some management practices are based on the percentage of headed plants within a field. This should not be confused with the degree to which a single panicle has emerged from the boot or with the number of completely headed stems. Fifty percent heading means half of the stems in a sample have a range from barely extended to completely exposed panicles. It is not the degree of exposure of each

Fig. 4-15. Open floret with floral parts showing.

panicle but the percentage of stems with any panicle exposure that is important.

Each floret or flower is enclosed by protective structures called the lemma and palea. These become the hulls of mature grain. These hulls protect the delicate reproductive structures. The female reproductive organ is the pistil. At the tip of the pistil are two purplish feathery structures called stigmas. They are visible when the hulls open during flowering. More obvious are the male or pollen-bearing stamens. Each rice floret has a single pistil and six stamens. Pollen is produced and stored in anthers, tiny sacks at the tip of each stamen.

As heading progresses, flowering begins. During the middle hours of the day, mature florets open, exposing both the stigmas and anthers to air (Fig. 4-15). Pollen is shed as the anthers dry, split open and spill the pollen. The pollen then is carried by wind to the stigmas of the same or nearby plants. Special cells of the pollen grain join special cells within the pistil, completing fertilization and initiating grain formation.

Grain Filling

During grain filling, florets on the main stem become immature grains of rice. Formation of grain results mainly from accumulation of carbohydrates in the pistils of the florets. The primary source of the carbohydrate is from photosynthesis occurring in the uppermost three to four leaves and the stem. The carbohydrate that accumulates in grain is stored in the form of starch. The starchy portion of the grain is the endosperm. Initially, the starch is white and milky in consistency. When this milky accumulation is first noticeable inside florets on the main stem, the stage is milk stage (Fig. 4-16).

Fig. 4-16. Milk stage.

Fig. 4-17. Soft dough stage.

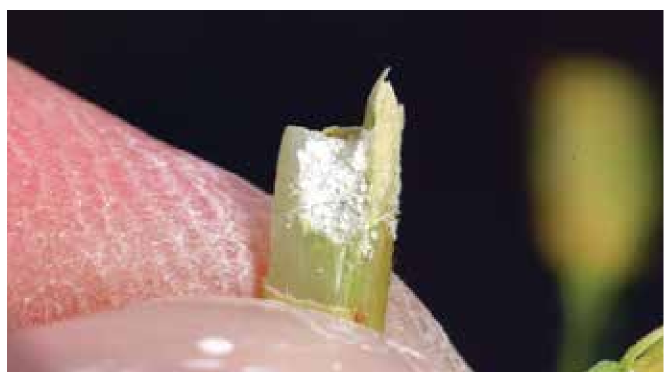

Fig. 4-18. Hard dough stage.

Prior to pollination, the panicle in most varieties is green, relatively compact and erect. During milk stage, the accumulation of carbohydrate increases floret weight. Since the florets that accumulate carbohydrate first are located near the tip of the panicle, the panicle begins to lean and eventually will turn down. The milky consistency of the starch in the endosperm changes as it loses moisture. When the texture of the carbohydrate of the first florets pollinated on the main stem is like bread dough or firmer, this stage of growth is referred to as the dough stage (Fig. 4-17).

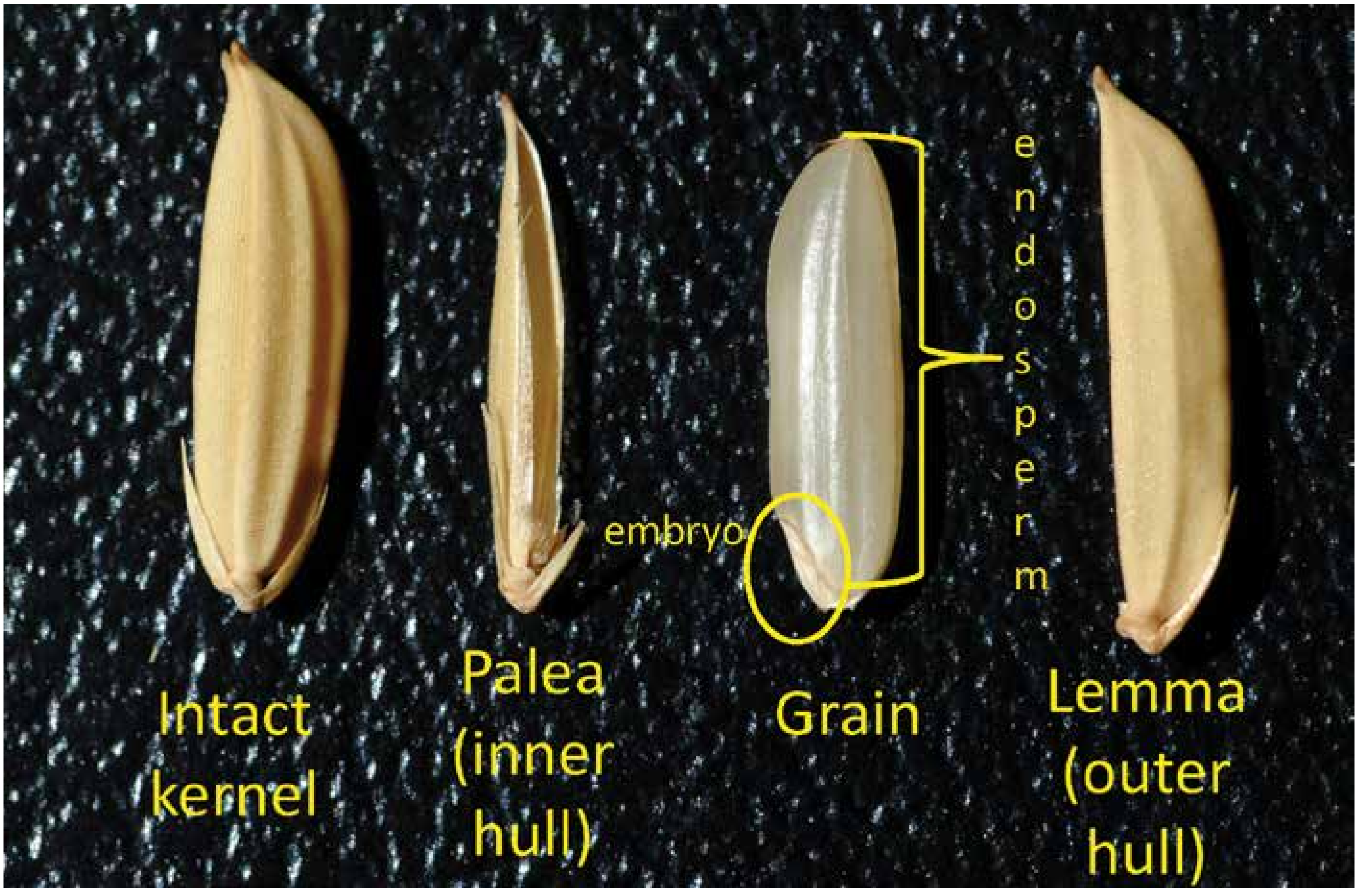

Fig. 4-19. Mature grain, intact and dissected.

As the carbohydrate in these florets continues to solidify during the dough stage, the endosperm becomes firm and has a chalky texture. Grains capable of being dented without breaking are in the soft dough stage. As more moisture is lost, grains become chalky and brittle. These grains are in the hard dough stage (Fig. 4-18).

During the grain filling stages, the florets develop and mature unevenly because pollination and subsequently grain filling occur unevenly. In the dough stage, only the florets on the main stem, which pollinated first, have an endosperm with the texture of bread dough. At the same time, the florets which pollinated later, including those on the tillers, may be in the milk stage. These are the last florets to accumulate carbohydrate. As more and more florets fill with carbohydrate, the translocation of carbohydrate to the panicle starts to decline, and the final phases of grain filling occur.

The panicle changes in color and form as the florets develop and mature. For most varieties of rice, the panicle changes from a uniform light green at the milk stage to a mixture of shades of brown and green during the dough stage. As the color changes so does the grain shape as a consequence of carbohydrate accumulation in the florets. The weight of the carbohydrate causes the panicle to bend over and the panicle branches to be less compact around the panicle axis. At the end of the grain filling stages, the panicle on the main culm has a bent and slightly open shape and is various shades of brown and green. The bent and slightly open configuration of the panicle remains unchanged from dough to maturity.

Maturity

Maturity occurs when carbohydrate is no longer translocated to the panicle. The moisture content of the grain is high after grain filling, and the primary process, which occurs in the panicle during the maturity stages, is the loss of moisture from the grain. The moisture content of the grain is used as the basis for judging degree of maturity. When the physiological

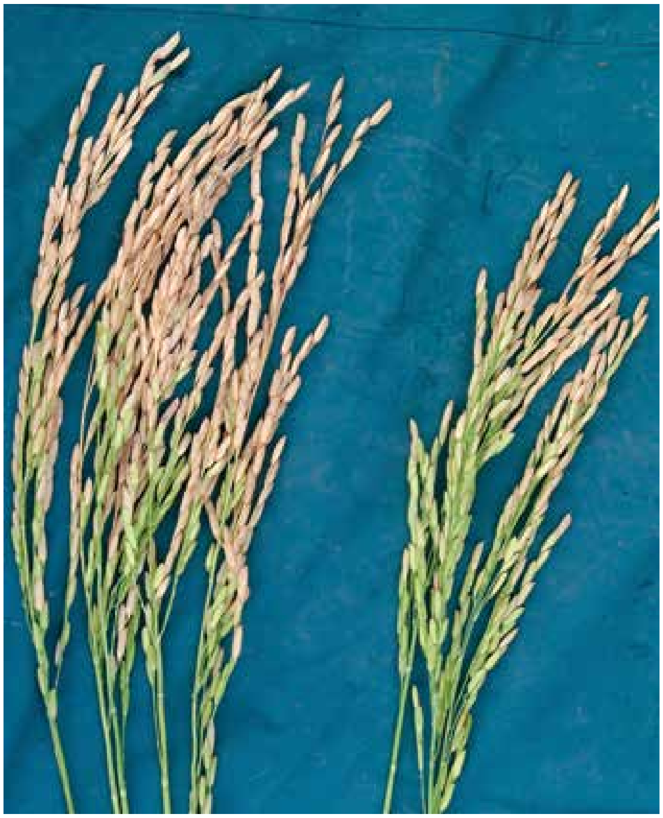

Fig. 4-20. Left panicles are two-thirds ripe. Right panicles are half ripe.

processes associated with grain filling cease and the collective moisture content of the grain on the main stem is 25 to 30%, the plant has reached physiological maturity (Fig. 4-19).

At this time, the endosperm of all grains on the panicle of a main stem is firm. Most grains are some shade of brown and the grains in the lower quarter of the panicle are the only ones with a greenish tint (Fig. 4-20). As maturity progresses and moisture is lost, the greenish tint of the hulls fades and the endosperm of all grains becomes uniformly hard and translucent. Once the average moisture content of the grains on the main stem is 15 to 18% (crop grain moisture, 18 to 21%), the plant has reached harvest maturity.

Second (Ratoon) Crop

Second crop stems originate from small axillary buds at the crown and stem nodes of the stubble remaining after harvest of the first crop (Fig. 4-21). At each node just above the area of attachment of the leaf sheath to the stem is a bud called an axillary bud.

Fig. 4-21. Axillary bud on stem.

Fig. 4-22. Crown or axillary buds at base of stem.

The leaf sheath is wrapped around the stem keeping it hidden unless the leaf itself is damaged or the bud begins to grow. As long as the apical bud, the one that eventually becomes the panicle, remains intact, axillary buds are suppressed. Removal of the panicle through harvesting or injury removes the suppressive effect, called apical dominance, permitting axillary buds to grow. In the crown, buds are difficult to detect (Fig. 4-22). At the stem nodes on first crop stubble they appear as a small (⅛ inch), mostly white, fleshy, triangular shaped structure. Buds that appear necrotic (have dark or dead tissue) and are associated with nodes that also appear necrotic usually do not develop into second crop growth.

There is one bud per node. Because each bud is associated with a single leaf, bud development on a stem follows the same pattern of leaf development.

Depending on stubble height, as many as three nodes can be on a stem of stubble with the potential to produce second crop growth. Once a bud on a stem above the crown develops, it usually inhibits the development of other similar buds. Buds on the crown usually are not suppressed. Five to six shoots can appear from the crown of a single plant. Second crop panicles can be produced from both axillary stem buds and from the crown. Shoots and stems originating from the crown usually produce larger panicles with higher quality grain than those originating from axillary buds on the stem; however, panicles originating from the crown mature later than those originating from axillary buds.

These buds are easily observed by pulling back the leaf sheath from the stem. This is particularly true of buds located at stem nodes. As axillary buds grow, they elongate within the cover of sheaths of first crop leaves. Depending on the node and integrity of the attached sheath, buds can elongate several inches before emerging from the sheaths. Once a developing bud senses sunlight, it differentiates into a green leaf. Leaf formation can occur before ratoon growth emerges from a first crop leaf sheath.

Second crop growth first appears as leaves originating from the crown or a leaf emerging through the sheath of a leaf from the first crop that remains attached to stubble. This usually occurs within 5 days after harvest, depending on first crop maturity at harvest.

Generally, the second crop begins to initiate when the first crop approaches harvest moisture (18 to 21 percent). It is not uncommon to see second crop growth initiated prior to harvest of the first crop.

Shoots develop in the second crop as they do in the first crop. New leaves emerge through sheaths of leaves on the first crop stubble; eventually, internode formation occurs, followed by panicle initiation (PI) and panicle differentiation (PD), booting, heading, grain filling and maturity. Development of buds on the crown is essentially the same process of tillering without the presence of a distinct primary shoot.

Second crop growth is small and much more variable in all aspects compared with the first crop. There are fewer leaves and internodes per stem, a shorter maturation period (time from bud initiation to heading) and shorter mature plant height. There are fewer panicles per acre and per plant and fewer grains per panicle. Second crop yields are generally less than 40 percent of first crop yields. Second crop growth and development are limited by declining day length and falling temperatures at the end of summer and during the fall, which is opposite from the first crop that experiences mostly increasing day length and temperatures from planting to heading during the spring and early summer. The reduction in total sunlight translates to lower photosynthesis, which accounts in part for the lower yields. Reduced input costs often make ratoon cropping profitable despite lower yields.