Rice Growth and Development

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I. Introduction

So you want to grow a 12,000 lb/acre rice crop. The modern short-statured varieties for California certainly are capable of producing yields this high or higher. Of course, not all the conditions to achieve such yields will be under your control. Most notably, untimely rainfall, cold temperatures and many other weather-related events are simply out of your control. But many things are under your control, and most all of them require a good knowledge of how the rice plant grows from seedling to grain filling. This knowledge will help you make informed decisions and better use the many practices and tools you have available. This section will be a lesson in applied rice botany for the primary purpose of understanding what goes into the making of a rice grain crop.

II. The Yield Components

Generally one thinks of yield as the grand (or maybe not so grand) weight of rough rice from a field, usually in "sacks" or cwt per acre. At harvest you may think in terms of trailer loads to compare a field's performance from the previous year as sort of a "back of the envelope" estimate of yield. But just how is all that grain in the trailer made? Rice grain yields are the product of the plant's yield components. Why is it important to know about yield components? Every management practice you use will affect the yield components—but the question is, which ones and when? So, before trying to understand where yield components fit into the life cycle of the plant and how to maximize them, we need to know what they are. Yield components are 1) the number of panicles per given area (often called fertile panicles) 2) the number of spikelets or grains per panicle 3) the percentage of filled kernels or grains and 4) the weight of the kernel—each grain. Generally, you assess crop health at the whole field leveland not at the details of the plant. However, the clues to what went right or wrong in a season if you don't know, can often be determined from the yield components. Yield, then, is the product of each of the four components.

Panicles/area x spiklets (grains)/panicle x % filled spikelets x kernel wt =YIELD

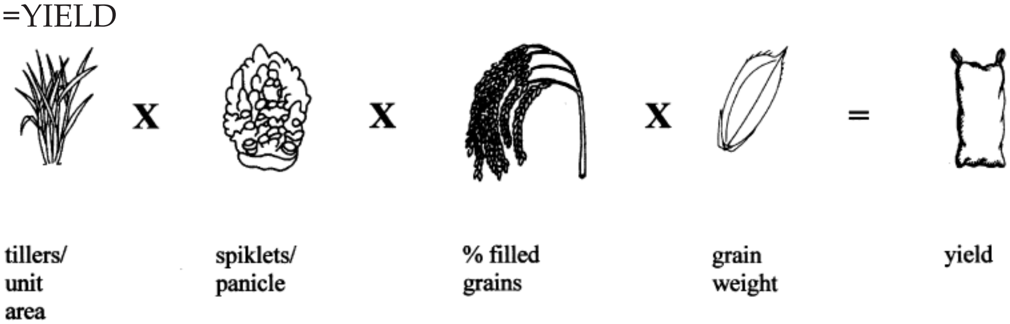


Figure 1. Rice yield components

Let's use an example of yield components converted to a per acre basis to see how they all add up to yield:

Example: Your crop has 60 panicles per square foot and each has 70 kernels. The kernel weight is 30 grams/1000 grains, there is 10% blanking, what is the yield?

Conversion Factors: 1 lb = 454 grams

1 ac = 43,560 ft^2

Abbreviations: grams = g

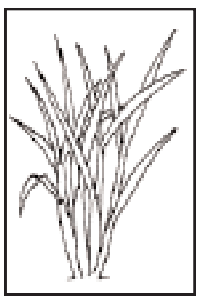
Pound = lb

Square foot = ft^2

Step 1: 60 panicle/ft^2 x 70 kernel/panicle x 90% filled spikelets = 3780 kernels/ft^2

Step 2: 30 g/1000 kernels x 3780 kernel/ft^2 ÷ 454 g/lb = 0.250 lb/ft^2

Step 3: 0.250 lb/ft^2 x 43,560 ft^2/acre = 10,880 lb/acre



Panicles per unit area

The total number of panicles in a given area is a product of the number of established seedlings and the number of fertile tillers produced by each seedling. A fertile tiller is one that produces a panicle. In some cases, such as in very dense stands, many of the tillers are shaded out and die shortly after panicle initiation (PI) and therefore do not produce panicles. Of all the yield components, the number of panicles per unit area is the most easily influenced by management practices. The number of seedlings per unit area, we commonly call "stand," is directly related to the seeding rate. Seeding rates of 125 lb/a to 200 lb/a typically provide seed densities as shown in Table 1.

Table 1. *Field seed densities from typical seeding rates.*

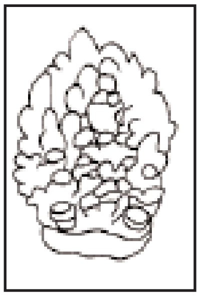
Seeding Rate (lb/ac)	Density (seed/ft2)	Range (seed/ft2)38-55
125	45-50	38-55
150	55-55	46-66
175	55-60	54-77
200	68-72	61-88

These are ballpark figures. The number of seeds/ft^2 can range widely depending on the seed size of the varieties. Koshihikari is the smallest and S-102 the largest of currently grown varieties (see table 9, pg V-12 in the variety section). Thus, some adjustment in seeding rate may be necessary to compensate for seed size. Research has shown that 60 to 70 panicles/ft^2 are about optimum for good yields with calrose type varieties (Table 2).

***Table 2**: Rice stand, yield and yield components.*

Seeding Rate	Yield Components					
	Established Plant Stand	Panicle Density	Grain Weight	Spikelets/ Panicle	Filled Spikelet	Yield
seeds/ft^2	plants/ft^2	ft^2	mg	no.	%	lbs/ac
11	11	53	25.2	90.8	86.6	8692
22	21	65	25.6	74.8	85.8	9267
33	27	61	25.8	71.6	86.2	9438
45	34	66	25.5	64.3	85.6	9393
56	34	68	25.9	63.1	86.2	9423
78	43	75	25.9	58.9	86.8	9456

For example, M-202 at a seeding rate of 150 lb/acre, would give 50+ seeds/ft^2 almost enough, if they all survived, to provide an adequate number of panicles without tillering. However, we all are familiar with damage to stands from wind, tadpole shrimp, bakanae and many other things that can cause moderate to heavy stand losses. High seeding rates are a form of insurance against stand losses. As a cautionary note, however, too high seeding rates can result in weak stems and increased foliar disease incidence. The bottom line is that to achieve panicles densities high enough for good yields tillers must be produced by each seedling. Varieties vary in their tiller capacity, ranging from high tillering tropical indicas to our relatively lower tillering calrose or japonica types. All of California varieties, however, have more than adequate tillering capacity to produce high yields in direct-seeded culture. If conditions are good during the tillering stage, the plant is capable of producing many more tillers than are needed for high yields. If conditions are not good, then an inadequate number of tillers will be developed and yields will suffer. Fortunately, the rice plant has a remarkable ability to compensate for low stands. As stand density goes down, tillers per plant increase. For example, in a Butte County nitrogen by variety trial in 1984 and 1985, 12 plants/ft^2 produced 4.8 tillers per plant, 21 plants/ft^2 produced 3.1 tillers per plant and 27 up to 34 plants/ft^2 produced about 2 tillers per plant. Only at the lowest stand density of 12 plants/ft^2 were yields significantly lower and then not by much. Generally, adequate stands require only the development of primary tillers that develop over a relatively short period. However, at densities of 5-7 plants/ft^2, 10-12 tillers/plant would be needed to achieve an adequate panicle density. This would require a longer tiller development period for each plant and usually results in lower yields and lower quality due to a longer maturation period. This is why a field with anything less than 5-7 plants/ft^2 is considered on the borderline for reseeding or overseeding.



Spikelets Per Panicle

Spikelets are formed when the apical meristem or growing point changes from producing leaves to producing the panicle. This occurs late in the tillering stage and triggers PI or reproductive growth. The entire panicle—branches and spikelets are developed at this time. Although they cannot be seen with the naked eye, under a microscope their surface appears as a series of small nodes, each to become a spikelet or grain. Typically we identify PI by cutting the stem or culm longitudinally with a pocketknife to find the young panicle within the stem Figure 2. Usually by the time we see the panicle, the plant is a few days past PI. The maximum panicle size of most California calrose types is around 100 spikelets per panicle, but is more on the order of 70 spikelets per panicle with typical densities of 60 to 70 panicles/ft^2. The number of spikelets per panicle, however, can vary genetically from varieties with relatively small panicles to varieties with panicles of over 150 spikelets or more. Some of the Chinese hybrids, for example, have very large panicles. Management practices can influence the number of spikelets per panicle. Most commonly, stand density has the greatest influence on panicle size. Rice plants will compensate for low stand densities by producing more spikelets per panicle (as well as by producing more tillers per plant) as shown in Table 2. Usually, however, panicle size will not increase enough to overcome lower yields from poor stands.

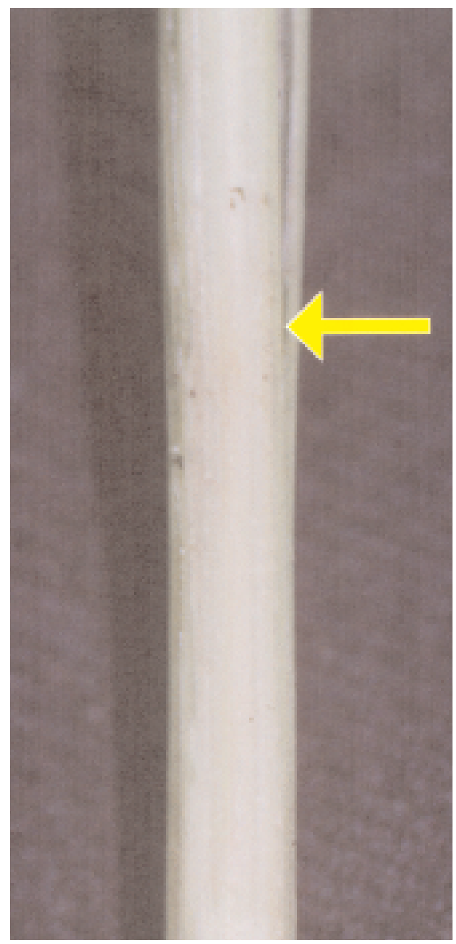


Figure 2. Young panicle

Percentage Filled Grains

The percentage of filled spikelets per panicle can be greatly reduced by cold temperature. California varieties are among the most cold tolerant in the world, but they can still be damaged at PI by temperatures at or below 55º F. When this occurs, the spikelets become sterile and result in “blanks.” Blanking can be as high as 40-50% when low nighttime temperatures continue for four or five consecutive days. Blanking on a “normal” year is around 12%. Proper water management can greatly reduce cold damage. Water should be raised to a level above the young panicle to act as a heat sink and thus keep temperatures above 55º F.

Kernel weight

Kernel weight differs among varieties (see Table 9 in the variety section) from a 1000 kernel weight for the small-seeded koshihikari 23.8 g, to M-401 and S-102 at 32 g and 34 g, respectively. In the field, kernel weights are the least variable yield component. They generally cannot be increased by good management practices to compensate for poor tillering or smaller panicles. For example, Table 2 shows that across all seeding rates and resulting panicle densities, and even at the lowest seeding rate where panicle size increases, grain weight remains constant at about 25 g per 1000 kernels. Kernel weight, however, can be reduced by bad management or bad luck (such as draining too soon or from drying north winds). Fields that are too dry at the end of the harvest can limit grain filling and reduce kernel weight as well as quality.

III. Rice Growth and Formation of Yield Components

The yield components described above develop in different stages in the life cycle of the rice plant. Thus, management practices must be timed properly to positively influence the desired yield component. For example, once plant/crop growth is beyond the critical stage of tiller development, management practices, no matter how well intended, cannot increase the number of tillers. The growth of the rice plant can be divided into three stages: vegetative, from seed germination to PI; the reproductive stage from PI to flowering; and the ripening stage from flowering to grain maturity. The time required for each of these stages is dependent largely on the choice of variety, but is also affected by management practices, weather and other environmental conditions.

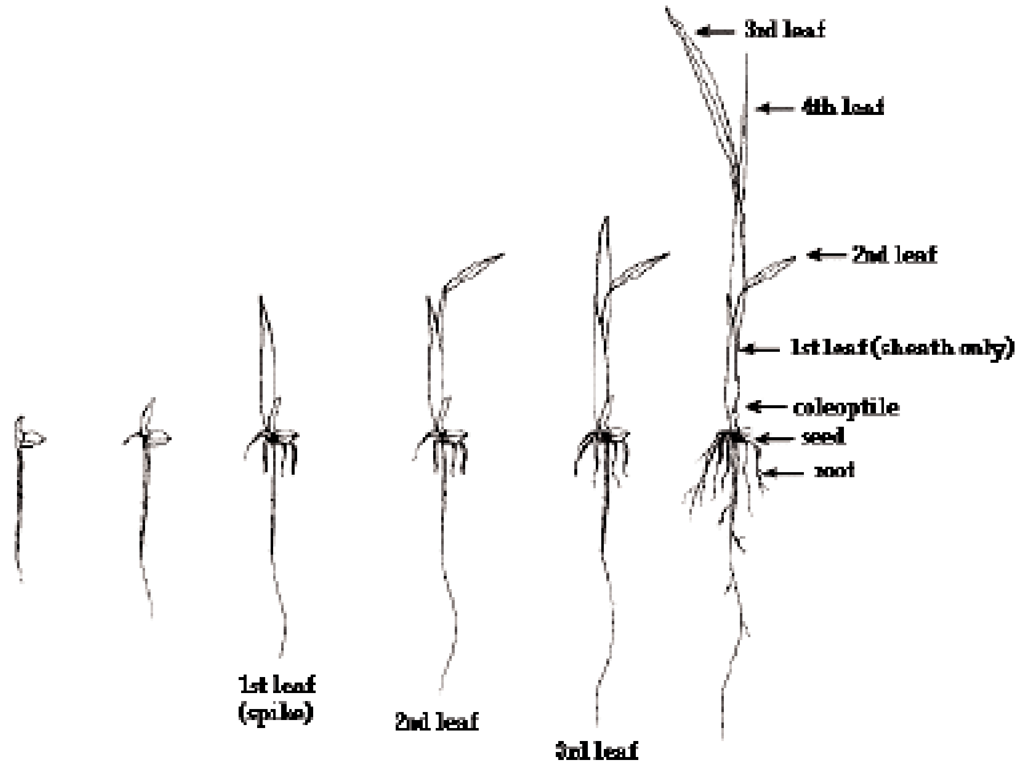


Figure 3a. The early growth stages of rice

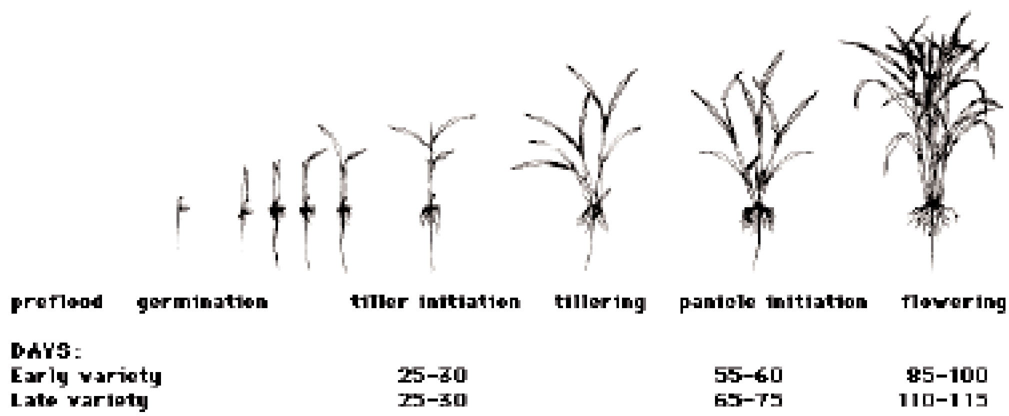


Figure 3b. The full season growth stages of rice

The Vegetative Stage

Vegetative growth begins with seed germination and lasts through the tillering stage. It can be subdivided into seedling growth and tillering. The best opportunity for management practices to influence yield is in the vegetative stage. In the seedling stage, good seedling emergence, stand establishment and seedling growth can be enhanced by the use of high quality seed, proper seed soaking, land leveling, seedbed grooving and other management practices that are described in detail in other sections of this workbook. For the first few days up to about the 3-leaf stage the seedling is dependent on the stored seed reserves for growth (Figure 4).

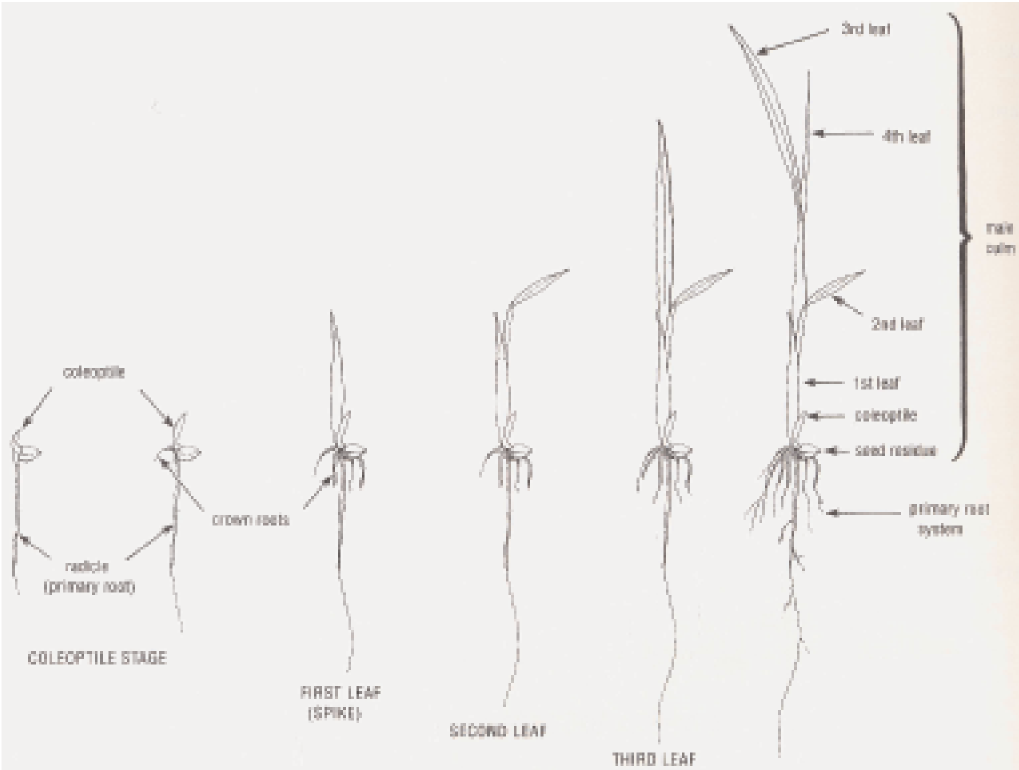


Figure 4. The stages of seedling development

At about the 4-leaf stage the young rice plant becomes self-supporting or autotrophic, relying on the sun's energy and nutrients from the soil for growth. Practices to enhance rooting and allow for emergence through the water will enhance rice stands. Generally, plant stands of 15 to 20 seedlings per ft^2 will provide optimum tiller and panicle densities.

The seedling develops into the main stem. At tillering, the second stage of vegetative growth, the primary tillers develop in the axils (base) of each leaf beginning with the second leaf. Tillers typically begin to appear at about the fifth leaf stage (Figure 5).

When the sixth leaf appears, the second tiller emerges from the third leaf and so on. Each tiller is also capable of

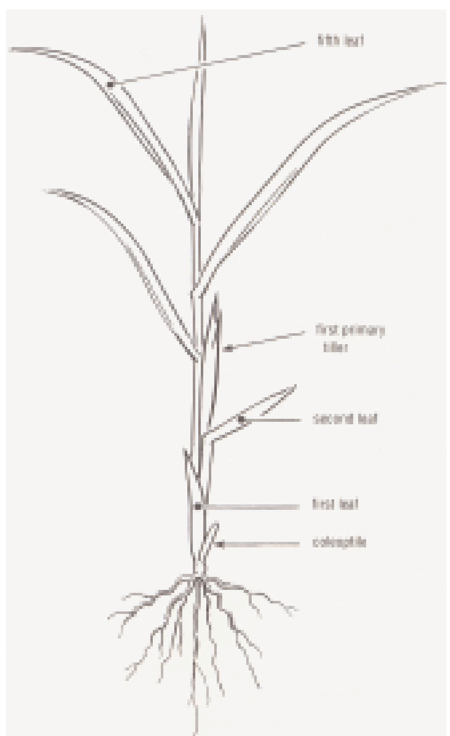


Figure 5. Tiller initiation at the 5th leaf stage from the axil of the 2nd leaf

developing sub-tillers or secondary tillers. The total number of tillers developed from a single seedling depends on stand density, nitrogen and other nutrient status, weed competition and damage from pests. The tillering stage is even more important to final panicle density and yield than the number of seedlings established. It is also one of the critical stages that can be most influenced by management practices. The period of tillering varies with the maturity group of the variety. Late or long-season varieties such as M-401, have a longer vegetative stage, meaning that tiller initiation may extend over a longer period. The management factors affecting tiller formation include good nutrition, especially N management, water management (deep water reduces tillering, but usually not below critical levels when other factors are well managed—see Figure 4 in Water Management section), weed competition, insects and diseases. The management of these factors is discussed in other sections of this workbook. Generally, panicle densities should be in the range of 60 to 70 fertile tillers per ft^2 to maximize yields. Under good conditions, the number of tillers formed on the plant at maximum tillering may be twice what is necessary for high yields. In this case, many of the tillers die before flowering. Figure 6 shows how tillers develop over the season at different seeding rates. Note that at very low seeding rates, all the tillers survive (and are needed for high yield) whereas at high seeding rates the number of tillers is very high at maximum tillering but about half die off from shading. Final tiller number is about constant across these seeding rates.

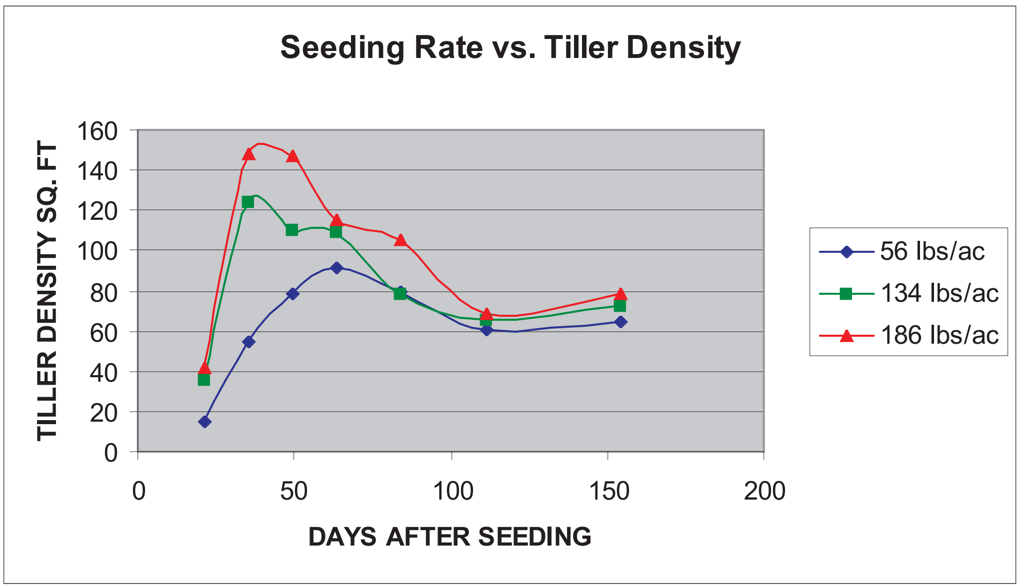


Figure 6. Tiller development over the season

The Reproductive Stage

The reproductive stage begins at PI and extends through flowering. Late varieties are sensitive to daylength and PI must be induced by shorter days. This means that PI in late varieties is triggered after the summer solstice (June 21) when daylength begins to get shorter. Early and Very Early varieties have little or no photosensitivity and do not need a daylength signal to switch from the vegetative to reproductive stage. The panicle develops within each tiller at the base of the plant just above the soil surface. At about one week following PI the young panicle is large enough to see when the stem is sliced longitudinally through the base (usually starting to bulge). At this time jointing or stem elongation of the upper internodes begins. The young panicle is about 1-2 inches above the soil surface and differentiating into spikelets; the number of spikelets per panicle are determined at this time. In the final stages of differentiation, pollen is formed within each immature spikelet and this is the most sensitive period to cold temperatures. Cold temperatures of 55°F or less can cause sterility by inhibiting pollen formation and resulting in excessive blanking. This is referred to as cold-temperature induced blanking. Although field practices cannot increase the number of spikelets formed during PI, raising the water level above the developing panicle at PI to mitigate cold temperature can greatly increase the percentage of spikelets that become filled grains. This is the most important management practice available at PI to maintain good yields. Figure 7 shows how to identify the most cold sensitive period before flowering. Of lesser importance is spikelet sterility caused by too much N. Excessive N from over fertilization, particularly in a cool season or from fertilizer overlaps can increase sterility and blanking. This is why it is important to fertilize preplant only for a cool year and topdress as needed if the season is warm. Other management practices such as herbicide treatments at PI may also have an effect on grain filling. Although no longer used in California rice, the herbicides 2,4-D and MCPA both caused panicle deformities and yield reduction if applied during this time. In fact, the Grandstand label restricts application during this period.

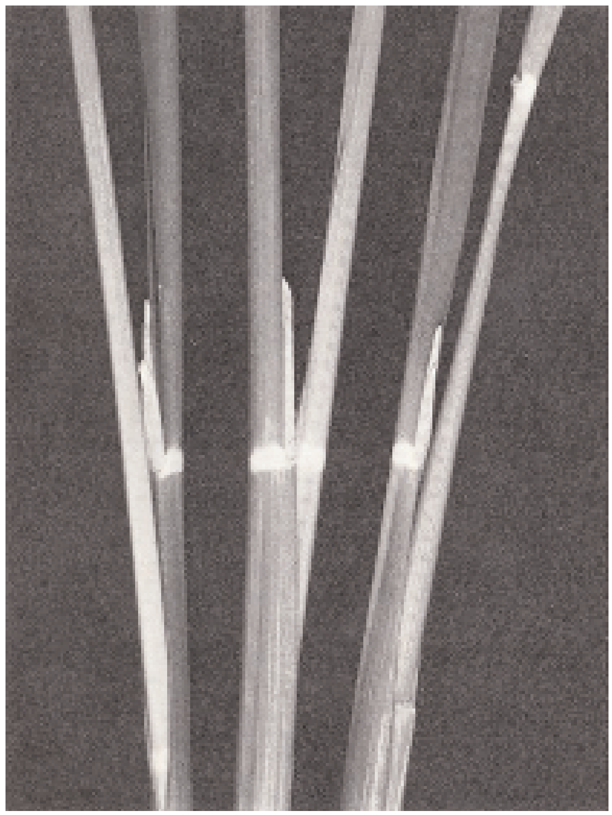


Figure 7. Pollen formation and cold sensitivity occurs when the collar of the flag leaf is aligned with the collar of the previous leaf (center).

The exact day of PI is not easy to determine and given the spread in tiller formation, occurs over at least a two-week period. Table 3 gives an approximation of the length of the vegetative stage for different maturity groups. This is extrapolated from the date of 50% heading. Note that there is a large degree of variability in the heading date for the same variety across locations (Butte, Glenn, Sacramento and San Joaquin) as well as from year to year (Table 3, last column).

Table 3*: Average date to 50% heading, estimated time to PI and variation in PI estimates over the ten year period from 1992-2002 (excluding 1999).*

Cultivar	Maturity Group	Location (county)	Ave. heading date	1992-2002 Ave. PI	Est. range in PI (days)
CM-101	VE	Butte	78	48-56	± 5
		Sac.	83	53-61	± 6
		SJ	91	61-69	± 8
M-104	Early	Butte	77	47-55	± 4
		Sac.	81	51-59	± 6
		SJ	92	62-70	± 6
M-202	Early	Butte	85	55-63	± 5
		Glenn	90	60-68	± 8
		Sac.	91	61-69	± 5
		SJ	100	70-78	± 6
M-401	Late	Butte	106	76-84	± 6
		Glenn	109	79-87	± 10

Flowering, the second part of the reproductive stage, occurs over two to three weeks. The time of flowering varies with the varietal maturity group as shown for average heading date in Table 3 or in Table 5, page V-7 of the variety section of this workbook. Very high temperatures at flowering can dry the germinating pollen tube before fertilization and cause blanking. Generally, these temperatures must be above 104 to 105°F. Heat induced sterility is of far less consequence to yield than is cold temperature induced floret sterility which occurs at or near PI. Nothing can be done to mitigate high temperature damage by management practices.

The Ripening Stage

The fourth and final yield component, kernel weight, is determined at ripening. Ripening begins at the completion of flowering and lasts through physiological maturity. The developing kernel is filled from materials stored in the leaves and stem and from new carbohydrate produced from photosynthesis in the uppermost leaves. The kernel reaches physiological maturity at about 30% moisture. For translocation of stored materials and photosynthesis to remain active, the maturing plant must have adequate soil moisture for a long enough period to ripen late maturing kernels. While it is not possible to increase kernel weight above the genetic potential of the variety, it is possible to lower kernel weight by soil drying too soon. Thus, decisions about when to drain the field are critical. Early draining facilitates harvest but may allow the field to dry too soon to complete grain filling, thus reducing both kernel weight and milling quality. This decision is often a tradeoff between a smooth harvest and lower head rice or “mucking” out the harvest to achieve higher head rice. Generally the field is ready for harvest when 90% of the grains are hard and the hulls are yellow.

VI. SUMMARY

Yield components are the product of the number of panicles per unit area, the number of spikelets per panicle, the % filled spikelets and the kernel weight. Generally, a seeding density of 15-20 established seedlings/ft^2 result in an adequate density of 60 to 70 fertile panicles/ft^2. Management practices have the biggest influence on final yield during the vegetative stage when the panicle number is determined. This yield component is completely formed in the first 45-60 days of the season and cannot be changed after that time. The number of spikelets per panicle and the percentage of filled kernels are determined at, and shortly after PI. The panicle size and spikelet number cannot be increased, but good management of water to reduce exposure to cold temperatures can minimize excessive blanking. Similarly, kernel weight cannot be increased over the genetic potential of the variety, but management practices such as field draining for harvest can affect grain filling. Rice management practices are described in detail in the following sections of this workbook. It is important to think about when these occur in the life of the rice plant and what effect they might have on specific yield components. The knowledge of yield component formation can also help in diagnosing problems after the fact.