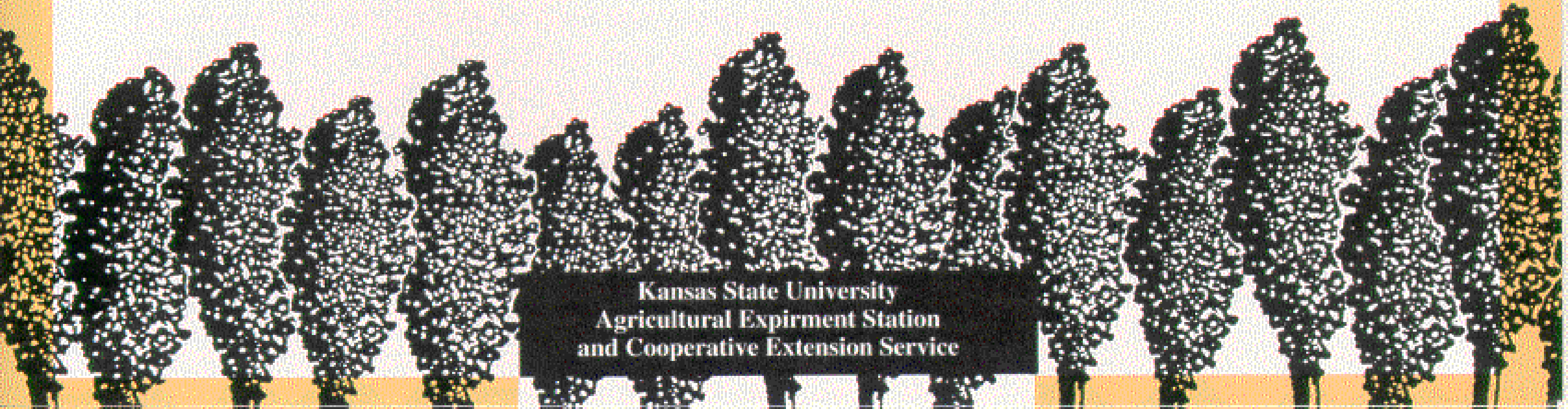
HOW A SORGHUM PLANT DEVELOPS



Kansas State University
Agricultural Expirment Station
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Acknowledgement

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How a Sorghum Plant Develops

R. L. VANDERLIP *

Sorghum's importance as a feed grain has increased in the U. S., and it is a major human food in other areas of the world. To manage the sorghum crop for maximum production, the producer must understand how the plant grows and develops and what factors affect its growth, development, and nutrient uptake.

This publication describes the general growth and nutrient accumulation pattern of the sorghum plant, it divides the growth of the plant into several identifiable stages and it relates the plant's growth and development during each stage to various management factors you can control.

Crop yields can be considered from several angles. Some people compare a crop to a factory and consider each factor that affects production from the factory.

No matter how the production of a crop is viewed, two factors are basic: the plant and its environment or surroundings. Just as people vary in abilities, plants—varieties or hybrids—vary in ability to produce. Certainly the environment in which the plants grow—the particular field—greatly affects the yield produced. It is necessary to select the proper variety or hybrid and provide the best possible environment to obtain highest yields. That can be done only when we understand how the plant grows and develops.

Once the basic growth pattern of grain sorghum plants is understood, it is much easier to judge the merit of changing a management practice. Also, possible effects of entirely new practices or problems can be much better anticipated.

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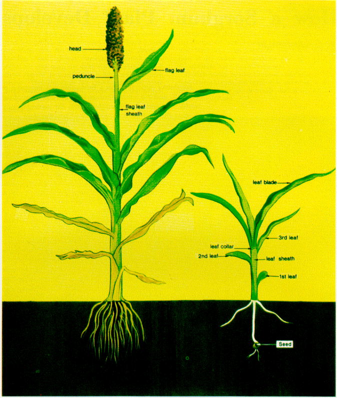

head
peduncle
flag leaf
flag leaf
sheath
leaf blade
3rd leaf
leaf collar
2nd leaf
leaf sheath
1st leaf
Seed

Figure 1

Identifying Stages of Growth

Growth and development of the grain sorghum plant are described only in general terms in this publication. The pictures represent a hybrid of RS610 maturity grown at Manhattan, Kansas. While other hybrids growing at other locations would follow the same general growth pattern, the specific timing between growth stages and number of leaves developed at later growth stages may vary among hybrids, seasons, or locations.

Some definitions of plant parts are necessary to identify various stages of plant development described in this publication. Figure 1 shows a young sorghum plant and a mature plant. Some of the early stages of development are defined by the number of fully developed leaves.

The mature plant in Figure 1 shows other parts later in the season. Several lower leaves have been lost.

A leaf is counted when the collar (the point where the leaf blade and leaf sheath attach) is visible without tearing the plant apart. The young plant shown has three fully developed leaves. Identification of individual leaves early in the growing season may also be aided by considering the shape of the first (lowest) leaf. The first leaf produced by the sorghum plant has a rounded tip. If the lowest leaf on the plant is pointed, then at least one leaf has been lost.

Table 1. Identifying characteristics and approximate time intervals between growth stages of sorghum.

Growth stage	Approximate days after emergence *	Identifying characteristic
0	0	**Emergence.** Coleoptile visible at soil surface.
1	10	**Collar of 3rd leaf visible.**
2	20	**Collar of 5th leaf visible.**
3	30	**Growing point differentiation.** Approximately 8-leaf stage by previous criteria.
4	40	**Final leaf visible in whorl.**
5	50	**Boot.** Head extended into flag leaf sheath.
6	60	**Half-bloom.** Half of plants at some stage of bloom.
7	70	**Soft dough.**
8	85	**Hard dough.**
9	95	**Physiological maturity.** Maximum dry matter accumulation.

* Approximate days required for hybrids of RS610 maturity grown at Manhattan, Kansas.

Stages of development have been assigned numbers from zero to nine, similar to the numbering system used for corn. Thus growth of the plant is defined from Stage 0—emergence—to Stage 9—physiological maturity. Characteristics to identify each stage are presented in Table 1. Time required to reach each stage depends both on the hybrid and the environment in which it is growing. The times presented are for comparative purposes only. They would change for the same hybrid at the same location if planting date were changed or if results from two seasons were compared. Other factors such as soil fertility, insect or disease damage, moisture stress, plant population, and weed competition may also affect both timing of the various stages of development and condition of the plants at each stage of development.

Figure 2 shows the pattern of growth (dry weight) and nutrient accumulation during growth of sorghum plants. Note that dry matter, nitrogen, phosphorus, and potassium all are expressed on the basis of total weight of each factor so that all reach 100 percent at maturity.

It is important to recognize that nutrient uptake curves fall above the dry matter curve for most of the growth period. For example, look at the vertical line that designates half-bloom at 60 days after emergence: about one-half of the total plant weight has been produced; however, nearly 60 percent of the phosphorus, 70 percent of the nitrogen, and 80 percent of the potassium already have been taken up. Those percentages emphasize how important early growth stages are in the nutrition of the sorghum plant.

Growth of the various plant parts—in terms of dry weight—is shown in Figure 3. The first 30-35 days after the plant emerges, nearly all growth is leaves. Then the culm or stalk starts rapid growth, and leaves and stalk continue until maximum leaf weight is reached at about 60 days and maximum stalk weight at about 65 days. After about 50 days the head increases in weight rapidly. Then following pollination the grain increases in weight rapidly, sometimes faster than the rate total dry matter accumulates. That results in a net decrease in the stalk weight as materials are moved from the stalk to the head.

In considering descriptions of stages of growth that follow, the effects of management practices, insect or hail damage, fertilization, weed control, or other practices can be best understood by keeping Figures 2 and 3 in mind.

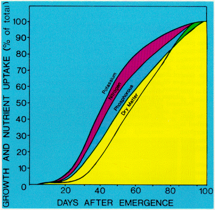


Figure 2

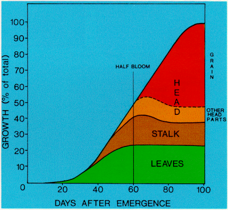


Figure 3

Sorghum Seed

Of the three major spring-planted crops—corn, sorghum, and soybeans—sorghum has by far the smallest seed. It also varies greatly in seed size. The above photograph is of seed from two hybrids submitted for the Kansas Grain Sorghum Performance Tests. If planting were by weight of seed per acre, one would be seeded much thicker than the other. For example, the following table shows what would happen if both of those hybrids were planted at 4 pounds per acre and each had 75 percent field establishment.

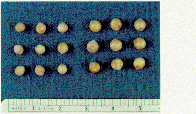


Table 2. Effect of seed size on planting rate and plant population when planting is based on pounds per acre.

	Seed lot A	Seed lot B
Seed weight, g./1,000 seeds	19.0	34.3
Seeds/acre @ 4 lb./acre	95,500	52,900
Plants/acre @ 75% field establishment	71,600	39,700

So to obtain the desired plant population, it is necessary to know more than how many pounds per acre we are using. In the example it was assumed that the field establishment for the two lots of seed was equal. That may not be the case. Even when two lots have similar high germination, it is not uncommon for field establishment to differ greatly (20 to 50 percent) from laboratory germination. While there seems to be poor relationship between seed size and field performance when many sorghum hybrids are compared, if seed sizes within a seed-lot are considered, both extremely small and extremely large seed have lower-than-average establishment capability.

Management Guide

To obtain the desired field stands, get high-quality seed that germinates well. Planting rate should be determined by spacing between seeds dropped and percentage establishment rather than by pounds per acre. Recommended planting rates vary from about 20,000 to 100,000 plants per acre depending on moisture conditions. Table 3 gives suggested *seed* spacings for grain sorghum in Kansas.

Table 3. Suggested seed spacing for grain sorghums grown in indicated areas in Kansas.[1]

Row width inches	Suggested seed spacing (inches) in row: Western, less than 20 in. precip.	West Central, 20-26 in. precip.	East Central, 26-32 in. precip.	Eastern more than 32 in. precip.	Irrigated
10	20-32	12-24	8-16	6-12	3-4
20	10-16	6-12	4-10	3-6	1-2
30	7-12	4-9	3-8	2-4	1-2
40	5-8	3-6	2-5	1½-3	

1. Suggestions assume high germinating seed (90% or better) and at least 65% field emergence.

Stage 0

Emergence—when the plant first breaks through the soil surface—generally occurs 3 to 10 days after planting. The time required depends on soil temperature, moisture conditions, depth of planting, and vigor of the seed. During this period growth depends on the seed for nutrients and food reserves. Cool, wet conditions during this time may favor disease organisms that seriously damage stands.

Management Guide

Depth and date of planting greatly affect emergence rate. Planting should be timed so that germination and early growth occur during warm temperatures and so that flowering will occur before the hottest period of summer. Planting too early delays emergence and subjects the seed to longer attack of soil microorganisms.

Seed should be treated with a fungicide before planting. At the same time, weed control should be considered. Should a pre-plant or pre-emergent herbicide be used? If weeds can be thus controlled, later competition (because wet field conditions prevent weed control by cultivation or herbicides) may be avoided.

Stage 1

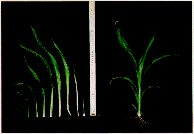
Three-leaf stage—Leaves are counted when the collar (the place where the leaf blade and leaf sheath attach, Figure 1) of the leaf can be seen without tearing the plant apart. The growing point of the plant is still below the soil surface. While the plant's growth rate depends largely on temperature, this stage usually will occur about 10 days after emergence.

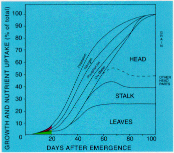
Management Guide

It is important that the date of planting be late enough so that sorghum can grow rapidly during Stage 1. Since the plant is quite small, relatively slow growth and poor weed control during Stage 1 can seriously reduce yields. As the growing point is still below the soil surface, much of the leaf area can be removed—by hail, for example—without killing the plant. Sorghum, however, does not recover as vigorously as corn.

Stage 2

Five-leaf stage—Approximately 3 weeks after it emerges a sorghum plant has 5 leaves fully expanded; its root system is developing rapidly and roots produced at the lower nodes may push the lower leaf off the plant. This usually does not cause difficulty in identifying the five-leaf stage because the lower leaf has a rounded tip and the second leaf is pointed (Figure 1). The plant enters its "grand period of growth" in Stage 2. Dry matter accumulates at nearly a constant rate until maturity, if growing conditions are satisfactory (Figure 2).





Management Guide

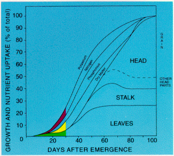
The growing point is still below the soil surface so leaf loss will not necessarily kill the plant. Regrowth is more vigorous than at the three-leaf stage but still less vigorous than corn. During Stage 2 the potential for the plant to develop is determined. Weed competition, nutrient and water stress, or other problems, such as insect damage at Stage 2, can seriously reduce yields if they are not corrected.

Stage 3

Growing point differentiation—About 30 days after sorghum emerges, its growing point changes from vegetative (leaf producing) to reproductive (head producing). The total number of leaves has been determined and potential head size will soon be determined. About one-third of the total leaf area has fully developed—7 to 10 leaves depending on maturity class—and the lower 1 to 3 leaves may have been lost. Culm or stalk growth increases rapidly following growing point differentiation. Nutrient uptake is rapid. Time from planting to growing point differentiation generally is about one-third of the time from planting to physiological maturity (maximum dry weight).

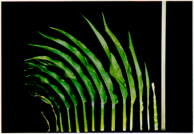
Management Guide

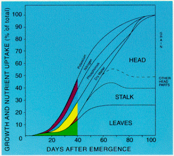
Growth and nutrient uptake are rapid during Stage 3. Adequate supplies of nutrients and water are necessary to provide maximum growth. Sorghum plants are now quite competitive which helps maintain good weed control the remainder of the growing season.



Stage 4

Flag leaf visibile — Following growing point differentiation, rapid culm elongation and rapid leaf development occur simultaneously until, at Stage 4, the flag leaf (final leaf) is visible in the whorl. By then all except the final 3 to 4 leaves are fully expanded and about 80 percent of the total leaf area is present. Light interception is approaching maximum, and growth and nutrient uptake continue at a rapid rate. The head is developing. The lower 2 to 5 leaves have been lost. Any reference to leaf number from now on should be from the top, counting the flag leaf as leaf number 1. While only about one-fifth of the total growth has occurred, nutrient uptake is far greater with more than 40 percent of the potassium already taken up.



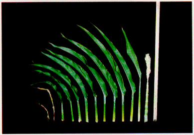


Management Guide

Same as during Stage 3.

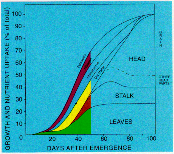
Stage 5

Boot stage—All leaves are now fully expanded, providing maximum leaf area and light interception. The head has now developed to nearly full size and is enclosed in the flag-leaf sheath. Except for the peduncle (see Figure 1) culm elongation is essentially complete. Peduncle elongation is beginning and will result in exertion of the head from the flag-leaf sheath. Potential head size has been determined.



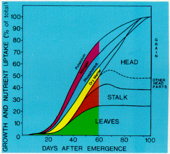
Management Guide

Rapid growth and nutrient uptake are continuing. Severe moisture stress or herbicide injury during Stage 5 may prevent the head from exerting completely from the flag-leaf sheath. This prevents complete pollination at flowering time.



Stage 6

Half-bloom—Following the boot stage the peduncle grows rapidly extending the head through the flag-leaf sheath. Even in combine sorghums, the peduncle is not reduced in length as is the rest of the stalk. Although height of combine-sorghum plants has been reduced, heads are well above the leaves, which makes combining easier. Half-bloom is usually defined as when one-half of the plants in a field or area are in some stage of bloom. However, because an individual sorghum head flowers from the tip downward over 4 to 9 days, half-bloom on an individual plant is when the flowering has progressed half-way down the head. At half-bloom approximately one-half of the total dry weight of the plant has been produced. However, nutrient uptake has reached nearly 70, 60, and 80 percent of total for N, P, and K, respectively. Time required from planting to half-bloom depends on the maturity of the hybrid and environmental conditions; however, it usually represents two-thirds of the time from planting to physiological maturity.

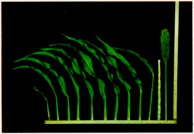


Management Guide

At this time grain formation begins; therefore, any limitation in plant size, leaf area, or plant numbers can no longer be corrected. However, if environmental conditions are favorable, the sorghum plant can still compensate for number of plants by increasing both seed number per head and seed weight. Severe moisture stress at Stage 6 can result in "blasting" and poor head filling. As mentioned earlier, hybrid maturity and planting date should be chosen so flowering will not occur when severe hot, dry weather is normal.

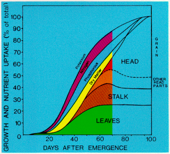
Stage 7

Soft-dough—Between half-bloom and soft-dough the grain fills rapidly; approximately half of its dry weight is accumulated in this period. The culm weight increases slightly following half-bloom; then, because grain is forming rapidly, the culm loses weight. The loss in culm weight may account for as much as 10 percent of the grain weight. Lower leaves are still being lost with 8 to 12 functional leaves remaining during Stage 7.



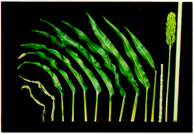
Management Guide

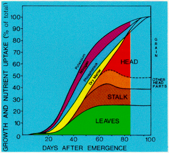
Final yield depends on the rate dry matter accumulates in the grain and the length of time that it accumulates. Dry matter accumulation rates do not vary much among hybrids. Therefore, so long as the hybrid is able to mature before frost and flowering does not coincide with severe moisture stress, later maturing hybrids yield more than early maturing ones.



Stage 8

Hard-dough—By hard-dough stage, about three-fourths of the grain dry weight has accumulated. The culm has declined to its lowest weight. Nutrient uptake is essentially complete. Additional leaves may have been lost.





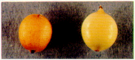
Management Guide

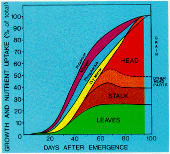
Severe moisture stress or a freeze before the grain matures will result in light, chaffy grain.

Stage 9

Physiological maturity—Maximum total dry weight of the plant has occurred. Physiological maturity can be determined by the dark spot on the opposite side of the kernel from the embryo (photograph at right). The kernel on the left is physiologically mature; the one on the right is not.

The time from flowering to physiological maturity varies with hybrid and environmental conditions; however, it represents about one-third of the total time from planting. Grain moisture content at physiological maturity varies with hybrid and growing conditions also. It usually is between 25 and 35 percent moisture. After physiological maturity, the remaining functional leaves may stay green or die and brown rapidly. If temperature and moisture conditions are favorable, branches may start to grow from several of the upper nodes (places where leaves attach—see Figure 1). Also, the culm or stalk weight may increase slightly near physiological maturity.





Management Guide

To reap maximum yields of silage or high-moisture grain, harvest as near physiological maturity as possible. The time required between physiological maturity and a grain moisture suitable for normal grain harvest depends upon hybrid and weather conditions. The plant will not reach physiological maturity and proper moisture content for normal harvest at the same time. Hybrid and weather conditions affect the time between maturity and the proper harvest date.

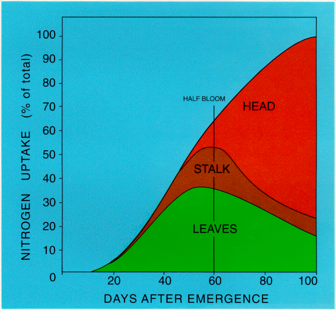
Nutrient Uptake

Nutrient uptake precedes dry matter accumulation because nutrients are required for growth and dry matter accumulation. Figures 4, 5, and 6 shows nutrient uptake (nitrogen, phosphorus, potassium) and distribution among various sorghum plant parts during growth. Figure 3 shows that on a relative basis potassium is taken up most rapidly followed by nitrogen, then phosphorus.

Large quantities of nitrogen and phosphorus and some potassium are translocated from the other plant parts to the grain as it develops. Unless adequate nutrients are available during grain filling this translocation may cause deficiencies in the leaves and premature leaf loss which may decrease yields. Thus an adequate supply of nutrients at all stages of development of the plant are necessary for maximum yields.

A large portion of the nitrogen and phosphorus but only a small portion of potassium is removed in the grain. Amounts removed depend upon the amount of each in the plant. A 135-bushel-per-acre grain crop contains (in the total aboveground plant): 185 pounds of nitrogen, 35 pounds of phosphorus, and 215 pounds of potassium. If the entire plant is harvested for silage or other forms of feed, much more potassium is removed because most of it is in the vegetative part of the plant.

Figure 4

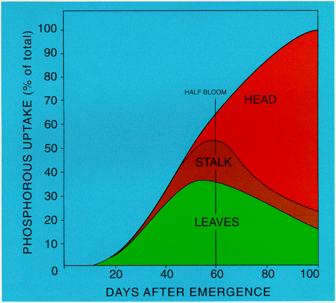


Sorghum grows slowly the first 20-25 days (up to Stage 2) with the aboveground part of the plant entirely leaves. As number of leaves and amount of leaf area increases, growth rate increases. Then in the next 35 to 45 days the remaining leaf area of the plant develops and expands to provide the photosynthetic, or manufacturing, apparatus for grain production. Most leaf growth occurs between Stages 3 and 5 during which time the upper 8 to 10 leaves develop. Starting about half-way through the period when leaves are produced, the culm starts to elongate and grows rapidly in length and weight until flowering occurs. Then the grain fills rapidly, using materials being manufactured by the leaves and being moved from the culm into the grain.

The general pattern of dry matter accumulation is the same for different sorghum hybrids. Later-maturing hybrids tend to be heavier at each stage of development than early maturing hybrids, particularly from Stage 3 (growing point differentiation) to maturity. Total dry matter accumulation rates for 3 hybrids grown in 2 years was 170 pounds per acre per day during the "grand period of growth" (Stage 4 to near Stage 9). The 3 hybrids had nearly identical rates of dry matter accumulation; the later one produced longer and thus yielded more.

Highest yields can be obtained only when the hybrid selected is adapted to the area and when environmental conditions are favorable during all stages of plant development.

Figure 5



Conclusions

The preceding illustrations show how a sorghum plant grows and takes up nutrients. They show the rates at which growth and nutrient uptake occur. The period of growth in which each plant part is produced is shown. Where nutrients are located in the plant at various times is also indicated. Using such information helps us provide conditions to help obtain maximum rate of dry matter accumulation for the longest period of time appropriate for an area. For best results:

Select high-quality, vigorous seed of adapted hybrids,

Fertilize according to soil tests for production realistically expected,

Plant at the proper time and at both correct population and spacing,

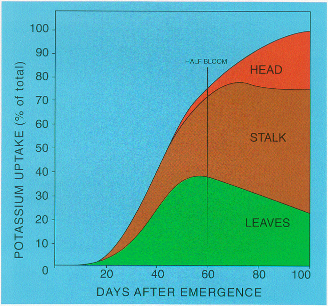
Control weeds, insects, and diseases,

Provide optimum moisture conditions possible,

Carry out other cultural practices with the general growth and nutrient uptake of the plant in mind.

Finally, use the information on growth and nutrient uptake as you look back on your last crop to determine what practices might be changed or to evaluate any new practices or products.

Figure 6



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S-3 January 1993

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