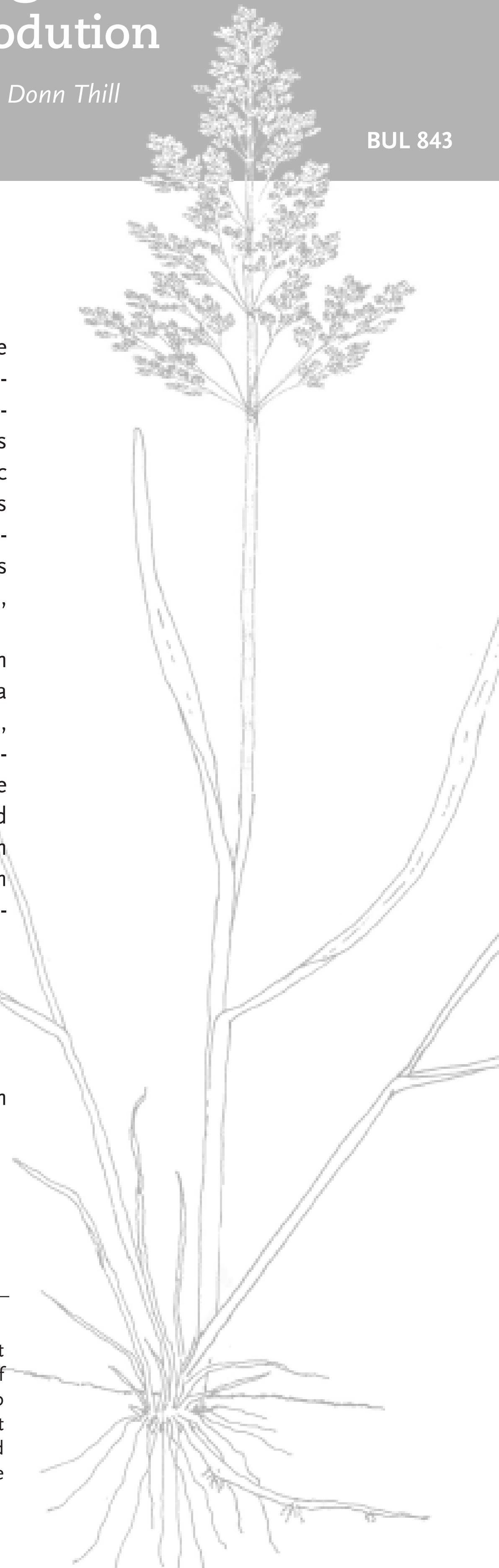
University of Idaho
College of Agricultural and Life Sciences

Kentucky Bluegrass
Growth, Development, and Seed Prodution

By John D. Holman and Donn Thill

BUL 843



INTRODUCTION

Burning plant residue is a historical practice that originated with Native Americans to increase plant productivity (Hardison 1976). Modern agricultural burning began in 1944 when the United States Forest Service discovered burning increased the seed production of native pasture grasses in Georgia (Hardison 1976). Burning grass seed fields in the Pacific Northwest began around 1950 to control diseases in perennial ryegrass and tall fescue. Burning has been used in the production of Kentucky bluegrass to maintain seed production and stand longevity. To compare effects of burning and non-burning on bluegrass production see BUL 842, Holman and Thill, 2005.

Unfortunately, emissions created by field burning are associated with negative air quality and public health impacts. Due to these impacts, a moratorium on grass field burning was implemented in Washington State, and restrictions on field burning were implemented in Idaho. Reduced-burn and no-burn production systems are currently being researched. The beneficial effects of burning on bluegrass growth and development need to be maintained in reduced-burn and no-burn production systems if high seed production and stand longevity are to be maintained. This bulletin summarizes what is documented about bluegrass growth and development and the effects of burning on seed production.

PLANT GROWTH

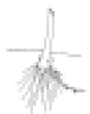
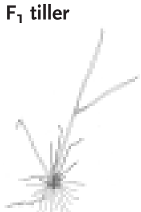
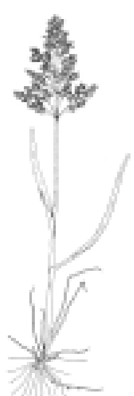
Phase 1: Fall Tiller Development and Floral Induction

Kentucky bluegrass tillers are classified by developmental stages, which include:

1. **D tiller** A new bud, or D tiller, develops into either F or C tillers or a rhizome—an underground stem;

NOTE: This publication is the second in a series evaluating the effects of residue management on bluegrass production, growth, and seed production. It specifically evaluates the impact of residue management on bluegrass seed production. It also identifies different tiller types to help growers better manage their crop. Please refer to other UI Extension publications for the effect of residue management on Kentucky bluegrass profitability (BUL 161 by Van Tassel, 2002), and Kentucky bluegrass production (BUL 842, Holman and Thill, 2005). Also find resources at the UI bluegrass website, *www.ag.uidhao.edu/bluegrass/*.

TABLE 1. Kentucky bluegrass tiller characteristics and impact of not burning on density.

Tiller	Development Characteristics	Time of Emergence	Produce Seed?	Plant size, identifiers	% of seed produced	Impact of not burning on density
D tillers 	A new bud that develops into a tiller (F_1, F_2, C) or a rhizome.	Anytime	No	Tiny, pointed nub just at or below ground level, located at the plant's crown.	0%	Reduces # of D tiller buds and may increase # of rhizomes.[1]
F_1 tiller 	An F_1 leafy tiller emerging from a D tiller bud does NOT produce seed the first year of emergence. It develops into a maximum seed-producing C tiller the second year after emergence.	In spring or late fall	Not in year one. (Abundant C tiller seeds are produced during year two).	By early April, F_1 tiller basal stems (at base of plant) are narrower than 2.5mm and leaves are narrower than 3mm for a common variety.	0% as an F_1 tiller. For second year production, see C tiller.	None known.
F_2 tiller 	A leafy tiller emerging from a D tiller bud produces a modest amount of seed (30%) within 1 year of emergence.	Early fall	Yes	Until seed head begins to develop, F_2 tillers look similar to F_1 tillers.	30%	None known.
C tillers 	A leafy tiller that began as a barren F_1 tiller produces seed 1 1/2 to 2 years after initial emergence. Tiller is surrounded by the previous year's F_1 leaf sheath.	Spring of the year prior to seed production, or late fall 2 years prior to seed production. It must be an F_1 tiller before it becomes a C tiller.	Yes	C tillers have a larger basal diameter and wider leaves than F_1 and F_2 tillers. By early April, stem base for a common variety is wider than 2.5mm and leaves are wider than 3mm. C tillers produce more spikelets and longer panicles. They complete floral induction earlier in the fall and produce more seeds than do F_2 tillers.	70%	None known.

1 Note. A decrease in D tiller density may not impact reproductive tiller density since not all D tillers develop into F and C tillers.

2. **F_1 tiller** A leafy tiller that emerges from a D tiller bud but does NOT produce seed within one year after emergence is a non-produtive F_1 tiller;
3. **F_2 tiller** A leafy tiller that emerges from a D tiller bud and produces seed within one year after emergence is an F_2 tiller;
4. **C tiller** The non-productive F_1 leafy tiller becomes the premier seed-producing C tiller 1 1/2 to 2 years after emergence (Sylvester and Reynolds 1999).

See more about these four types in table 1 and figures 1,2, and 3.

Identifying Tillers C and F_2 tillers produce 70 and 30 percent of a crop's total seed yield, respectively (Canode and Law 1979). C tillers can be distinguished from F tillers based on leaf width and tiller diameter in the spring. Both F_1 and F_2 tillers have narrower tiller diameters (< 2.5 millimeters) and narrower leaves (< 3 millimeters) than C tillers. See figure 2. In addition, C tillers are surrounded by the previous year's F_1

tiller leaf sheath, and they produce more spikelets, longer panicles and more seed. They also complete floral induction earlier in the fall than do F_2 tillers.

Impacts of not burning The impact of not burning on tiller production is uncertain. Not burning appears to reduce the number of D tiller buds, but it does not appear to impact C or F tiller size or density (Sylvester and Reynolds 1999). See figure 4.

Not burning may increase the number of rhizomes (Cordukes and Fisher 1974; Young, Younberg et al. 1984), resulting in an increased sod bound grass stand (Ensign, Hickey et al, 1983).

Tiller emergence and floral induction Tiller emergence depends on nutrient and water availability. A tiller can emerge in the early fall, late fall, or spring.

For a tiller to be reproductive (produce seed), it must complete the first stage of flowering, called floral induction: it ceases vegetative tissue production and begins reproductive tissue production.

Floral induction occurs after harvest, during the fall re-growth period. Scientists believe that in order for a bluegrass tiller to be floral induced, it must first complete a juvenile development period of at least two weeks and be > 0.04 inches in basal diameter.

A tiller will not complete the juvenile development period without adequate resources (nutrients, water, and growing degree days), and a tiller will not be floral induced without adequate stimuli—day length less than 13 hours and temperatures less than 50°F or 10°C (Canode and Law 1979; Rhoads, Dunn et al. 1992; Carlson, Ehlke et al. 1995; Sylvester and Reynolds 1999). A tiller that emerges in the early fall and has adequate resources is able to complete the floral induction requirement and produce seed the next year as an F_2 tiller.

A tiller that emerges in the late fall or early spring is unable to complete floral induction required for seed production, so it is a vegetative tiller the next year (F_1 tiller), but it produces seed the year after as a C tiller. See table 1 and figures 1, 2, and 3.

Post Harvest It is critical that post-harvest residue management and fall fertilization be implemented appropriately to maximize fall growth and floral induction.

Delaying residue removal and fertilizer application can shorten the fall re-growth period, resulting in fewer reproductive tillers and decreased seed production.

In a burn system, fertilizer should be applied in October, since applying earlier can result in too much

FIGURE 1. Kentucky bluegrass tiller type (F_1, F_2, C) is dependent on its date of emergence from a D tiller bud. D tillers can develop anytime of the year, when resources—water and nutrients—are available. Most D tillers form in the spring and fall when resources are most abundant.

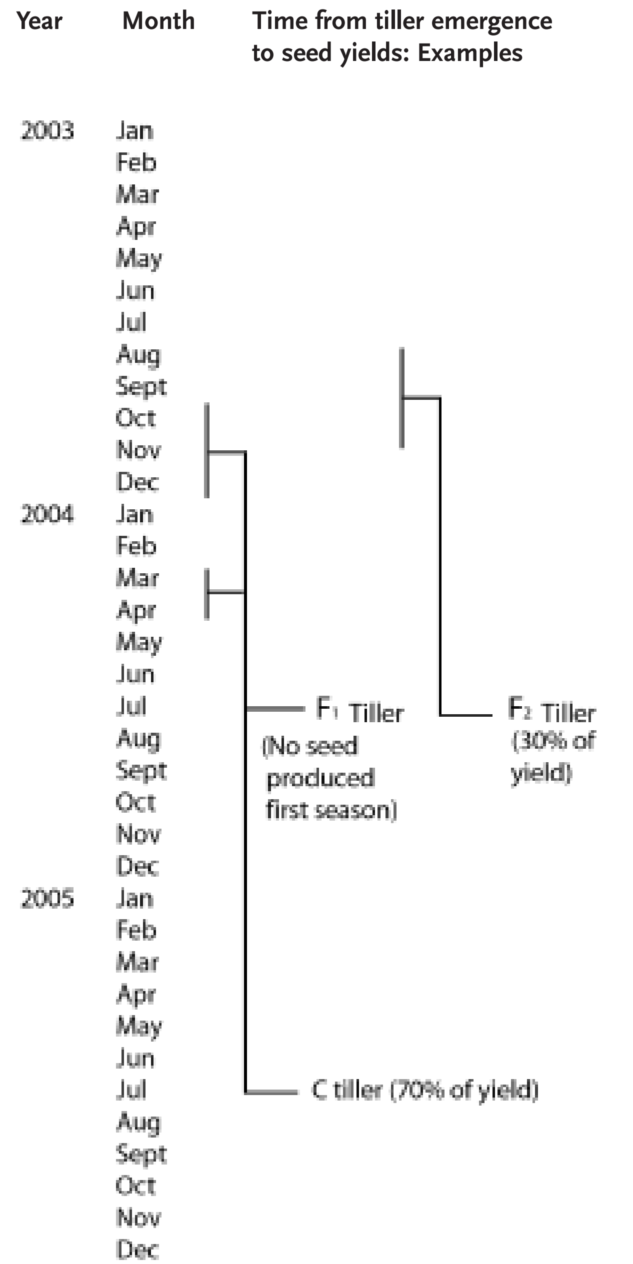
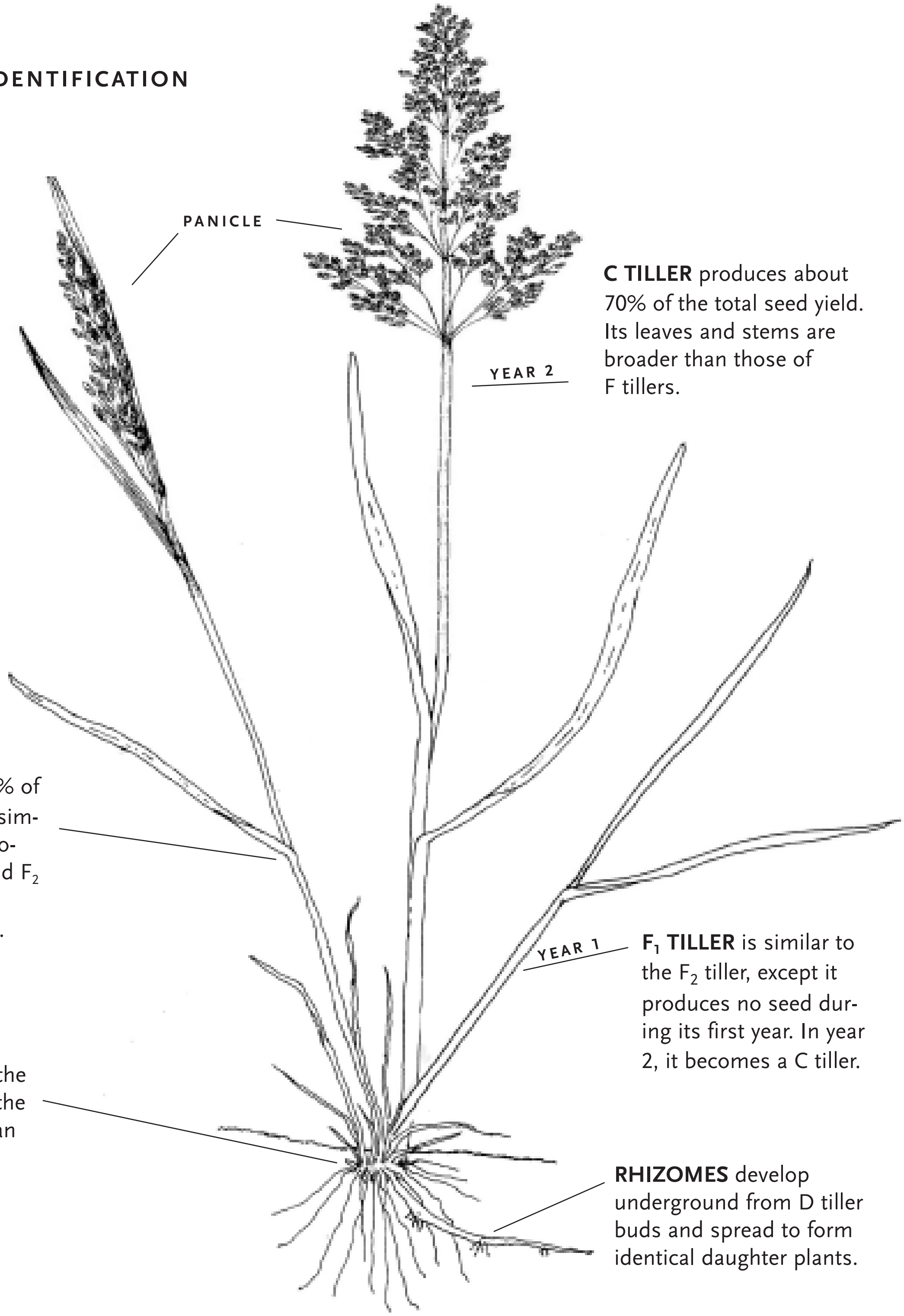


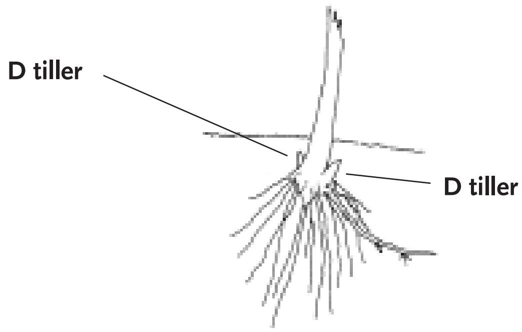
FIGURE 2. A typical Kentucky bluegrass plant consists of several tiller types (D, F_1, F_2, C). Growers logically would spend less on crop inputs on years when non-seed producing F_1 tillers predominate. But, they would provide resources to support the potential high yield in years when C tillers predominate. Unfortunately, the yield potential is not known until the spring, after most crop inputs have been applied. See grower tip below.



GROWER TIP: When a high density of F_1 tillers is present in the spring, the potential exists for a large crop of C tillers the following year, as long as resources remain sufficient. This includes the need to remove at least 80 percent of the post-harvest residue.

FIGURE 3. Kentucky bluegrass tiller development.

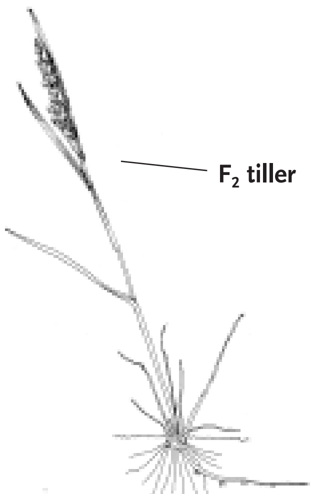
GROWTH PERIOD 1



Vegetative growth begins as a bud or D tiller just below soil level. Within months it will develop into an F_1 or F_2 tiller, or a rhizome.

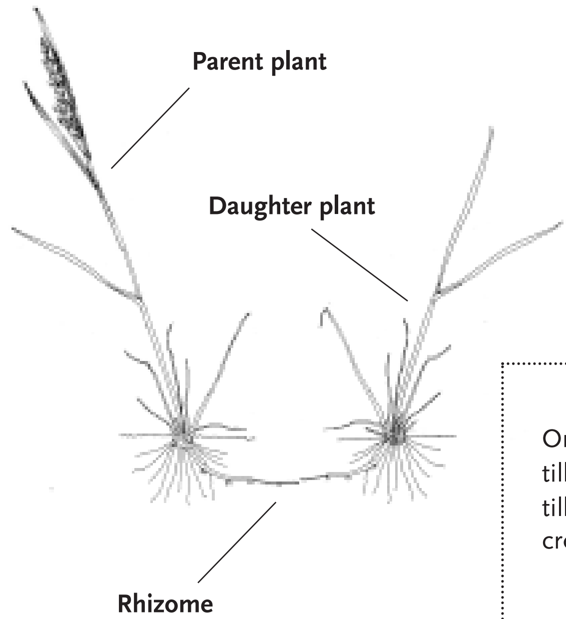
GROWTH PERIOD 2

GROWTH PERIOD 2A



The D tiller can form a leafy tiller. If the tiller emerges early in the fall and completes the juvenile growth requirement prior to fall floral induction, it can produce seed the next year as an F_2 tiller. F_2 tillers produce 30% of a crop's total seed yield.

GROWTH PERIOD 2C



D tillers can form rhizomes (underground stems), from which new daughter plants can establish. The daugher plant is identical in genetic composition to the parent plant. Parent and daughter plants can produce additional D tillers.

GROWTH PERIOD 2B

If the tiller emerges late in the fall or in the spring, it must grow as a leafy F_1 tiller (no seed production) the first year.

GROWTH PERIOD 3

One year after emerging as an F_1 tiller, the plant grows into a C tiller. C tillers produce 70% of a crop's total seed yield.

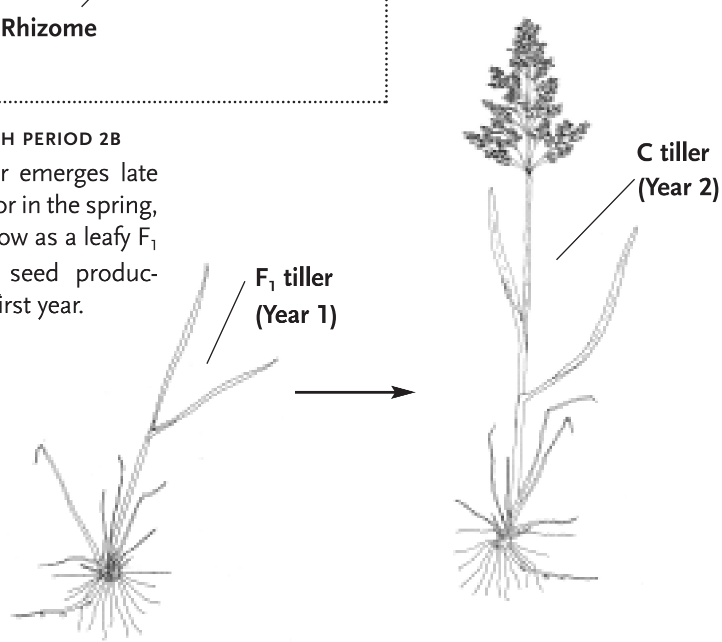
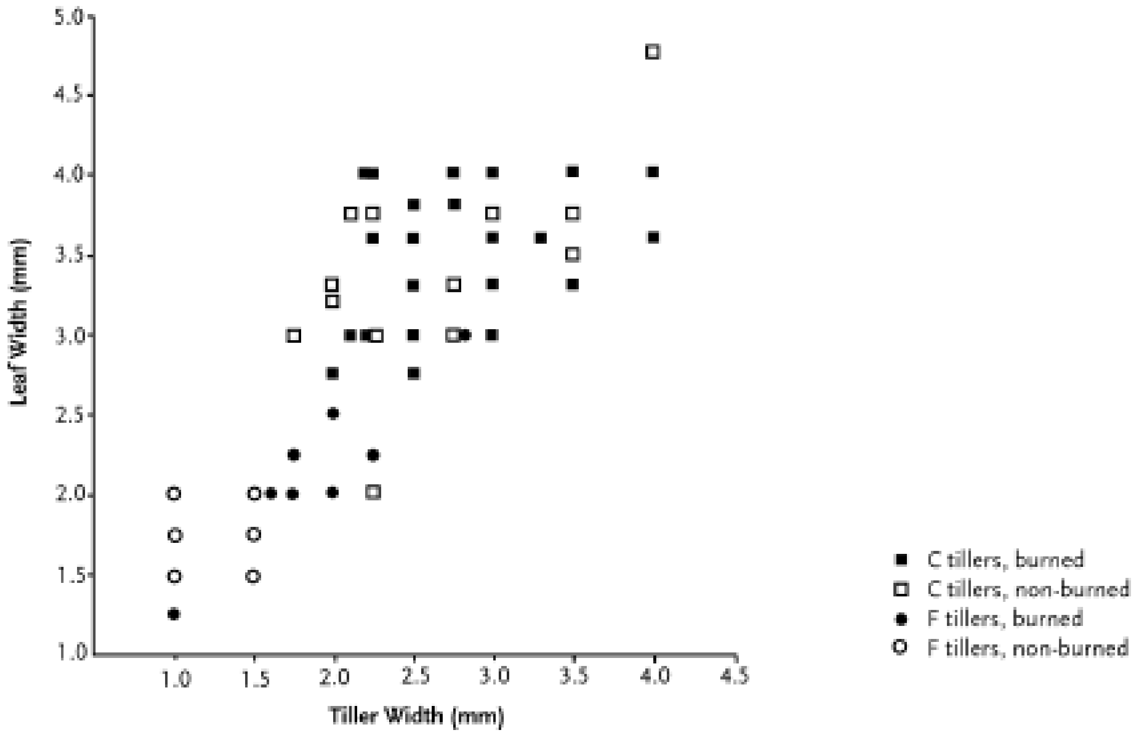


FIGURE 4. Graph shows measurement of tiller width vs. leaf width in C and F tillers from samples collected in early April from burned and non-burned plants. Leaf width and tiller width are correlated (that is, tillers with wider leaves also have wider stem widths). C tillers have wider stems and leaves than do F tillers. [Source: A.W. Sylvester and J.O. Reynolds, Annual and biennial flowering habit of Kentucky bluegrass tillers, Crop Science 39:500–508 (1999).]



fall re-growth, and applying later can result in too little re-growth, both resulting in decreased seed production (Lamb and Murray 1999).

Current research is investigating the optimum time and rate of fertilizer application in no-burn and reduced-burn systems, since nutrient management may need to be amended in these systems.

Baling and removing the baled post-harvest residue off the field results in lower seed production compared to burning in all years except following the first harvest year. This may be the result of less post-harvest residue accumulation in a new stand compared to an established stand.

Accumulation of post-harvest residue reduces tiller floral induction by reducing the extent of diurnal temperature fluctuation, increasing nighttime temperature, and decreasing the amount of light irradiance at the plant crown (base of the plant) during the fall and winter (Picha 1976; Canode and Law 1979). Removing 90 percent of the post-harvest residue using no-burn methods results in the same amount of light reaching the plant crown as burning (Chastain, Kiemnec et al. 1997).

New UI Residue Management Study A residue management study was implemented in the fall of 2003 following the fourth seed harvest in Lewis County. It was repeated the fall of 2004 following the fifth seed harvest in Latah County. Post-harvest residue was burned at both locations prior to each UI study. The study evaluated five post-harvest residue management treatments for residue removal, seed yield, and profitability. Treatments included 1) full load burn, 2) bale + burn, 3) full load graze, 4) bale + graze, and 5) mechanical—bale + mow + harrow. The bale + graze treatment removed more residue in 2003 than 2004 due to more thorough grazing in 2003. Results indicate cattle grazing must be maintained until the residue is thoroughly removed for post-treatment residue levels in graze treatments to be comparable to full load burn. See results in table 2 and figure 5.

Seed Declines Seed yield often declines in burned stands after 8 to 10 years of production. This yield decrease may be partly due to a gradual increase in residue accumulation and increased competition among bluegrass plants for resources (intraspecific

TABLE 2. University of Idaho specialists evaluated five different post-harvest residue management treatments in Lewis and Latah counties for potential alternatives to burning. This table lists amount of post-harvest residue (pounds per acre) before and after treatments were applied for the first two years of trials. Seed yield for 2005 in Latah County will be available during winter 2006. However, definitive answers will not be available until several more years of field trials and an economic analysis have been completed.

	LEWIS CO. (FALL 2003)				LATAH CO. (FALL 2004)		
Residue Management Treatment	Initial Residue	Remaining Residue	Residue Removed	Seed yield (2004)	Initial Residue	Remaining Residue	% Residue Removed
	lb/ac	lb/ac[a]	%	lb/ac	lb/ac	lb/ac	%
Bale + burn	536	69 a	87	411 a	536	84 a	84
Bale + graze	568	80 ab	86	351 ab	577	205 c	65
Full load burn	592	87 ab	85	317 bc	522	113 ab	78
Full load graze	554	117 bc	79	269 bc	586	172 bc	71
Mechanical	542	140 c	74	238 c	556	283 d	49

a Values within column without common letter differ significantly (P=0.05).

competition) caused by increased plant density (sod-bound stand) (Canode and Law 1979).

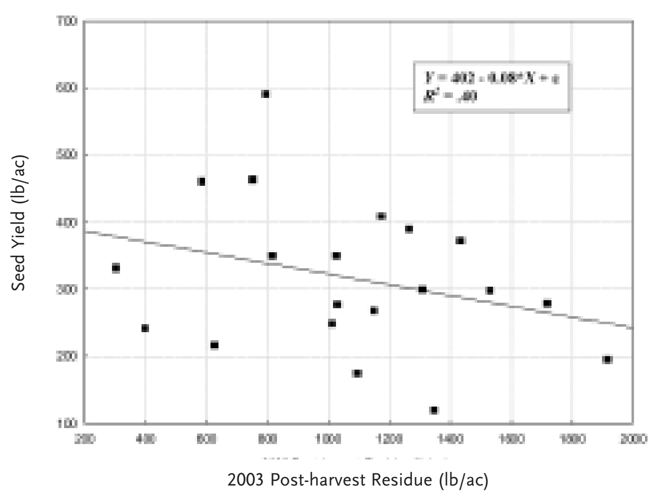
Phase 2: Over-Wintering and Vernalization

The second phase of flowering is vernalization. Vernalization is the process of hastening flower development and is caused by winter's cool temperatures and short day lengths. Vernalization is required for a floral induced tiller to produce seed. Thus, there are two requirements for a tiller to produce seed.

First, the tiller must complete juvenility and be floral induced; and second, it must complete vernalization. The vernalization requirement varies by variety, environment, nutrient availability, thatch accumulation, and stand age. The vernalization requirement for Kentucky bluegrass is approximately 6 to 9 weeks of temperatures below 41°F (5°C) and day lengths of less than 13 hours during the winter (Peterson and Loomis 1949; Meijer 1984; Rhoads, Dunn et al. 1992; Carlson, Ehlke et al. 1995). In the absence of burning, post-harvest residue remaining on the soil surface may insulate the plant crown, resulting in warmer temperatures at night near the plant crown and decreased vernalization.

The apical meristem (growing point of the stem) of Kentucky bluegrass remains below ground during the winter until stem elongation in the spring. This growth habit protects the meristem from frost injury by insulating it from the wind and cold temperatures (Ehrenreich and Aikman 1963).

FIGURE 5. Graph shows the effect of 2003 post-harvest residue (pounds per acre)—using the five residue management treatments in table 2—on the following year's seed yield (2004). Seed yield decreases as the amount of post-harvest residue remaining on the field in the fall increases. These results are from the Lewis County study.



Phase 3: Spring Growth and Stem Elongation

Vernalized tillers initiate stem elongation in the spring. In no-burn production systems, tiller growth is elongated, etiolated (pale in color), smaller in basal diameter, and longer in leaf sheath and leaf length compared to tiller growth in burn systems (Picha 1976; Meijer 1984; Chastain, Kiemnec et al. 1997). Post-harvest residue may insulate and lower temperatures at the plant crown in the spring, delaying or slowing spring growth (Sylvester and Reynolds 1999). The difference in tiller growth between burn and no-burn systems appears to be related to fewer floral induced tillers and reduced plant vigor in the no-burn production systems (Picha 1976; Chastain, Kiemnec et al. 1997; Sylvester and Reynolds 1997).

Phase 4: Floral Development and Seed Set

The fourth phase of flowering is floral development, which is the formation of the inflorescence (flowering structure in which the seed is produced). Floral development is initiated during the spring when temperatures are above 50°F (10°C) and day length is longer than 13 hours (Rhoads, Dunn et al. 1992; Carlson, Ehlke et al. 1995).

DID YOU KNOW THAT…

Kentucky bluegrass has four different types of tillers: C tillers produce 70% of seed; F_2 tillers produce 30% of seed; F_1 tillers develop into C tillers; D tiller buds develop into rhizomes or F_1, F_2, or C tillers

Kentucky bluegrass is a facultative apomictic plant—meaning that under certain conditions it reproduces asexually (does not require pollen from itself or another plant to produce seed) or sexually (requires pollen from itself or another plant to produce seed). Kentucky bluegrass reproduces primarily asexually. This maintains the genetic integrity of a cultivar, but it also makes the development of new cultivars difficult (Johnson, Johnston et al. 2003).

In addition to reproducing seed, Kentucky bluegrass is capable of vegetative reproduction (the development of new daughter plants from rhizomes). Vegetative reproduction needs to be minimized in seed production fields to prevent the stand from becoming sod bound, since seed yields decline in sod-bound stands. Vegetative reproduction, however, makes Kentucky bluegrass an ideal turf grass and helps prevent weeds from establishing.

SEED PRODUCTION

Yield—C tillers produce the most seed

Kentucky bluegrass yield is dependent upon reproductive tiller density and the number of seeds produced per tiller. Kentucky bluegrass yield is maximized for the varieties Abbey and Bristol at 250 reproductive tillers per square foot (Chastain, Kiemnec et al. 1997). C tillers produce more seed than F_2 tillers (Picha 1976; Sylvester and Reynolds 1999).

Burning increases the number of floral induced (reproductive) tillers and may increase the number of seed produced per tiller (Picha 1976). Differences in floret number and seed weight do not appear to significantly affect yield (Meijer 1984). In order for no-burn production systems to yield comparably with burn production systems, the reproductive C tiller density and amount of seed produced per tiller needs to be comparable between the two systems.

Stand Longevity—
Removing 80 Percent of Post-Harvest Residue Helps

Kentucky bluegrass yield decreases with stand age due to a reduction in the number of reproductive tillers produced from the center of the crown, resulting in reproductive tillers being produced along the outer circumference of the crown only (Canode and Law 1979). The reduction in tiller density at the center of the crown is primarily due to thatch accumulation (Picha 1976; Canode and Law 1979).

The greater the amount of post-harvest residue removal, the longer a stand will remain productive (Ensign, Lee et al. 1976). Preliminary data suggests that at least 80 percent of the post-harvest residue needs to be removed to maintain stand productivity (Holman, unpublished data). Baling alone removes 50 to 70 percent of the post-harvest residue, and keeps a ‘common’ cultivar stand productive for 3 years compared to about 10 years in a burn system (Ensign, Lee et al. 1976).

Other factors influencing stand life include nutrient availability, pest incidence, moisture, environment, location, and variety. For example, seed production of Kentucky bluegrass in Alberta, Canada decreased 50 percent after 2 years, even in a burn production system (Gossen, Soroka et Al. 2002). By comparison, seed production in a bale + mow production system in Oregon yielded similar to burn production during the first 4 years of production (Ensign, Lee et al. 1976). Elite Kentucky bluegrass varieties are frequently more aggressive, sod in quicker, and have a shorter stand life than common varieties. Aggressive varieties tend to remain productive for 3 to 4 years, whether burned or not (Van Tassell 2002).

Quality Seed—
No Weed Seed, Inert Material, or Disease

Seed quality is an important component of seed crops such as Kentucky bluegrass. High quality seed lacks weed seed, inert material, and disease contamination, and is high in test weight and germination. Low quality Kentucky bluegrass seed is subject to price discounts and in extreme cases may not be sellable. Research on grasses other than Kentucky bluegrass have found that pure seed percentage is reduced and weed seed contamination increases in no-burn production systems (Chilcote and Young 1991; Chastain, Young et al. 2000).

Kentucky bluegrass seed quality appears to not be impacted during the first three years of implementing a no-burn production system (Young, Younberg et al. 1984). However, research suggests that weed seed and inert material contamination increases under long-term no-burn production (Chastain, Kiemnec et al. 1997). An increase in the amount of weed seed contamination might be due to higher weed populations in no-burn production systems. Kentucky bluegrass seed weight and germination have been shown to be unaffected by residue management or stand age (Coats, Crowe et al. 1995; Chastain, Kiemnec et al. 1997; Chastain, Young et al. 2000).

BEST BURN MANAGEMENT PRACTICES

Post-harvest residue should be burned soon after harvest to maximize the fall regrowth period and subsequent year's seed production, minimize particulate emissions, and reduce disease and weed incidence. A delay in the fall regrowth period can result in decreased floral induction, and thus fewer reproductive tillers the following year (Ensign, Guthrie et al. 1975; Sylvester and Reynolds 1999). Burning high moisture residue decreases the burn temperature and increases the amount of incomplete combusted material, which results in higher particulate emissions (Boubel, Darley et al. 1969). Therefore, residue should be burned when it is dry, which often occurs early in the fall prior to fall precipitation and plant regrowth. Reduced-burn production systems such as bale + burn will likely result in fewer particulate emissions being produced than burn production systems (Johnston and Schaaf 2003). However, bale + burn may not burn as well as full load burn systems if fall regrowth has occurred or if the post-harvest residue is wet.

Mechanically removing the post-harvest residue can result in yields as high as or higher than burning under certain circumstances. Under severe moisture stress conditions, burning the post-harvest residue can result in stand thinning and lower seed production than if the residue is mechanically removed or baled prior to burning (bale + burn) (Canode and Law 1979). Baling + mowing the post-harvest residue results in yields similar to burning for the first 2 years of production in northern Idaho and eastern Washington, and for the first 3 to 4 years in Oregon (Ensign, Augustin et al. 1974; Ensign and Hickey 1980). Therefore, burning may not be necessary following the first or second seed harvest.

Unknown However, the long term impact on stand longevity and yield from not burning after the first or second seed harvest is unknown. Burning is a useful tool for maintaining stand productivity and profitability, and using it judiciously will minimize the amount of particulate emissions produced.

LITERATURE CITED

SUMMARY TIPS FOR GROWERS

Plant Growth

1. Kentucky bluegrass tillers are classified by developmental stage. Yield potential can be partially estimated by identifying tiller type and density. See table 1.
2. Not burning reduces the number of D tiller buds, but does not appear to affect reproductive tiller size or density.
3. Not burning may increase the number of rhizomes.
4. Soil moisture, nitrogen, growing degree days, photoperiod, and temperature stimuli are required for fall tiller growth, floral induction, vernalization, and floral development.
5. Delaying residue removal and fertilizer application can shorten the fall regrowth period, resulting in fewer reproductive tillers and decreased seed production.
6. In a burn production system, fertilizer should be applied in October. Current research is investigating the best time and rate to apply fertilizer in no-burn and reduced-burn systems.
7. Kentucky bluegrass reproduces asexually, sexually, and vegetatively.
8. Vegetative reproduction should be minimized to maintain seed production.

Seed Production

9. Yield is primarily dependent on reproductive tiller density and the number of seed produced per tiller. Several cultivar yields are maximized at 250 reproductive tillers/ft^2. (Note: a decrease in reproductive tiller density can result in more seed produced per tiller).
10. In a no-burn system, preliminary data indicates that at least 80 percent of the post-harvest residue needs to be removed to maintain seed production. Baling the post-harvest residue removes 50 to 70 percent of the residue. (Caution: tilling or aggressively harrowing a stand will injure the stand and result in weed seedling establishment.)
11. 'Common' varieties remain productive for about 3 years without burning, and for 10 years with burning. 'Elite' varieties tend to remain productive for 3 to 4 years, whether burned or not.
12. Seed quality decreases in no-burn production due to an increase in weed seed and inert material contamination.
13. Kentucky bluegrass seed weight and germination appear to be unaffected by stand age and burning.

Best Burn Management Practices

14. Post-harvest residue should be burned soon after harvest to maximize the fall regrowth period and seed production, minimize particulate emissions, and reduce disease and weed incidence.
15. Residue should be burned when it is dry.
16. Under severe moisture stress conditions, burning can result in more stand thinning and lower seed production than if the residue is mechanically removed or baled before burning (bale + burn).
17. Baling + mowing the post-harvest residue results in yields similar to burning for the first 2 years of production in northern Idaho and eastern Washington, and for the first 3 to 4 years in Oregon. (Note: the long term impact on stand longevity and yield from not burning after the first or second seed harvest is unknown.)
18. Baling the post-harvest residue prior to burning can reduce the amount of particulate emissions produced.
19. Burning is a useful tool for maintaining stand productivity and profitability, and using it judiciously will minimize the amount of particulate emissions produced.

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ABOUT THE AUTHORS

John D. Holman is the grass seed cropping systems scientist at the University of Idaho Department of Plant, Soil and Entomological Sciences in Moscow. Email him at *jholman@uidaho.edu*. **Donn Thill** is chair of the crop and weed sciences division and professor of weed management, University of Idaho Department of Plant, Soil and Entomological Sciences, in Moscow. Email him at *dthill@uidaho.edu*

ABOUT THE ILLUSTRATIONS

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