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Postharvest Residue Management

for Grass Seed Production in Western Oregon

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Management of postharvest residue, including stubble and straw, is an important practice in grass seed production. Crop residues are managed for pest control, to stimulate seed yield of grasses, to remove large volumes of straw and stubble that might interfere with crop management operations, for income from straw sales, and to recycle nutrients to fields.

Traditional straw management changed rapidly beginning in the mid-1980s as the practice of open-field burning was legislatively reduced in western Oregon. Previously, this practice was the predominant residue management method, but since 2007 it has been used on less than 10 percent of the grass seed crop acreage (Figure 4, page 2). This reduction has taken place even as the acreage of grass seed crops has reached record levels.

Three primary residue management methods used by Oregon grass seed growers

Thermal. This method includes fire-based straw and stubble removal—usually by burning with the full straw load in place on the field (open-field burning, Figure 1) or propane burning. In some instances, straw is removed from the field and burned in stacks. Field burning has been an effective, economical, and controversial method of crop residue removal and pest control in grass seed crops for more than 50 years. Currently, it is not allowed in western Oregon for perennial ryegrass, annual ryegrass, orchardgrass, or tall fescue seed production. It can be used for western Oregon fine fescue and bentgrass production and for Kentucky bluegrass and other species grown in the Columbia Basin, central, and eastern Oregon.

Full straw load. This method involves no straw removal. The straw is allowed to decompose in the field (Figure 2). Straw length may be reduced by mowing and/or use of a combine straw chopper. In this publication, we use the term "chop" for this operation. The straw decomposes in place, allowing for nutrient recycling.

Clean nonthermal. In this method, a swather cuts the crop, the seed is removed with a combine, and the straw is then raked and baled (Figure 3). Straw removed from grass seed fields is used for animal feed, especially in export markets, as well as for other products. It also has potential for use as a feedstock for the production of biofuels.

Figure 1.—Until recently, open-field burning was the most common method of thermal straw management. Photo by Tom Silberstein

Figure 2.—Under full straw load management, straw is left in the field to decompose. Here the straw is being flail mowed to reduce straw length and evenly distribute it over the remaining grass stubble. Photo by Mark Mellbye

Figure 3.—Clean nonthermal residue management removes baled straw from the field after harvest. Photo by Tom Silberstein

Oregon State University Extension Service

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When the discussion on banning open-field burning began, the initial perception was that maximum grass seed yields could not be achieved if substantial straw residue was left on the surface. Subsequent research, coupled with grower input, resulted in the development of management practices that can achieve comparable grass seed yields without residue removal.

Postharvest residue management varies around the world. For example, producers in New Zealand, Washington State, and England routinely remove straw for use as feed in dairies and other animal production enterprises. In Argentina, annual and perennial ryegrass straw is usually baled, but it sometimes is chopped before direct seeding the next crop. Danish growers usually bale after the first 2 years of grass seed production. After the last harvest in a rotation, if they are not able to sell the straw for animal feed or biofuel, it is chopped. In Denmark, use of some fungicides and growth regulators prevent straw use as animal feed.

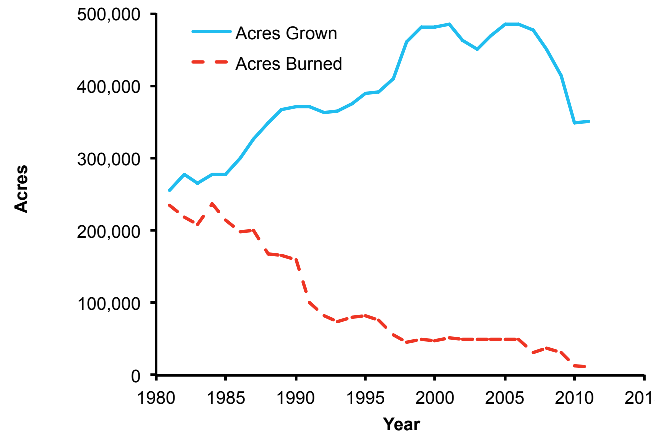


Figure 4.—Trends in grass seed production and open-field burning of grass seed crops in western Oregon. Source: Tom Chastain

Straw utilization

As a result of reduced open-field burning, each year approximately 1 to 1.1 million tons of grass straw from western Oregon fields need to be managed in a different manner. One alternative use is forage. While grass straw is generally considered a low-quality forage source, with proper nutritional management, ruminant animals can effectively utilize it. This combination of supply, nutrition management, and need for forage led to an initial export market almost exclusively in Japan, where straw was already used as a source of roughage in the dairy industry.

Before 1990, this small export market for grass straw was developed through the efforts of the Agricultural Fiber Association (a nonprofit association of straw merchants). Volume grew from fewer than 3,000 tons in 1980 to approximately 220,000 tons in 1990. The market has continued to expand; currently, on average more than 650,000 tons of straw are exported annually. Thus, approximately one-half of the estimated total production of grass straw is now exported. Current export destinations and the proportion of various grass species exported are shown in Figures 5 and 6.

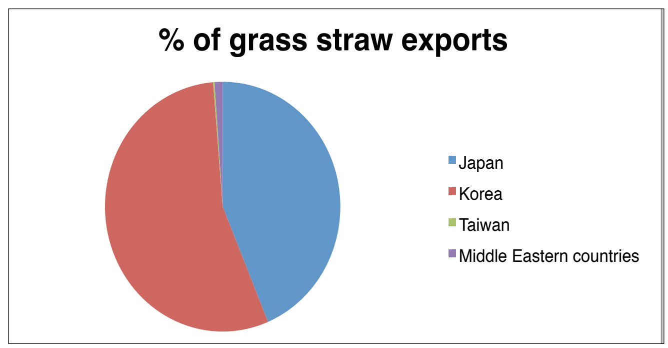


Figure 5.—Japan and Korea are the major export markets for Oregon grass straw. Source: John Hart, based on data from the Oregon Department of Agriculture

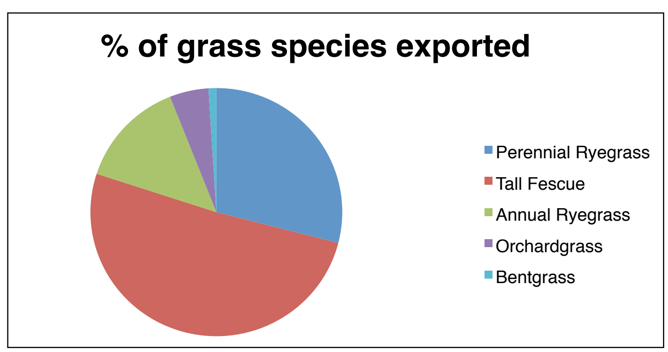


Figure 6.—Tall fescue and perennial ryegrass represent the bulk of Oregon's grass straw exports. Source: John Hart, based on data from the Oregon Department of Agriculture

No "right or wrong" residue management system exists; rather, management choices and costs influence decisions. The choice to bale or chop straw is not always straightforward, and the best option can differ among fields and with stand age. Factors such as economics (straw price, as well as fertilizer, fuel, and labor cost), crop rotation, weed problems, and stand age interact with grower preferences to determine whether straw should be removed or remain in the field.

Seed yield and quality

With careful and timely management, little difference in grass seed yield is measured regardless of whether straw is baled or remains in the field.

Light penetration to the growing point of the grass plant is critical to the success of either approach. Straw must be removed from the plant crown for adequate sunlight to be received. Timing is critical. Remove straw as soon as possible after harvest, preferably within a week.

Where straw is returned to the field, spread it across the field as uniformly as possible during threshing and subsequent chopping operations. Although finely chopped straw more easily settles between rows than coarsely chopped straw, uniform spreading of all straw is important for adequate light penetration.

When swathing is clean and uniform, and straw is baled in a neat and timely fashion, expending an additional $10 to $15/a to chop the remaining stubble is not economically prudent (Figure 8, page 4).

Soils and settings for grass seed production in western Oregon

The combination of productive soil and other environmental factors provides a setting for high-quality production of several species of cool-season grasses.

Annual and perennial cool-season grasses are grown for seed in western Oregon's Willamette Valley region, including the foothills of the Coast and Cascade mountain ranges in Benton, Clackamas, Lane, Linn, Marion, Polk, Washington, and Yamhill counties. "Western Oregon" is used to describe the area for which recommendations in this publication are applicable.

Cool-season grasses grown for seed occupy a range of soil types and settings. Annual ryegrass is grown for seed on Bashaw, Conser, Dayton, Wapato, and similar poorly drained soils. Dayton, called "white soil" by growers, is found on broad, flat areas of the southern Willamette Valley floor. Bashaw, a black, sticky clay sometimes called "gumbo soil" by growers, is located on the low-lying and gently concave areas associated with narrow stream valleys and at the edges of some hill slopes. These soils are not well suited to perennial grass production because of poor drainage, which causes "ponding" on the soil surface during winter months.

In the southern part of the Willamette Valley, a combination of management practices has increased the success of growing perennial grasses on somewhat poorly drained soil types such as Dayton. Increased use of lime and fertilizer, along with returning the full straw load, have removed soil pH and nutrient limitations on many grass seed fields. In these situations, surface ditching and tiling are essential to promote a soil environment conducive to perennial grass seed production.

In the central and northern portion of the Willamette Valley, grass for seed is planted on soils formed in stratified glacio-lacustrine silts, such as Amity, Willamette, and Woodburn, as well as on alluvial soil series such as Chehalis, Malabon, McBee, and Newberg. These latter soils are characterized as either moderately well drained or well drained. Most of these fields have some relief or "roll" that provides drainage. Many have tile installed to improve surface and internal drainage.

In addition to tall fescue and perennial ryegrass, fine fescue seed is produced on foothills on the east side of the Willamette Valley, primarily on Nekia, Jory, and Stayton series. On the west side of the Willamette River, fields are located on Hazelair, Helmick, and Steiwer soil series.

In addition to the soil series used for grass seed production in the central Willamette Valley, Aloha, Verboort, Laurelwood, Wapato, Helvetia, and Cove soils formed in loess and mixed alluvium are planted with grass seed in the Tualatin Valley.

Figure 7.—Grass is grown for seed on a variety of soils in the Willamette Valley. Photo by W.C. Young III

Comparisons between chopping the full straw load and baling cannot be reduced to a simple statement that seed yield increases or decreases with use of either system. In addition to interacting with straw management, seed yield changes with stand age. This concept is shown for a perennial ryegrass field in Figure 9.

Seed yield also varies annually. Thus, to compare the effect of straw management, Figure 9 uses an index, or relative yield, for each year. Each year, the "bale" treatment was the standard, or 100 percent. The full straw load treatment yield was slightly less in all years. In general, yield differences between bale or full straw load management are not large, but even a slightly lower yield is a concern for producers.

Perennial ryegrass seed yield under various straw management options was compared in 25 situations during a 5-year period. The average seed yield was 8 percent less when the full straw load was chopped onto the field, compared to removal with baling. For a 1,500 lb/a yield, the average reduction would be approximately 120 lb/a.

A similar number of comparisons have been made for tall fescue seed yield. The seed yield was comparable for both straw management options. For example, in two second-year tall fescue seed fields, average seed yield when chopping the full straw load was 99 percent of the seed yield with complete straw removal treatment. Partial straw removal produced a similar seed yield—101 percent compared to complete straw removal treatment.

In addition to seed yield, the influence of straw management on seed quality is a consideration. Fortunately, returning straw to fields of perennial ryegrass or tall fescue does not reduce seed purity and germination (Table 1). Seed quality is comparable for both straw management options.

Figure 8.—With clean and timely swathing and baling, the need to chop the remaining stubble is eliminated. Photo by Mark Mellbye

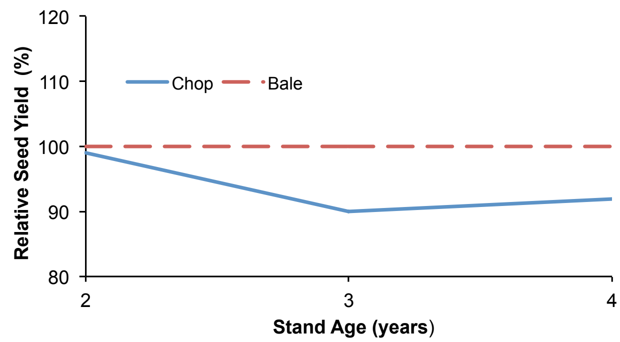


Figure 9.—Relative seed yield related to stand age in two straw management systems for perennial ryegrass. Baled treatments were selected as 100 percent yield. Source: John Hart, from data from Tom Chastain and Bill Young.

Table 1.—Perennial ryegrass and tall fescue seed purity and germination in 300+ comparisons from 7 fields during 5 years.

Grass species/ Residue management	Purity				Germination
	Pure seed	Other crop	Inert matter	Weed seed	
			(%)		(%)
Tall fescue					
Chop	95.9	0.4	3.7	0.1	91.4
Bale	96.1	0.3	3.5	0.1	91.4
Perennial ryegrass					
Chop	93.8	2.0	3.9	0.1	91.6
Bale	94.2	1.9	3.8	0.1	92.4

Nutrient management considerations

This section examines nutrient management topics for different residue management systems in grass seed production. Recommendations apply to perennial ryegrass, tall fescue, and annual ryegrass produced for seed in western Oregon.

Nutrient removal and cycling

Removal of all above-ground biomass (seed and vegetative matter) is the standard practice for several crops commonly grown in western Oregon. Peppermint, silage corn, alfalfa, grass hay, and Christmas trees are examples. Nutrient removal is substantial in these situations, but varies among crops (Table 2). Nutrient removal is part of the production cost for these crops. Likewise, this cost should be considered in grass seed production when baling straw (Figure 10).

When only a portion of the crop is harvested, such as pods of green beans or rhubarb stalks, nutrient removal is lower (Table 3). For a crop grown for seed, such as wheat, most of the N is removed with the grain, but most of the K remains in the straw (Table 3).

Table 2.—Nutrient removal for commonly grown western Oregon crops with total above-ground portion removed.[1]

	Nutrient removal					
Crop	N	P	K	Ca	Mg	S
	(lb/a)					
Alfalfa	500	45	500	220	50	50
Corn silage	175	16	125	35	25	12
Grass hay	120	20	150	20	10	12
Peppermint	200	35	275	90	30	20

[1]Assumes a yield of 90 lb oil/a for peppermint, 25 t/a for corn silage, 3 t/a for grass hay, and 8 t/a for alfalfa. Elemental phosphorus and potassium removal are used rather than oxide forms, P_2O_5 or K_2O.

Nutrient abbreviations

B	Boron
Ca	Calcium
Cu	Copper
K	Potassium
KCl	Potassium chloride (muriate of potash)
K_2O	An oxide expression of K used on fertilizer packaging
Mg	Magnesium
N	Nitrogen
P	Phosphorus
P_2O_5	An oxide expression of P used on fertilizer packaging
S	Sulfur
Zn	Zinc

Table 3.—Nutrient removal for commonly grown western Oregon crops when only a portion of the crop plant is harvested.[1]

	Nutrient removal					
Crop	N	P	K	Ca	Mg	S
	(lb/a)					
Rhubarb	65	10	130	65	5	3
Green beans	35	5	25	6	3	2
Wheat grain	90	20	28	5	10	7
Wheat straw	16	3	80	55	40	30

[1]Assumes a yield of 8 t/a for rhubarb, 100 bu/a for wheat grain, 3 t/a for wheat straw, and 6 t/a for green beans. Elemental phosphorus and potassium are used rather than oxide forms, P_2O_5 or K_2O.

Figure 10.—Some nutrients are removed in harvested crops, especially if the straw is removed from the field. Photo by Tom Silberstein

Summary of nutrient recommendations

- **Nitrogen:** N supply differences are small regardless of residue management practice. Use the same rate of N regardless of straw management (see page 7).
- **Phosphorus:** Soil test P decline is small and gradual when straw is baled and does not decline when straw is chopped. Monitor soil P by regular soil analysis and apply P as recommended in OSU nutrient management or fertilizer guides. Use the same rate of P regardless of straw management (see page 7).
- **Potassium:** When straw is chopped and the preplant soil test for K is above 150 ppm, K is adequate for the life of the stand. When straw is baled, monitor soil test K annually or every 2 years and apply K using rates provided in Table 8 (see page 9).

Table 4.—Seed and straw nutrient content of commonly grown grass species in western Oregon.

Grass species/Component	Weight	N	P	K	Ca	Mg	S
				(lb/a)			
Annual ryegrass							
Seed	2,000	40	8	15	3	3	1
Straw	4,000	40	8	40	17	4	8
Total	—	80	16	55	20	7	9
Perennial ryegrass							
Seed	1,500	30	5	7	3	3	1
Straw	4,500	55	6	93	11	7	7
Total	—	85	11	100	14	10	8
Tall fescue							
Seed	1,400	30	5	7	3	3	1
Straw	5,000	55	6	103	17	10	8
Total	—	85	11	110	20	13	9

Table 5.—Perennial ryegrass and tall fescue straw nutrient concentration.

Grass species	Nutrient				
	N	P	K	Ca	Mg
			(%)		
Perennial ryegrass					
Range	0.75–1.75	0.05–0.2	0.3–2.5	0.25–0.5	0.1–0.2
Average	1.0	0.1	2.0	0.35	0.12
Tall fescue					
Range	0.7–2.0	0.05–0.2	0.5–3.0	0.2–0.5	0.1–0.3
Average	1.0	0.1	2.0	0.3	0.18

When straw remains in the field, nutrient removal in grass seed crops is small, compared to crops such as peppermint, alfalfa, or grass hay, where the entire above-ground biomass is removed (Tables 2 and 4). Reduced nutrient removal is one reason given for chopping rather than baling straw.

Nutrient management recommendation: *No seed yield increase from added nutrient supply has been attributed to chopping straw when soil test levels are adequate*.

Nutrient removal is driven by two factors—the amount of straw removed and the concentration of nutrients in straw. Chopping returns 3 to 4 tons straw/a. Baling removes 70 to 80 percent of this amount. Baling contractors associated with the Agricultural Fiber Association (a nonprofit association of Oregon straw merchants) estimate that 4,500 lb straw/a is removed from perennial ryegrass fields and 5,000 lb/a from tall fescue fields. If the amount of straw removed is relatively constant, then tissue nutrient concentration determines differences in nutrient removal. Table 5 shows ranges of nutrient concentrations for perennial ryegrass and tall fescue.

Because straw nutrient concentration varies (Table 5), keep in mind that the nutrient removal data in Table 4 should be used only as an example and not for management decisions. When straw nutrient concentration will be used to make management decisions, annual analyses for individual fields are necessary.

Micronutrient removal is also a concern of growers. Compared to N, P, and K, the amount of boron (B) and zinc (Zn) in grass straw is very small (Table 6). Even so, growers frequently ask whether micronutrient addition is needed. Research in the past 20 years has not demonstrated the need for micronutrient addition (see Appendix A). For example, B application did not increase seed yield 90 percent of the time in western Oregon field studies.

Table 6.—Micronutrient content in seed and straw of tall fescue and perennial ryegrass.

Grass species	Weight	B	Cu	Zn
	(lb/a)		(oz/a)	
Tall fescue				
Straw	5,000	0.6	0.2	1.0
Seed	1,400	0.1	0.2	0.9
Total	—	0.7	0.4	1.9
Perennial ryegrass				
Straw	4,500	0.6	0.2	0.9
Seed	1,500	0.1	0.2	1.0
Total	—	0.7	0.4	1.9

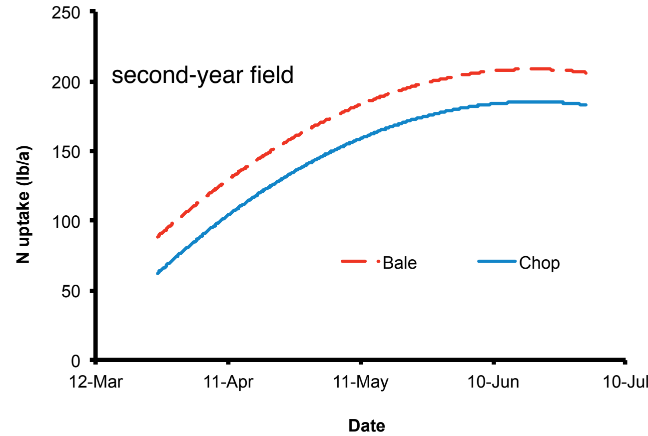
Nitrogen (N)

Nutrient management recommendation: *Since N supply differences are small regardless of residue management practice, and no research has evaluated whether N rate can be reduced when straw is returned, use the same rate of N regardless of straw management.*

One concern with addition of organic residue such as straw is immobilization or preferential use of N by microbes as they decompose the organic material. Immobilization can decrease plant growth when the plant-available N supply is low or when plant demand is high.

However, to decompose straw, microbes require moisture and moderate temperatures. These environmental factors are not achieved until late April or early May in western Oregon. Straw remains relatively undecomposed until this time, and then disappears rapidly. Meanwhile, plant demand for N is typically highest in mid-April, just before rapid decomposition (and potential immobilization) occur.

Chopping all the straw onto a field does not immobilize significant amounts of N. Evidence to support this statement is found in the difference between N uptake in treatments that were baled and those where all of the straw was chopped (Figure 11). The difference in N uptake was small, about 15 lb/a, and changed with stand age. In the second year of the stand, tall fescue receiving the full straw load contained slightly less N than did the grass where straw was baled. The situation was reversed in a fourth-year field. Similar results are expected in most fields as no adjustment in N rate is necessary when straw is chopped.



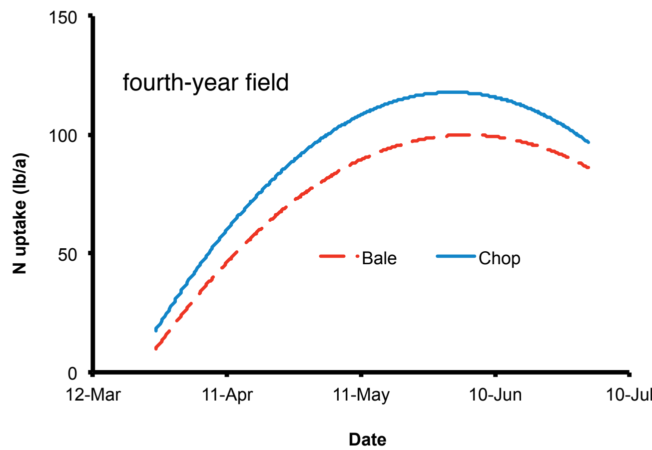


Figure 11.—The amount of tall fescue N uptake in second-year fields (top) and fourth-year fields (bottom). Source: John Hart

Phosphorus (P)

Nutrient management recommendation: *Soil test P does not decline when straw is chopped, and its decline is small and gradual when straw is baled. Monitor soil P by regular soil analysis, apply P as recommended in OSU nutrient management or fertilizer guides, and use the same rate of P regardless of straw management.*

A similar amount of P is found in grass seed and grass straw. Even though baling straw doubles P removal, P use is small compared to N and K use by grass seed crops (Table 4, page 6).

Soil test P declines 1 ppm or less each year with straw removal. This small quantity of P removed with straw will not be detected in a P soil test, especially when soil test P is more than 40 ppm.

Phosphorus soil tests from two sample depths for bale and chopped straw management were compared on two annual ryegrass fields for 3 years (Table 7). Phosphorus in the surface 2 inches was likely influenced more by annual fertilizer application than by straw management. In the second sampling depth (2 to 8 inches), soil test P was 1 to 2 ppm lower in the area where straw was baled compared to the chopped area. This rate of decline is minimal and is not a reason to change the P application rate.

Table 7.—Soil test P decline with straw removal in annual ryegrass seed production on Woodburn soil when straw is baled and removed.

Straw management and soil test P	Soil test depth	
	0–2 inches	2–8 inches
	Soil test P (ppm)	
Moderate soil test P		
Bale	20	15
Chop	20	16
High soil test P		
Bale	48	47
Chop	47	49

Soil test P also decreased slightly in the surface inch of soil in a tall fescue grass seed field when straw was baled. After 3 years of baling straw, soil test P from the surface inch of soil was 4 ppm less than in soil where straw had been chopped. The soil test values below the surface inch were the same (Figure 12, page 8).

Buffering and Bashaw soil

The Bashaw soil is high in clay—more than 50 percent—and also contains more than 10 percent organic matter. Soils high in clay and organic matter are "buffered," meaning that soil test values do not readily change. For example, an application of 1 lb P_2O_5/a or ½ lb P/a to the Bashaw soil increases the P soil test by only 0.05 ppm. Thus, 20 lb P_2O_5/a are needed to increase soil test P by 1 ppm; 200 lb/a of material are needed for a 10 ppm increase.

A similar decline has been measured in perennial ryegrass (Figure 13). When no P fertilizer was topdressed and straw was removed from a perennial ryegrass seed field, the P soil test declined 1 ppm/year. Over 3 years, soil test P declined from 17 to 14 ppm in the surface inch of a Bashaw soil (Figure 13). Slow and slight changes in P soil test values are expected for this soil series, as it is well "buffered" (see sidebar above).

In contrast to the buffered Bashaw soil, a very sandy golf putting green has little buffering capacity, and rapid soil test change is expected with clipping removal. Figure 14 shows the decline in soil test P for 15 years from a bentgrass putting green with clippings removed and no P fertilizer added. Maximum P soil test decline is expected in this situation. Even so, the rate of decline was slow, only 3 ppm per year.

These examples illustrate that straw removal changes soil test P slowly, despite doubling P removal. Soil with more than 35 ppm soil test P can adequately supply P to grass seed crops even when straw is baled for many years, as long as a decade.

Potassium (K)

Nutrient management recommendations: *When straw is chopped and the preplant soil test for K is above 150 ppm, K is adequate for the life of the stand. You do not need to soil test for K or add K for the life of a perennial ryegrass stand or for 3 to 4 years for other grass species. When straw is baled, monitor soil test K annually or every 2 years and apply K using rates provided in Table 8 (page 9).*

Vegetative plant material contains a substantial amount of K (Tables 2 and 4, pages 5 and 6). Removal of 75 percent or more of the vegetative plant material by baling straw removes 10 times more K than does chopping the straw. Table 4 shows that in some grass species grown for seed less than 10 lb K/a is removed in grass seed and approximately 100 lb K/a is removed with straw.

Potassium concentration of most perennial ryegrass straw is 1 to 2 percent, but it can be higher (Table 5, page 6). Potassium removed in 4,500 lb perennial ryegrass straw ranges from 45 lb/a to 90 lb/a. The extent of this

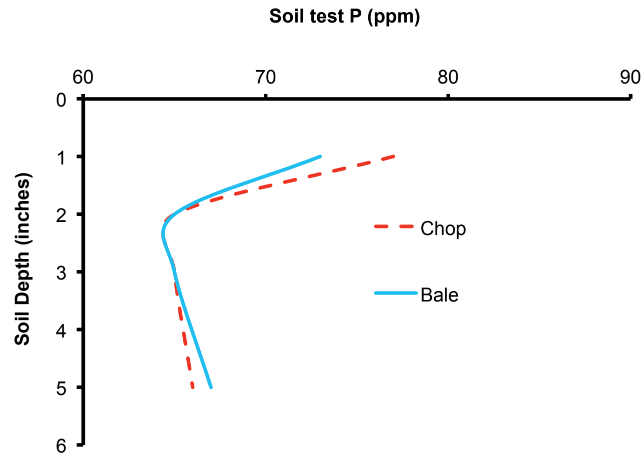


Figure 12.—Soil test P in the surface inch of soil from a tall fescue grass seed field when straw is baled or chopped. Source: John Hart

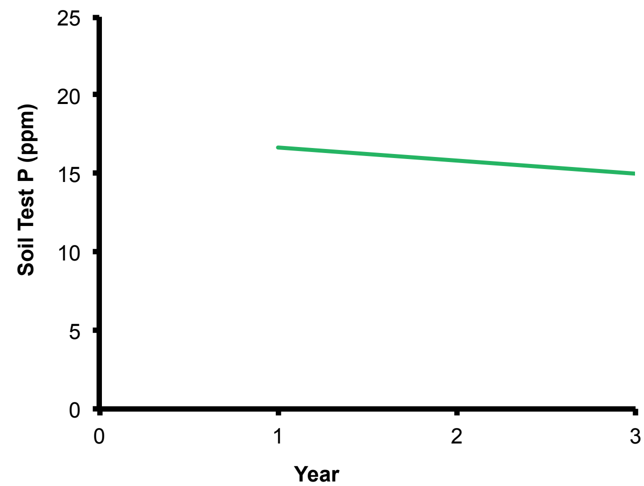


Figure 13.—Soil test P decline in the surface inch of a Bashaw soil in perennial ryegrass seed production when straw is baled and no P fertilizer is added. Source: John Hart

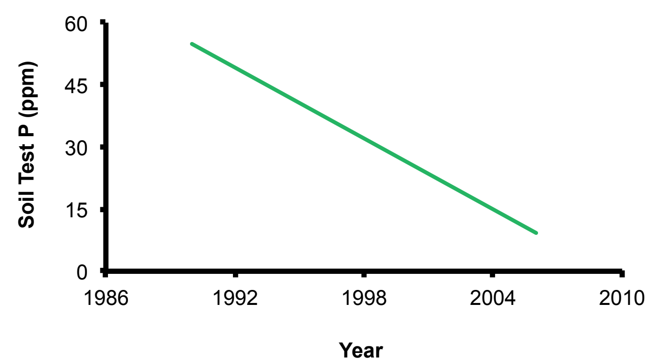


Figure 14.—Soil test P decline in a bentgrass putting green constructed on sand when clippings are removed. Source: John Hart

range emphasizes the need for monitoring soil test K when straw is baled.

The large amount of K removed when straw is baled causes soil test K to decline for all grass species. The decline in soil test K depends on the amount of straw removed, K concentration in the straw, and buffering capacity or clay content of the soil.

Soil test K values higher than 400 ppm are likely to decline faster than soil test values below 200 ppm. When soil test K exceeds 400 ppm, soluble and easily exchangeable K is a larger proportion of the total available K than when soil test K is 200 ppm. Stopping K application while removing straw under these conditions can cause an initial rapid decrease in soil test K as the easily exchangeable and soluble K is removed by plants. These statements are relevant for western Oregon soils with moderate clay content and are not applicable to soils with high clay content.

Unlike P, soil test K decline is variable. The surface 1 to 2 inches of soil can change quickly, sometimes as much as 50 ppm/year or as little as 5 ppm/year (Figure 16). The rapid decrease in soil test K in the surface inch stems from high soil test values near the surface, limited soil volume, and the amount of fine grass roots present to efficiently use K.

Soil test K in the surface 2 inches is often two to four times greater than soil test K at a depth of 5 or 6 inches (Figure 17). Since K is not mobile in soil, and grass seed fields are not tilled for several years, K accumulates near the surface from top-dressed fertilizer and recycled crop residue.

Potassium recycling from crop residue is also shown in Figure 17. Potassium is readily leached from dry plant material. As little as ¼ inch of rain will leach K from wheat straw. The same principle applies to grass straw. Soil samples were collected immediately after harvest from a field where the full straw load was chopped. After rain fell, a second soil sample was collected. Soil test K was about 150 ppm higher in the surface inch of soil after the rain compared to the sample collected at harvest.

Baling straw requires monitoring soil test K. We recommend collecting a soil sample (6- to 7-inch depth) every other year if the initial K soil test result is above 250 ppm and every year if the soil test result is less than 250 ppm.

Apply K fertilizer using soil test values in Table 8.

Table 8.—Potassium fertilizer recommendations for perennial grass seed crops based on soil sample collection depth of 6 to 7 inches.

Soil test K (ppm)	Bale	Chop
	Apply this amount of K_2O (lb/a)	
0–50	150–200	100–150
50–100	75–150	50–100
100–150	0–75	0–50
above 150	0	0

Figure 15.—A large amount of K is removed when straw is baled, causing soil test K to decline. Photo by Tom Silberstein

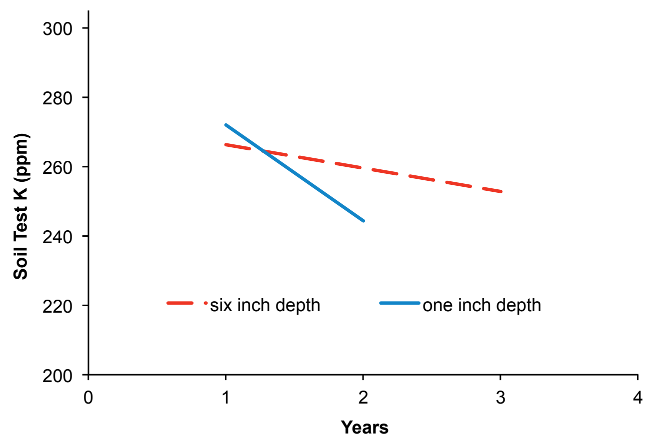


Figure 16.—Soil test K decline from two sample collection depths in a tall fescue grass seed field where no K fertilizer was applied and straw was baled. Source: John Hart

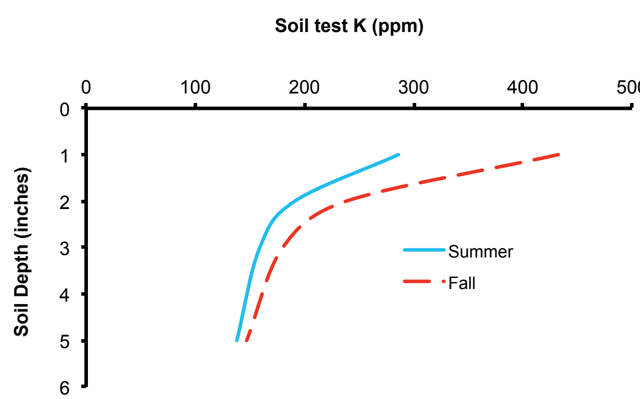


Figure 17.—Soil test K from a tall fescue field with all straw chopped. Samples were collected immediately after harvest (summer) and after rain had fallen (fall). Source: John Hart

Additional soil characteristics

Soil pH and organic matter—Straw management choices result in small changes in soil organic matter and pH. Straw removal decreases soil pH 0.1 unit during the course of 3 years. This amount is small enough to be within the error of normal sampling and laboratory techniques. From a field management point of view, baling straw does not change soil pH for 3 to 5 years, the maximum stand life of many grass seed crops.

Similar to soil pH, organic matter changes slowly. It increases with a change from baling to chopping the full straw load. However, the increase is small (0.1 to 0.2 percent), and usually is limited to the surface 1 to 2 inches of soil.

Calcium and magnesium (Ca and Mg). Calcium, Mg, and K are cation bases, part of the soil system regulating soil pH. Between 15 and 35 lb/a of Ca and Mg combined are removed annually with straw. When Ca and Mg removal is combined with K removal, 1 ton of lime is required every 4 to 6 years to replace the equivalent of the basic cations removed when grass straw is continuously baled.

Sulfur (S). Soil testing for S is not recommended. When straw is chopped, a spring application is prudent in the first year to offset S use by microorganisms during decomposition of straw. Applying 10 to 15 lb S/a should be adequate. Application in subsequent years is not usually needed.

Sulfur is also needed when straw is baled. A rate of 10 to 15 lb S/a can be applied annually or 20 to 25 lb S/a every other year. Sulfur can be applied in the spring or fall, but spring application (with the first N application) is recommended.

Economic comparison

Growers often ask for an economic comparison of straw management systems. This task is not simple, as management systems vary among producers, and situations change as stand age increases. Although the economics vary and are complicated, analyzing these costs annually is important when making residue management decisions. Keep in mind that each farm, and sometimes each field, will have its own production costs.

Potassium is the nutrient cost of greatest importance, as it is the only nutrient that is managed differently for the two straw management systems. The per-acre value of K in straw is about 10 percent of the cost of a ton of K fertilizer. Table 9 provides values for 100 lb K, an average amount removed per acre when straw is baled, with increasing cost of potassium chloride (KCl) or muriate of potash (0-0-60). See Tables 4 and 5 (page 6) for information about the amount of straw removed and the K content in straw.

Table 9.—Value of 100 lb of K in grass straw (the average amount removed per acre when straw is baled).

KCl price ($/ton)	K value in grass straw ($/a)
450	45
500	50
550	55
600	60
650	65
700	70
750	75
800	80
850	85
900	90
950	95
1,000	100

This approach can be considered a "short-term" or single-rotation view. Crop residue return usually provides only slight changes in soil properties even after a decade of residue return. Although growers often observe signs of increased organic matter with residue return, such as increased earthworm populations, translating residue return into economic terms is not straightforward.

Conversely, long-term straw baling removes small or moderate amounts of nutrients. Even a small amount of nutrient removal for a long time creates a need for monitoring and possibly for addition of nutrients. For example, our estimate is that 1 ton of lime will be required every 4 to 6 years to replace the equivalent of the basic cations removed with continuous grass straw baling.

Conclusion

Each postharvest residue management option has benefits and disadvantages that are summarized in Table 10 (page 11). The choice to bale or chop differs, depending on straw price, fertilizer and fuel cost, labor cost, crop rotation, field condition, weed pressure, stand age, and grower outlook. An economic comparison of systems is complicated and varies yearly, as fuel and fertilizer prices are volatile. An additional variable is the straw price received by growers, as it varied from 0 to $30/a over the past 10 years.

With good management, most grass seed species can be produced under a full straw load or baling system. Growers should consider their economic situation and make a decision that best suits their farm.

Table 10.—Comparison of straw management systems in western Oregon.

Bale		Chop full straw load	
Benefit	**Disadvantage**	**Benefit**	**Disadvantage**
About 5 percent more seed yield than chop	Cost to replace nutrients removed	Carbon to build or maintain soil organic matter	Seed yield reduced about 5 percent
Improved weed control	Slightly accelerates soil pH decline	Recycles nutrients, especially K	Labor, fuel, and equipment cost
Possibly better slug and vole control		*Poa annua* suppression	Possible increased cost of slug and vole control
Income from sale of straw			Possible *Poa trivialis* density increase
Save cost of chopping straw			Reduced efficacy of soil-applied herbicides

For more information

The following Oregon State University Extension Service publications are available online or for purchase at http://extension.oregonstate.edu/catalog/

Annual Ryegrass Nutrient Management Guide for Western Oregon, EM 8854 (revised 2011).

Evaluating Soil Nutrients and pH by Depth in Situations of Limited or no Tillage in Western Oregon, EM 9014 (2010).

Fertilizer Guide: Fine Fescue Seed (Western Oregon—West of the Cascades), FG 6 (revised 2003).

Fertilizer Guide: Perennial Ryegrass Grown for Seed (Western Oregon), FG 46-E (revised 2005).

Fertilizer Guide: Tall Fescue Grown for Seed (Western Oregon—West of Cascades), FG 36-E (revised 2005).

PNW Weed Management Handbook, Grass Seed Crops Chapter. http://pnwhandbooks.org/weed/agronomic/grass-seed-crops

Weed Management in Grass Seed Production, EM 8788 (2001).

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Appendix A

Research on which this publication is based

The 1969 Oregon Legislature gave the Oregon Sanitary Authority (now the Department of Environmental Quality) the power to limit the amount of field burning. A field burning permit fee system was initiated in 1971 to pay the administrative cost of a regulatory smoke management program, and to establish a research and development program to seek alternatives to open-field burning. Thus began a long history of research to quantify the advantages of field burning and to develop practical, nonthermal alternatives.

In the early 1970s, attention was focused on thermal sanitation alternatives to open-field burning in the form of machine sanitizers. In addition, propane flaming of stubble following removal of straw was evaluated. Studies of seed production without thermal sanitation were also initiated. Results were mixed, depending on species and the thoroughness of mechanical residue removal.

Subsequent legislation continued to restrict open-field burning, while research continued to provide growers with guidance in managing seed crops using nonthermal cropping systems. Studies have addressed all aspects of agronomy, including disease, weed, and insect control; crop physiology; and nutrient management. In 2011, only 11,806 acres of grass seed crops were burned—less than 4 percent of the acres in production in western Oregon.

- **1989–1991:** A long-term investigation to consider the interaction between postharvest residue management, N, and K was established. Research was conducted on two perennial ryegrass and two tall fescue fields. Removal of straw following seed harvest removes significantly more K than that "lost" in the seed crop alone. As a result, soil test K is lower when crop residues are removed. On the other hand, changing to a nonthermal cropping system did not result in a significant loss of N, as grass straw contains only about 1 percent N.
- **1990–1993:** Nonthermal residue management treatments were evaluated in grower-established perennial ryegrass and tall fescue fields at 13 locations. Trials continued for a second year at 10 of the original sites, and 6 sites were evaluated for a third year. Four nonthermal postharvest techniques were common to most locations. Perennial ryegrass stands were more adversely affected by the presence of greater amounts of postharvest residue than was tall fescue. However, increased weed pressure was observed in both species.
- **1992–1998:** A statewide investigation of nonthermal postharvest residue management in seven seed crop species was launched using field-scale replicated treatments in commercial production fields over a 6-year period. Residue management techniques varied among species and locations, but three basic approaches were tested: (1) full straw management (chopped in place; no straw removal), (2) clean, nonthermal management (bale, bale + flail, bale + flail + rake, bale +vacuum sweep), and (3) thermal methods (open-field burn and propane flame stubble after straw removal). Species differed greatly in seed yield performance under clean nonthermal management and full straw load approaches.
- **1998–2002:** Large-scale on-farm trials were conducted in perennial ryegrass, tall fescue, fine fescue, and annual ryegrass over several seasons to evaluate optimal spring N rate. Applying more than the optimal rates did not ensure increased seed yield. Soil test results at optimal use rates showed little potential for leaching losses, as applied N was efficiently used by the crop.

Figure 18.—Early straw management research evaluated numerous practices, including raking grass straw into large windrows that were pushed into piles and burned. Photo by Gale Gingrich

Figure 19.—One aspect of research was measuring yield from large-scale straw management plots in grower fields. Photo by Gale Gingrich

Appendix B

Voles and slugs

Growers comment that increased populations of some pests, such as voles and slugs, occur when straw is left on the field. A logical assumption is that straw provides increased habitat and food sources. However, comparisons of no-till production (residue is left on the field) and conventional tillage (no residue is left) indicate that for slug populations, tillage is more important than the amount of straw left on the field. Tillage likely destroys and disrupts pest habitat.

Voles

The gray-tailed vole is native to Willamette Valley prairie grasslands that are now dominated by agriculture, including substantial acreage of grass grown for seed. Voles construct networks of surface runways and burrows. Grazing damage to grass seed crops by voles varies annually and tends to peak in 4- to 6-year patterns. When such peaks occur, grazing and tunneling can cause substantial economic losses (Figure 20).

Two crop management factors influence vole activity: the method of crop establishment and the crops grown immediately preceding the grass crop. Established perennial grass seed stands provide a stable habitat for vole populations compared to annual crops such as crimson clover, meadowfoam, or cereal crops. In addition, establishment of crops using direct seeding maintains undisturbed habitat for voles, whereas tillage disrupts pathways and burrows, reduces available food supply, and likely causes vole mortality.

Rotating perennial grass seed crops with crops such as wheat, meadowfoam, vegetables, or annual clovers reduces vole populations, even when direct seeding is used. This phenomenon may occur because annual crops provide less cover during winter and early spring than do established perennial grass seed stands. Also, with many annual crops, relatively little cover remains after summer harvest.

Elimination of field burning to dispose of perennial grass straw after harvest raises questions about whether voles are more numerous when straw is removed by baling or when the full straw load is returned. Studies in the Willamette Valley show that full straw chop-back compared to bale/flail management practices do not change short-term vole activity in perennial grass seed fields. Both straw management practices provide sufficient cover to maintain vole populations. In addition to cover provided by residue and crown regrowth, seed left in the field after harvest and roots from remaining plants result in a sufficient food supply to sustain vole activity.

Baiting with zinc phosphide can reduce vole populations in some circumstances. However, baiting poses a risk to nontarget species, and little information is known about timing, rate per hole, or number of holes to treat. Currently, zinc phosphide bait is registered for use on a SLN Section 24(c) label in Oregon. If you are considering a zinc phosphide application, determine whether a current registration exists and which product(s) are allowed. Follow all guidelines from the Oregon Department of Agriculture.

Slugs

Historically, tillage and open-field burning helped reduce slug and other pest populations to manageable levels in western Oregon perennial grass seed systems. In the absence of such practices, substantial pest pressure can cause crop loss (Figure 21). Chopping the full straw load increases the quantity of surface residue, creating the food, habitat, and moisture essential for increasing slug populations.

Figure 20.—Vole populations tend to peak every 4 to 6 years. In peak years, they can cause significant damage to grass seed fields through tunneling (shown above) and feeding activities. Photo by Jennifer Gervais

Figure 21.—Slug damage can be significant when tillage and open-field burning are not practiced. The large bare patches indicate significant slug activity. Photo by George Hoffman

A laboratory study found that as straw residue and biomass increase, optimal environments for slug egg laying and juvenile survival in late winter also increase (Table 11). Conversely, a field study conducted on annual ryegrass showed no significant difference in adult slug populations due to residue management practices.

Regardless of the amount of residue left in a field, reducing slug populations to a manageable level with chemical control can be difficult and costly. Surface residue can make bait "discovery" difficult, reducing control. Thus, multiple applications of baits, sprays, or granules are typically needed to reduce slug populations, especially where surface residue is high.

Currently (2012), metaldehyde, iron phosphate, and iron EDTA are registered for use on grass seed crops in Oregon. Apply baits and other products in the fall, before mid-November. Apply to moist soil when nighttime temperatures are above 45°F and wind speed is less than 10 mph. Baits may be applied again in the spring when temperatures rise. Success of applications will vary.

Table 11.—Late-winter residual straw provides the brown-banded Arion slug with an optimum environment for egg laying.

Residue	Straw biomass (g/ft^2)	Egg density (ft^2)
High	784	33
Low	36	3

In conclusion, established perennial grass seed stands provide a stable medium for vole and slug populations compared to annual crops. In addition, establishment of crops using direct seeding maintains undisturbed habitat for voles and slugs, whereas tillage disrupts pathways and burrows, reduces available food supply, and likely causes mortality for these pests.

Appendix C

Weed management

The presence of weeds in perennial grass seed fields negatively affects grass seed yield and quality. Weed management also increases production costs (including herbicide and application costs), and the presence of weed seeds in harvested grass seed increases seed cleaning costs. Weeds may also have indirect production costs; for example, the life of perennial grass stands may be reduced, and growers are sometimes forced to rotate to less profitable crops in an effort to manage problem weed populations.

Management of both grass and broadleaf weeds is critical for achieving consistently high grass seed yield and quality. In general, grass weed species reduce grass seed yield and quality more than do broadleaf weeds. Unfortunately, grass weed species are often more difficult to manage in grass seed crops than are broadleaf species.

Some grass weed species, including annual bluegrass; roughstalk bluegrass; various brome species, such as California brome and downy brome; bentgrass species; and rattail fescue can be especially difficult to manage because their life cycles are similar to those of grass seed crops. Some of these species have also developed herbicide-resistant biotypes. In some cases, there simply is a lack of effective selective herbicides to manage these grass weed species in grass seed crops.

For example, Alderman et al. (2011) analyzed data from fine fescue seed lots (chewings, creeping red, and hard fescues) submitted to the Oregon State University Seed Laboratory for purity analysis and weed seed contamination analysis from 1986–1995 and 2002–2006. They found that the most common weed seed contaminants were rattail fescue, annual bluegrass, and downy brome.

Effects of straw management on weed management: The role of herbicide chemistry

Management of volunteer grass "sprout" and grass weed species in perennial grass seed crops typically occurs through the use of soil-applied herbicides coinciding with the onset of fall rains. Thus, straw management practices immediately following grass seed harvest can influence weed management decisions.

The ultimate goal is to use the most effective herbicides that match the weed species spectrum present in an individual field. At the same time, certain herbicide properties affect weed management efficacy. One important factor is the relationship of the herbicide product to soil organic matter content and crop residues on the soil surface. Growers need to consider this factor in order to select products and application timings that complement straw management strategies.

Soils contain organic matter, clay particles, and crop residues. Following herbicide application, these soil materials control herbicide adsorption, or accumulation of the herbicide active ingredient on the surfaces of solids in the soil/water/air interphase near the soil surface. The interaction between crop residues and herbicides, and the resulting impacts on weed control efficacy, are extremely complex. This interaction is further influenced by environment or by management practices (for example, precipitation or irrigation following application of soil-applied herbicides).

One way to characterize soil-applied herbicide products and match them to a straw management system in perennial grass seed crops is to use the K_{oc} value associated with each herbicide. The K_{oc}, or the normalized soil-water partition coefficient for organic compounds, is a measure of the affinity of a particular herbicide to organic material. Herbicides with high affinity to organic materials tend to have high K_{oc} values and vice versa.

Soil-applied herbicides with very high K_{oc} values will bind with crop residues and soil organic matter and are never active in the soil solution. Thus, they provide poor weed control unless they are applied to bare soil or somehow incorporated into the soil solution, for example, through tillage or irrigation. The particular formulation of a given herbicide product plays only a small role in the adsorption and desorption dynamics of the active ingredient in soils and crop residues. The chemistry of the active ingredient itself drives the process.

Soil-active, fall-applied herbicides are those most affected by straw management in grass seed cropping systems. Table 12 (page 18) lists all of the commonly used, soil-applied herbicides for grass weed management during typical fall application in western Oregon, as well as their associated average K_{oc} values. Note that not all of the herbicides listed in Table 12 are registered for use in all perennial grasses grown for seed in western Oregon.

In Table 12 we see that the K_{oc} values for flufenacet are much lower than those for pendimethalin, indicating that pendimethalin has a much higher affinity for organic materials than does flufenacet. Therefore, where the majority of straw residue is returned to the soil surface, a fraction of the applied pendimethalin will be adsorbed to the grass straw residue. Thus, pendimethalin would be expected to have less herbicidal activity on grass weed species, such as annual or roughstalk bluegrass, than would flufenacet. Similar reduced weed management efficacy would be expected in a heavy straw load situation for herbicides that have a high affinity for organic materials (Table 12).

However, products such as pendimethalin or diuron are used successfully in grass seed cropping systems when they are applied to predominantly bare soil. Examples include relatively young perennial grass seed stands (perennial ryegrass in its second crop year or tall fescue in the fall/winter following spring planting) or when grass straw is baled. Also, the herbicide adsorption process to crop residue can be partially overcome with supplemental irrigation immediately following herbicide applications.

Grass seed production practices continue to change. Thus, an understanding of the interactions between herbicide chemistry and straw management systems is critical to successful weed management. Grass seed growers need to utilize the herbicide product, all other management considerations and costs being equal, that best fits with their straw management practices in individual fields.

Specific weed management recommendations in various grass species grown for seed, including herbicide application rates and suggested application timings, are found in the Grass Seed Crops chapter of the *PNW Weed Management Handbook*, which is updated annually. See the OSU Extension publication EM 8788, *Weed Management in Grass Seed Production*, for weed identification.

The herbicide adsorption phenomenon discussed above has led to continual refinement of site-specific application rates in many crops. For some soil-applied herbicides, rates are based on soil type and organic matter content, with the goal of maximizing weed-control efficacy while limiting risk of crop injury. Optimizing the use of these soil-applied herbicides, taking into consideration the strengths and weaknesses of each product, has been the focus of research at Oregon State University beginning in the early 1950s and continuing today. This research was pioneered by Orvid Lee, Arnold Appleby, George Mueller-Warrant, Ron Burr, Bill Brewster, and Carol Mallory-Smith, working with others in private industry.

Table 12.—K_{oc} values for commonly used, soil-active herbicides for grass and broadleaf weed management in perennial grasses grown for seed in western Oregon.

Active ingredient	Trade name	Average reported K_{oc} values (mL/g)[1]	Affinity for organic materials
chlorsulfuron	Glean XP	40	Low–moderate
dimethenamid-P	Outlook	55–125	Moderate
diuron	several	480	Moderate–high
ethofumesate	several	340	Moderate
flufenacet	component of Axiom	113–613	Moderate–high
S-metolachlor	several	21–200	Low–moderate
mesotrione	Callisto	14–390	Low–moderate
metribuzin	several, component of Axiom	3–60	Low
oxyfluorfen	Goal	2,891–32,381	High
pendimethalin	Prowl H20	13,000–29,400	High
pronamide	Kerb	570–2240	Moderate–high
terbacil	Sinbar	55	Low
paraquat[2]	several	1,000,000	Extremely high

[1]Source of K_{oc} values: *Herbicide Handbook*, Weed Science Society of America, 9th edition, 2007.

[2]Paraquat is not a soil-applied herbicide, nor is it registered for use in grasses grown for seed, but is included in this table as an example of an herbicide active ingredient with an extremely high K_{oc} value and one that has no soil activity in contrast to the other herbicides listed in the table.

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