5

Grass Seed Crops: Pest Management, Lodging Control, and Harvest Practices

5.1 *Introduction*

Controlling pests is an important aspect of grass seed production in the Pacific Northwest. Pests reduce the yield and quality of grass seed crops. Maintaining control of pests is challenging in grass seed crops since they are not the primary focus of development efforts by agrichemical manufacturers. Furthermore, restrictions on the use and availability of pesticides and the development of pesticide resistance complicates the control of pests in grass seed crops in the region. The loss of field burning as a management tool has encouraged the development of alternative pest management practices, but at greater financial costs to the producer.

Lodging is an impediment to achieving higher seed yields, especially in the wet Willamette Valley. Methods for control of lodging have been developed for grass seed crops. Harvest of the region's grass seed crops is now accomplished by equipment having higher capacity and efficiency, yet the loss of seed and the resultant volunteer crop is a continuing problem.

5.2 *Diseases*

Plant diseases can affect seed production of grasses in three areas of the plant: (i) **diseases of the seed**, (ii) **foliar and stem diseases**, and (iii) **diseases of the root system**. Of these three, diseases of the roots system are the most poorly understood in their impact on grass seed production.

Diseases of the seed in cool-season grasses include several that not well known outside the world of grass seed producers and one that has been important throughout human history, ergot. **Ergot** is a fungal disease that is caused by *Claviceps purpurea*. Plants are infected by wind-borne ascospores at flowering and the fungus induces production of a sugary solution known as honey dew (Mantle and Shaw, 1977). Sucrose in the honey dew provides nutrition for the fungus at the expense of the plant (Mower and Handcock, 1975). Unfortunately, sucrose is also the major source of carbohydrates utilized in seed development. Eventually, the fungus produces a sclerotium which replaces the seed. Ergot is a tissue-replacement disease in which tissues in the floret are degraded where the sclerotium develops, but compatible relationships are maintained with the host so that water and nutrients are available for the developing sclerotium (Luttrell, 1980). Chastain (1992) reported that ergot sclerotia from fields with low and high disease incidence accounted for 1.5 and 19.4% of total harvested weight, respectively. High ergot incidence (5% of potential seed sites) caused a 20% reduction in seed yield. Disease incidence did not influence seed weight or seed germination. The storability of seed harvested from infested tillers was somewhat poorer than from uninfested tillers. Sclerotia compete for resources at the expense of developing seeds on the same tiller and the negative consequences of this competition are manifested as reduced seed yield and storage life of seed

Ergot sclerotia reduces seed yield by reducing seed number. Seed harvested from infested fields generally contains ergot sclerotia. Ergot also increases seed cleaning costs and causes lost international marketing opportunities as many countries will not accept ergot sclerotia infested seed. Control measures for ergot include planting sclerotia-free seed, and fungicides. Tilt (flusilazole) and Punch (propiconazole) fungicides have been identified for controlling ergot in Kentucky bluegrass seed production fields (Brede et al., 1990; Schultz et al., 1993). Only Tilt is registered for ergot control. Burning of post-harvest residues has been a common method for controlling ergot in Kentucky bluegrass seed fields (Hardison, 1976), but pressure to abolish residue burning has increased in response to public concern over air quality issues. Ergot is a problem in all grass seed crops in the Pacific Northwest except orchardgrass and is most severe in Kentucky bluegrass.

Blind seed is another disease of the seed that is important in grass seed production. Blind seed is caused by *Gleotinia temulenta*. Blind seed kills the seed embryo and reduces germination. Blind seed is a problem in perennial ryegrass and tall fescue seed production (Alderman, 1991). This disease can be a major problem and was one of the primary reasons for the implementation of field burning in Oregon. Field burning, and timely harvest reduce the number of seeds that act as sites for the overwintering of the disease (Alderman, 2001). Nitrogen nutrition of the plant is thought to play a role in the development of the disease as well.

Grass seed endophyte is caused by *Acremonium coenophialum* and is found in tall fescue and perennial ryegrass. Infected seed produces plants that are also infected. Alkaloids produced by the pathogen cause poor performance and sickness in grazing livestock and abortion in horses. Grass seed endophyte is undesirable in forage seed. But these same alkaloids may impart insect and drought resistance in infected plants. So endophyte *is* desirable in turf seed. Screenings and straw may be contaminated with the alkaloids.

There are several important foliar and stem diseases that influence seed production in grasses. Foliar and stem diseases in grass seed crops are not controlled by crop rotation or field burning, only fungicides and genetic resistance of the crop are effective against these pests. Among these diseases, the rusts cause the greatest problems for grass seed producers in the Pacific Northwest. **Stripe rust** is caused by *Puccinia striiformis* and is found in Kentucky bluegrass and orchardgrass. **Stem rust** is caused by *P. graminis* ssp. *graminicola* and is found in perennial ryegrass, tall fescue, and Kentucky bluegrass. Rust infestations continue in fields from one season to the next by overwintering on infected plants. The infestation can expand to epidemic proportions with warming temperatures in the spring. Early warm springs tend to favor development over cool, wet springs, which tend to retard development of a rust epidemic.

Seed yield can be reduced when rust lesions appear on the leaves and especially when the flag leaf is not protected by fungicides. Welty and Azevedo (1994) found that up to three applications of Tilt (propiconazole) were required to attain maximum seed yield in perennial ryegrass at high levels of stem rust severity in the Willamette Valley. The seed

weight component of yield was significantly reduced in perennial ryegrass when the crop was not treated with a fungicide. Stem rust was not observed in tall fescue seed production in the Willamette Valley until 1989 (Welty and Mellbye, 1989), but is now a widespread disease that needs to be controlled with fungicides. Seed yield in tall fescue can be increased under stem rust pressure with the incorporation of resistance genes (Barker et al., 2003).

Crown rust is another important rust disease that is found in perennial ryegrass, tall fescue, and Kentucky bluegrass. Crown rust is caused by *P. coronata* and is controlled by the same fungicides that are effective in the control of stem rust. There are also rust diseases found in creeping red fescue and Chewings fescue that are caused by *P. crandallii*.

Other important foliar and stem diseases several leafspot diseases. **Eyespot** is a disease caused by *Mastigosporium rubricosum* and is found in orchardgrass. **Scald** is a leafspot disease caused by *Rhycosporium orthosporum* and is found in orchardgrass and tall fescue. The disease known as **Leafspot** is caused by *Dreshlera* (*Helminthosporium*) spp. and is found in perennial ryegrass and tall fescue. These diseases can reduce seed yield through the reduction in photosynthetically active leaf area, thereby making less assimilate available for seed filling. Welty (1991) reported that Bravo (chlorothalonil) applied for the control of scald at the boot stage or later increased seed yield in orchardgrass in the Willamette Valley. Powdery mildew is often found in the spring on leaf sheaths and blades of grass seed crops grown in areas east of the Cascade range. This disease can be controlled with one of several fungicides.

Choke is a fungal disease caused by one of two fungi: *Epichloe typhina* in orchardgrass, and *E. festucae* in the fine fescues. Mycelium of these fungi appear on the leaf sheath of fertile tillers in spring. Controls for these diseases are not well-established, but field burning may aid control in orchardgrass.

5.3 *Weeds*

There are several reasons for controlling weeds in grass seed crops:

1. **Seed quality**. Weed-free seed can command a premium price. Seed certification prohibits certain seeds of certain weed species whereas a limited number of seeds of other weed species are sometimes allowed in the harvested and cleaned seed.
2. **Competition**. Weed plants compete with the seed crop for water, light, and nutrients and can reduce seed yield.
3. **Seed conditioning costs**. Weed-contaminated seed costs more to clean. Re-cleaning further increases costs.
4. **Marketability**. Marketability is reduced by weed seeds.

The **volunteer crop** and **off-types** of the *same species* are the most difficult to control weeds in grass seed crops (Mueller-Warrant and Neidlinger, 1994). Grass seed crops are often damaged by herbicides applied to control volunteer crop plants because of the limited selectivity between the crop and the volunteer plants. Failure to control

volunteers can result in the loss of eligibility for certification. Control of volunteer perennial ryegrass and tall fescue plants is essential for maintaining seed yield in the absence of field burning (Mueller-Warrant et al., 1994a; Mueller-Warrant et al., 1994b; Mueller-Warrant et al., 1995a; Mueller-Warrant et al., 1995b). Failure to control volunteer plants often results in reduced seed yield in perennial ryegrass seed fields (Mueller-Warrant and Rosato, 2002a; Mueller-Warrant and Rosato, 2002b). Reductions in open-field burning have resulted in increased volunteer crop contamination of seed fields and some increases in weedy grass species have been noted (Chastain and Kiemnec, 1994; Chastain et al., 1995).

Plants of other grass seed crops and grass weeds are also difficult to control (Mueller-Warrant and Brewster, 1986). Grass weeds include **annual bluegrass** (*Poa annua*), **downy brome** (*Bromus tectorum*), **roughstalk bluegrass** (*Poa trivialis*), **rattail fescue** (*Vulpia myuros*), **California brome** (*Bromus carinatus*), and **wild oats** (*Avena fatua*).

Broadleaf weeds are easier to control because of increased herbicide selectivity and crop safety. Nevertheless, there are several broadleaf weed species that are considered to be problem weeds in grass seed crops.

Weed management strategies for grass seed crops include:

1. **Herbicides**. Several broadleaf herbicides are available to control these weeds in grass seed crops. Selective herbicides must be used to control grass weeds in grass seed crops. Registration and availability of herbicides for grass seeds crop change each year. Herbicide application techniques include broadcast spraying, weed wiper, and charcoal banding.
2. **Field burning**. Field burning destroys weed seeds and seedlings.
3. **Good crop management**. Must maintain vigorous, competitive crop growth to aid in the suppression of weeds. Nutrient and irrigation management are important aspects of general crop management that assist other methods of weed control.
4. **Crop rotation**. Rotation can be an effective weed management tool where suitable rotation crops are available.
5. Tillage/mechanical. Not widely practiced at this time, but may increase in the future.

Growers have noted that premature losses in stand have been widespread and have been accompanied by herbicide-induced crop damage. The susceptibility of perennial ryegrass seed fields to damage by herbicides increases with age of the stand (Mueller-Warrant and Rosato, 2002b). Restrictions on herbicide availability and use, and reductions in open-field burning have resulted in increased volunteer crop contamination of seed fields and some increases in weedy grass species have been reported. Furthermore, the development of resistant weed species further complicates this serious situation.

Crop competition can aid in the suppression of weeds in grass seed fields. Early canopy closure increases shading which can decrease weed seed germination, and also leaves fewer open niches for weeds. Vigorous growth and early closure of the crop canopy can be manipulated through changes in stand establishment practices. Aamlid (1994) reported that annual bluegrass contamination in harvested Kentucky bluegrass seed was

significantly reduced by higher seeding rates. Narrow row spacing tended to reduce annual bluegrass contamination in some trials but there was no overall significant effect of row spacing on weed seed levels.

Herbicides are applied in Willamette Valley grass seed fields in the wet season by using specially-designed sprayers equipped with high flotation tires. The sensitivity of grass seed crops to herbicides vary with stage of crop development and with age of the stand. Certain weeds can be controlled in grass seed crops based on a difference in height between the crop and weed at one or more stages of development. A device known as a **weed wiper** can be used to deliver a non-selective herbicide such as glyphosate to the taller weed by contact without causing injury to the crop. Spot spraying of individual weeds is also widely practiced in fields to control individual weeds or small groups of weeds in the field. Row spraying of non-selective herbicides by shielded sprayer is sometimes practiced to control weeds between the rows of grass seed crops.

5.4 *Other Pests*

Several insect and mite species cause economic damage in Pacific Northwest grass seed fields. **Sod webworm** (*Crambus* spp.) damages crown and root systems in Kentucky bluegrass, orchardgrass, and tall fescue. **Billbug** (*Hyalopteroides dactylis*) damages crowns and roots of Kentucky bluegrass and orchardgrass. **Grass gelechiid** (*Chinodes psiloptera*) damages roots, crowns, and lower stems of Kentucky bluegrass. Two species of crane flies affect grass seed crops in Oregon, the **European crane fly** (*Tipula paludosa*) and the **larger European crane fly** (*T. oleracea*). Larvae damage roots and crowns of plants, causing death of plants when infestations are severe. **Wireworms** (*Ctenicera* spp.) damages seedlings of grasses in newly seeded stands.

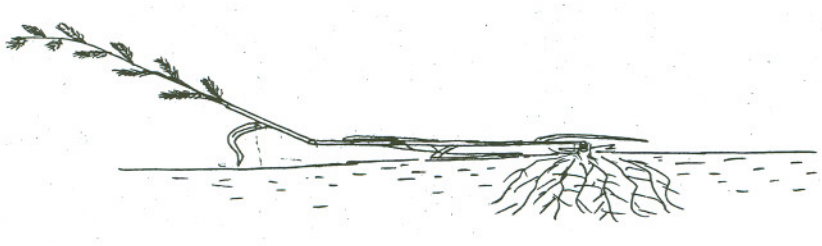
Silvertop is a poorly understood disorder that may be caused by the interaction of a fungal pathogen and one or more species of insects. The characteristic symptom of silvertop is the death of fertile tillers and is found in affected plants of Kentucky bluegrass and the fine-leaf fescues. **Winter grain mite** (*Penthaleus major*) damages leaves and causes reduced seed yield, plant vigor, and stand longevity in Kentucky bluegrass.

Integrated pest management strategies have been developed for insects and mite pests. Monitoring pest populations is an important component of insect and mite pest management strategies. This includes setting pheromone traps, conducting sweeps of fields to determine pest population levels. Insecticide and biological control measures are used when applicable to prevent these pest populations from causing economic injury.

Grass seed production in the Pacific Northwest is also affected by nematodes and slugs. **Seedgall nematode** (*Anguina agrostis*) is a problem in bentgrass seed fields that causes losses in seed yield. **Gray garden slug** (*Agriclimax reticulatus*) and the **gray field slug** (*A. laevis*) are controlled in seedling fields of perennial ryegrass and tall fescue with metaldehyde bait. This is an expensive practice. Slugs are not as severe in established fields.

5.5 *Lodging Control*

Lodging of the crop during flowering is generally thought to restrict pollination, reduce the rate of fertilization, and can later inhibit seed filling due to self-shading of the lodged crop. Young et al. (1996) reported that seed yield increases in perennial ryegrass by application of paclobutrazol, a plant growth regulator that inhibits GA biosynthesis, were caused by lodging control and the resultant improved floret site initiation. Control of lodging increases seed yield more than any other agronomic practice in grass seed crops, including weed control, rust control, and nitrogen fertilizer application.



Lodged perennial ryegrass plant.

Trinexepac-ethyl (Palisade) and prohexamide-calcium (Apogee) are growth regulators registered for use in grass seed crops in the Pacific Northwest. Trinexapac-ethyl and prohexamide-calcium retard plant growth by suppressing the biosynthesis of the growth active form of giberellic acid (GA). Specifically, trinexapac-ethyl and prohexamide-calcium inhibit the 3β-hydroxylation of GA_{20} (inactive form) to GA_1 (active form)(King et al., 1997). Trinexapac-ethyl and prohexamide-calcium is taken up by foliage and is translocated to other parts of the plant. Application of Palisade and Apogee can reduce or delay lodging in grass seed crops.

Silberstein and Young (1998) suggested that in addition to causing reduced culm length in perennial ryegrass, trinexapac-ethyl may have improved seed set. Subsequent trials have shown a consistent trend toward increased floret production, and increased seed set resulting in higher seed yield following application of trinexapac-ethyl (Silberstein et al., 2000a) and prohexadione-calcium (Silberstein et al., 2000b) in grass seed crops in the Willamette Valley. Early application timing of Palisade produced high seed yields in perennial ryegrass , especially at higher rates; however, later application dates still provided some degree of yield enhancement regardless of application rate (Fig. 5.1). The benefit from early application stems from increased floret production, while late application increased seed set.

Plant growth regulators influence seed yield in grasses through modification of yield component contributions. The following is work by Chastain et al. (2001) on the impact of trinexepac-ethyl (Palisade) on perennial ryegrass yield components and seed yield. No significant effect of Palisade on spike number, above ground dry weight, or spikelet number per spike in the 1st and 2nd year crops of perennial ryegrass (Table 5.1). Application of Palisade did increase seed yield by 25% over the untreated control in the 1st year and by 41% in the second year crop. An increased number of florets per spikelet

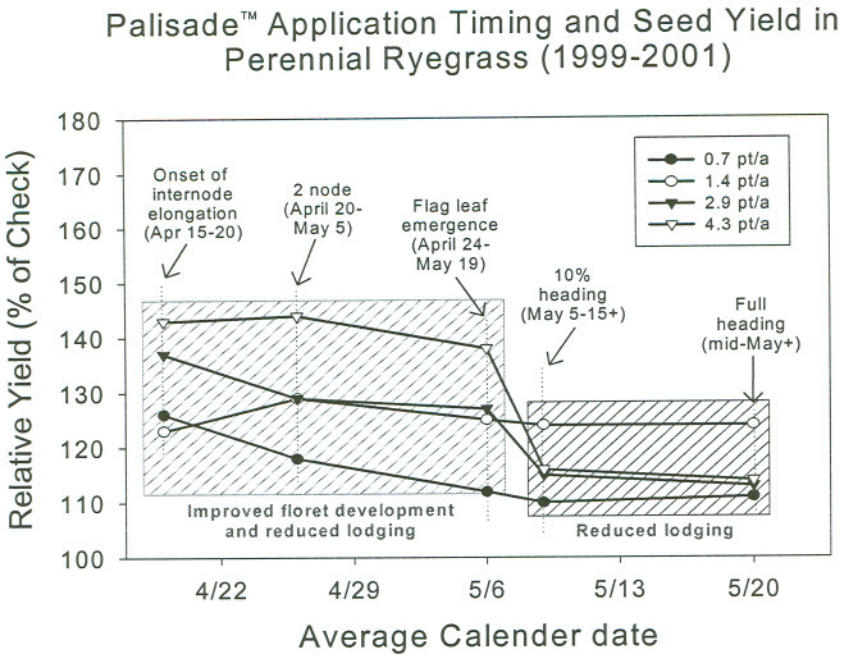


Figure 5.1. Palisade application timing and perennial ryegrass seed yield.

likely accounted for a portion of the seed yield increase noted in Palisade treated plots. Significant increases in floret number were noted in spikelets located in the top, middle, and bottom portions of the spike in the 1st year, but only in the middle portion in the 2nd year. Palisade also caused reduction in spike length that may have contributed to the increase in seed yield.

Spikes were harvested from the field trial in the 2nd year prior to seed shattering losses to determine whether Palisade alters source-sink relations within perennial ryegrass spikes and spikelets during seed maturation. Seeds were removed from paired spikelets in the top, middle, and bottom portions of each spike, and from within the distal (upper), central (middle), and proximal (lower) portions of these spikelets.

Floret conversion to seed (% seed set) was significantly increased by Palisade in top and middle spikelet positions within the spike (Table 5.2). In other words, more seed were produced in these spikelets were treated and this contributed to the seed yield increase. The greatest seed set was recorded in central and distal floret sites in Palisade-treated plots. Individual seed weight was affected by spike position and spikelet position but not by Palisade treatment. These results suggest that seed yield enhancement by Palisade resulted from increased seed number, not by increased seed weight in the 2nd seed crop.

Table 5.1. Palisade treatment effects on seed yield components of perennial ryegrass.

	Year 1		Year 2	
Yield component	Untreated	Treated	Untreated	Treated
Spikes/ft^2	276	277	338	308
Spikelets/spike	21	21	24	23
Spike length (cm)	22.6	19.9	21.4	20.1
Florets/spikelet				
Top	8.4	9.7	7.1	7.3
Middle	10.8	12.3	7.5	7.8
Bottom	9.1	11.0	7.2	7.5
Seed yield (lb/A)	2215	2772	1354	1912

Seed yields were increased by Palisade in both years, but this increase was manifested via a different mechanism in each of the years. Seed number increases in the 1st year crop attributable to Palisade were based on greater numbers of florets per spikelet without an increase in seed set. Seed number in the 2nd year crop was increased through Palisade-induced increases in seed set. The ability of Palisade to increase yield by more than one mechanism contributes to the consistency of results observed with this treatment. However, it is not clear whether increased seed yield results solely from the lodging control provided by Palisade or by other effects of this compound on development of crop yield components.

Seed yield declined as the stand aged from Year 1 to Year 3 regardless of treatment, but Palisade application greatly lessened this loss in yield (Table 5.3). Yield was increased by Palisade application in all of the treatment combinations over the untreated plots in all of the three years. Prior treatment of Palisade in one year typically had no effect in the yield of the seed crop in a subsequent year. In other words, there was generally no carry over effect of Palisade from one year to the next with one exception. When the crop was treated in each of the three years, seed yield in Year 3 was increased but not to the same extent that was observed for other plots that were treated in Year 3.

Cumulative seed yield over the three-year stand life was 4745 lbs./acre when the crop was not treated with Palisade. A single application of Palisade in any one of the three years (5372 cumulative yield) would have resulted in 627 lbs./acre increase over the untreated crop. Single applications of Palisade in two of the three years (5848 cumulative yield) produced an increase of 1103 when compared to the untreated crop. When the crop was treated in each of the three years (6142 cumulative yield), seed yield was improved by 1397 lbs./acre compared to the untreated crop. The magnitude of the seed yield increase resulting from annual single applications of Palisade in all three of the year was essentially equivalent to the seed yield that might be normally harvested from a 3rd year

crop of untreated perennial ryegrass (Table 5.3).

Table 5.2. Effect of Palisade treatment and seed position within spikes and spikelets on seed partitioning in Cutter perennial ryegrass (Year 2).

	Seed position			
Palisade treatment	Spike position	Spikelet position	Seed set	Seed weight
			%	mg
Treated	Top	---	87	1.94
	Middle	---	87	2.16
	Bottom	---	84	1.99
Untreated	Top	---	77	2.05
	Middle	---	80	2.14
	Bottom	---	80	1.95
Treated	---	Distal	76	1.68
	---	Central	91	2.10
	---	Proximal	92	2.31
Untreated	---	Distal	71	1.71
	---	Central	82	2.10
	---	Proximal	84	2.35

Table 5.3. Effect of stand age and Palisade application on perennial ryegrass seed yield.

Palisade treatment			Seed yield		
Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
			---------- lb/A ----------		
Untreated	Untreated	Untreated	2144 a	1325 a	1276 a
Treated	Treated	Treated	2719 b	1922 b	1501 b
Treated	Untreated	Untreated	2785 b	1336 a	1327 a
Treated	Treated	Untreated	2789 b	1926 b	1311 a
Untreated	Treated	Untreated	2179 a	1922 b	1300 a
Untreated	Treated	Treated	2209 a	1876 b	1655 c
Untreated	Untreated	Treated	2262 a	1354 a	1652 c
Treated	Untreated	Treated	2773 b	1399 a	1605 bc
Average treatment effect (yield increase)			25%	41%	23%

5.6 *Harvest Practices*

There are two methods for harvesting grass seed crops: (i) **windrow-combine** method and the **direct combine** method. The windrow-combine method is primarily used in the Pacific Northwest and other regions having low rainfall and humidity at the time of harvest. The standing crop is cut with a swather at high seed moisture content and the cut crop is dried in windrows until ready for combining (several days to 2 weeks depending on weather). The crop is then threshed at 12% seed moisture content by using combines with pickup attachments.

One question posed by seed growers in the Pacific Northwest concerns when is the optimum timing to windrow the crop. Proper harvest timing can reduce the volunteer crop population in grass seed crops and maximize seed yield and quality. Several methods have been employed by producers with varying degrees of success. The **visual observation method** is based on the apparent readiness of the crop for harvest as determined by color of seed at maturity. This is not a reliable method as the crop at maturity can appear quite green when preceded by a long period of cool-dry weather. In the **endosperm texture method**, the crop is cut at the firm dough stage of the seed. This method is a more reliable index than the color of seed but still not acceptable. The **seed shattering method** is based on timing the cutting of the crop when seed starts to shatter when individual tillers are struck. Growers that use this method find that they are usually too late to harvest at this stage since shattering losses will be great.

The **seed moisture method** is the most reliable method for determining time of cutting grass seed crops in the Pacific Northwest (Fig. 5.2). Seed growers use electronic meters, exhaust meters, and microwave ovens to determine seed moisture content. Optimum seed moisture contents for grass seed crops established by Klein and Harmond (1971) have been the recommended values for decades (Table 5.4). However, studies by Andrade et al.(1994) revealed that maximum seed yield in tall fescue grown in the Willamette Valley was attained when the crop was windrow harvested at 35 to 41% seed moisture content.

Table 5.4. Optimum seed moisture content for windrow harvest fo grass seed crops (Klein and Harmond, 1971).

Grass Seed Crop	Seed Moisture Content (%)
Orchardgrass	44
Tall fescue	43
Perennial ryegrass	35
Chewings fescue	30
Kentucky bluegrass	28
Creeping red fescue	25

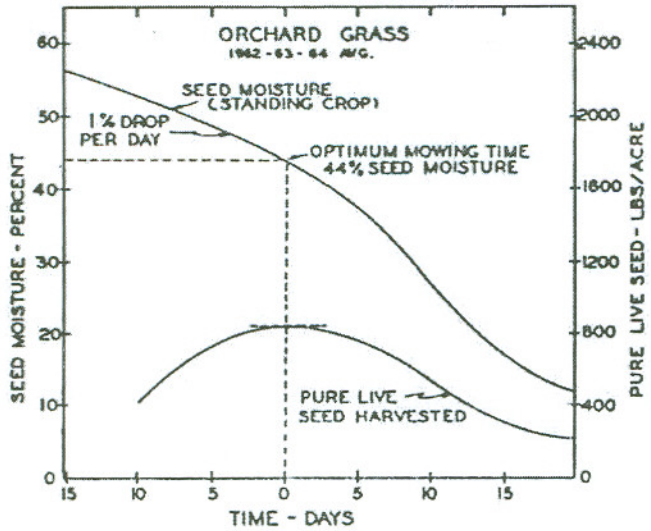


Figure 5.2. Seed moisture and harvest timing effects on seed yield in orchardgrass seed crops (Klein and Harmond, 1971).

The direct combine method is used in Europe and other regions having high rainfall and high relative humidity at harvest, and is rarely employed by producers in the Pacific Northwest. Seed germination of orchardgrass was reduced by up to 38% when using the direct combine method in the Willamette Valley rather than the two-step windrow-combine method (Rampton and Lee, 1969). Since seed is harvested at high seed moisture content it must be artificially dried prior to storage, thereby increasing the cost of production.

Finally, seed yield of perennial grass seed crops usually declines with each successive years harvest as the stand ages (Fig. 5.3). The cause or causes of this yield-loss phenomenon is not fully understood. In perennial ryegrass, the seed yield potential (expressed as floret production) and reproductive efficiency (seed:floret ratio) both decline as the stand age, resulting in lower seed yields (Table 5.5). These relationships seem to be indicative of an overall loss of crop vigor since fall tiller number (section 2.3) and root biomass (section 2.4) are inversely related to seed productivity over the life of the stand.

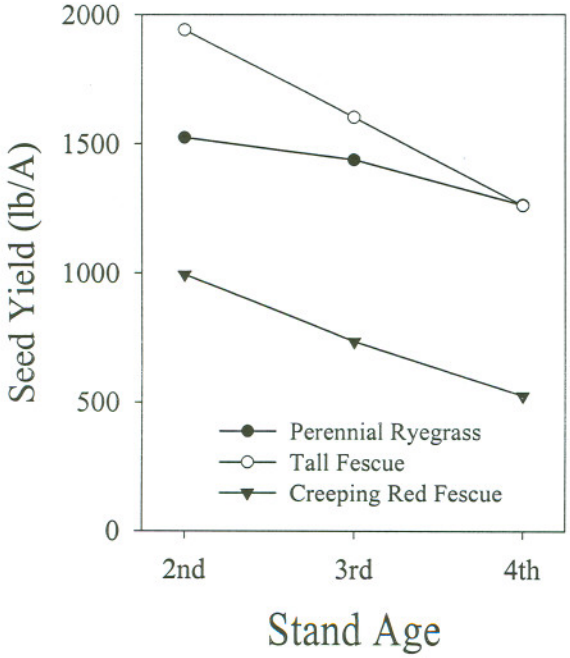


Figure 5.3. Stand age effects on seed yield of perennial grass seed crops in the Willamette Valley (Chastain, unpublished).

Table 5.5. Effect of stand age on seed yield, seed yield potential, and reproductive efficiency in three stands of Cutter perennial ryegrass in the Willamette Valley. The experimental stands were seeded in three consecutive years and harvested over a three-year period. (Chastain, unpublished).

	Stand Age		
Harvest Year	1st Year	2nd Year	3rd Year
		lbs/acre	
1998	1284		
1999	2144	1393	
2000	1753	1325	1040
2001		1108	1276
2002			1049
Stand Age Means:			
Seed Yield (lbs/acre)	1727	1275	1122
Potential Yield (florets/ft^2)	54,652	47,839	43,340
Reproductive Efficiency (%)	17.7	14.9	15.0

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