Post-Harvest Residue Management Effects on Seed Yield in Perennial Grass Seed Production
I. The Long-Term Effect From Non-Burning Techniques of Grass Seed Residue Removal[1]

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ABSTRACT

The influence of several post-harvest residue removal treatments on seed yield and yield components were measured over several years under field conditions. The effect of residue collection, by gathering and removing the straw and chaff during the combining operation, also was investigated. Species examined were 'Manhattan' perennial ryegrass (*Lolium perenne* L.), 'Encota' fine-leaf fescue (*Festuca rubra* L.), and 'Newport' Kentucky bluegrass (*Poa pratensis* L.).

The primary objective was to compare the effectiveness of the close-clip technique of stubble and chaff removal with the standard residue removal method, annual post-harvest burning. Open field burning was simulated with a mobile field sanitizer. A standard flail-chopper was also evaluated as a less intensive means of removing crop residue.

Species response to post-harvest residue removal differed significantly. Perennial ryegrass seed yield was most affected; all treatments significantly reduced seed yield, beginning with the first year of non-burning. Bluegrass seed yields were maintained through two years but declined in the third year when stubble was close-clipped or flail-chopped. No decline in fine-leaf fescue seed yield was observed through three years of close-clip stubble removal treatment.

Additional index words: Lolium perenne, Festuca rubra, Poa pratensis

INTRODUCTION

The mild winter and dry summer climatic characteristic of the Pacific Northwest favor the production of cool season turf and forage grasses. After grass seed harvest, however, 2.2 to 13.4 tons of straw residue per ha remain in the field. Burning of post-harvest residue has become an established cultural practice in the Willamette Valley of Oregon since the late 1940's for disease control and residue disposal (Hardison, 1976).

Early work by Burton (1944) and Musser (1947) in the southern and eastern U. S. demonstrated higher grass seed yields followed post-harvest burning. In western Oregon, burning controlled the major seed diseases (Hardison, 1976) and improved the effectiveness of soil-active herbicides used for the control of grass weeds and volunteer grass crop plants (Lee, 1969). Residue remaining on the fields seriously depressed seed production of several grass species by restricting tiller development (Chilcote et al., 1978). Smoke from open field burning, however, has contributed to air pollution during the summer burning season; therefore, other methods of residue removal have been investigated.

The research effort on non-burning alternatives in perennial grass seed production has centered on various techniques of mechanical removal of straw and/or stubble. Chilcote et al. (1978) reported that mechanical removal of the straw, leaving only short stubble and some organic accumulation on the soil surface, was inferior to burning the residue, but better than no removal. Their results suggested that higher seed yield following burning may be related to the time and extent of tillering, particularly axillary tillers. In subsequent studies, using a machine designed to close-clip the stubble to crown height and vacuum residue from fields after harvest, it was found that the more complete the residue removal, the higher the seed yield (Chilcote et al. 1983).

Pumphrey (1965) investigated residue management of Kentucky bluegrass (*Poa pratensis* L.) and red fescue (*Festuca rubra* L.) under eastern Oregon conditions. No significant difference was found between early burning and a complete removal of the residue by mowing the stubble and raking it from the plots. Partial removal of the residue by raking the straw from the plots had an intermediate effect between no removal and complete removal. Rampton and Jackson (1969) found similar results with orchardgrass (*Dactylis glomerata* L.) in the Willamette Valley of Oregon, where stubble was mowed and as much residue as possible removed; no significant reduction of seed yield resulted as compared to burning. Similar findings were reported by Canode (1972) in eastern Washington, who found post-harvest burning of orchardgrass did not result in increased seed yield when compared with raking and removing residue.

Chilcote and Youngberg (1975) reported that seed yield reduction as a result of mechanical removal technique was dependent upon grass species and that stand age also impacted the effect of mechanical removal. They reported that yields in newer stands were not reduced as greatly as in older stands. Canode (1972) found that mechanical removal of bluegrass residue produced higher seed yields in the second and third year crops and attributed yield depression from burning to wide row spacing. In a subsequent study,

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Canode and Law (1979) reported that open field burning of bluegrass fields may maintain the productivity of the stand for several years longer than mechanical removal. Thatching, mulching, gapping or increased row spacing, however, were not satisfactory alternatives to burning. Canode and Law (1978) also reported that red fescue, smooth bromegrass (*Bromus inermis* Leyss.) and crested wheatgrass (*Agropyron desertorum* (Fisch. ex Link) Shult.) responded with higher average seed yields when residue was burned, compared with two levels of mechanical removal. Furthermore, the removal of both stubble and straw resulted in increased yields of red fescue and smooth bromegrass when compared to straw removal alone. The yield of crested wheatgrass, however, was decreased.

Chilcote et al. (1983) reported that burning fields soon after harvest resulted in superior seed yield and residue removal. Burning late in the season (late September-October), when regrowth had started and straw moisture was high, reduced the effectiveness of residue removal and caused stand injury, as newly developed tillers were destroyed. However, the effect of delayed mechanical residue removal was not studied.

The research reported here was designed to determine the effect on seed yield and yield components of three species of cool season grasses by comparing annual post-harvest burning to alternative methods of residue removal over several years. In the standard post-harvest treatment, residue was burned early (within 2 weeks of harvest) using a mobile field sanitizer. Alternative methods of residue management removed straw and cut stubble using field-scale equipment soon after harvest, and also later in the season (late September-October). In addition, an experimental procedure using a chaff collection device attached to the combine to prevent residue from being discharged onto the ground, was compared to normal distribution of crop residue. Locations were selected within the Willamette Valley of Oregon to represent the soil types characteristic of commercial grass seed production. Species selected for study were perennnial ryegrass (*Lolium perenne* L.) cv. 'Manhattan', fine-leaf fescue (*Festuca rubra* L.) cv. 'Encota', and Kentucky bluegrass (*Poa pratensis* L.) cv. 'Newport'.

MATERIALS AND METHODS

This study was conducted in the Willamette Valley of Oregon within a radius of 100 kilometers of Corvallis, with experiments in growers' fields. Residue removal treatments were established on 'Manhattan' perennial ryegrass immediately after the second year seed crop in 1978. In 1979, treatments were established on 'Encota' fine-leaf fescue and 'Newport' Kentucky bluegrass immediately after the first- and tenth-year seed crop, respectively. Crop residue at all three locations was open field burned in the years prior to the initiation of this study, and had been managed for seed production by the growers since establishment.

Each residue management plot was 2.4 × 11 m, replicated six times. Treatments were arranged in a randomized split-plot design. Main plots were residue collected at seed harvest by gathering straw and chaff on a large canvas behind the combine, or allowing crop residue to be discharged onto the ground. On subplots, residue was removed by: 1) burning early, 2) flail-chopping early 3) flail chopping late, 4) close-clipping and removal of stubble early, and 5) close-clipping and removal late in the season. Straw on the ground was removed prior to close-clip and burn treatments. Burn treatments were applied using a mobile field sanitizing machine reported to be comparable to open field burning (Youngberg et al., 1975). Close-clip treatments were made using a modified orchard flail cutter with attached discharge chute and stackwagon built under contract for the Department of Environmental Quality by Rear's Manufacturing Co., 2140 Prairie Rd., Eugene, Oregon 97404. The design capabilities allowed for cutting stubble to 2.5 cm and provided sufficient vacuum to lift chaff from the field surface. Preliminary testing by Youngberg (1977), using a prototype model, demonstrated that the close-clipping of stubble and removal of residue from perennial grass crops could maintain seed yield. A commercially available Brady flail-chopper was used to remove straw. Flail-chop treatments cut stubble to approximately 7.5 cm.

Cultural practices throughout the study were consistent with recommendations for commercial seed production appropriate to the species. Perennial ryegrass received 34 kg ha^{-1} of nitrogen applied as diammonium phosphate in October and 100 kg ha^{-1} applied as a split-spring application (March and April), using ammonium nitrate. Fine-leaf fescue was similarly managed with 28 kg ha^{-1} of nitrogen in the fall (October) as 10-34-0 liquid fertilizer and 110 kg ha^{-1} spring-applied in March as ammonium nitrate. Total annual nitrogen requirements for bluegrass were supplied by applying 67 kg ha^{-1} as ammonium sulfate in February and 90 kg ha^{-1} as urea + ammonium sulfate (40-0-0-6) in March. Weed control for perennial ryegrass, fine-leaf fescue, and bluegrass was 1.68 kg ha^{-1} atrazine, 1.68 kg ha^{-1} simazine, and 4.5 kg ha^{-1} diuron, respectively, applied in October. Additionally, 0.56 kg a.i. ha^{-1} of 2,4-D and 0.28 kg a.i. ha^{-1} dicamba were applied to the fine-leaf fescue field each October for broadleaf weed control.

Fertile tiller number was determined from two 0.1 m^{-2} samples taken just prior to seed maturity for all species, beginning with the first harvest. In 1980 and 1981, spikelets per inflorescence and florets per spikelet were determined by selecting 10 tillers at random and counting the number of spikelets. Floret number per spikelet was determined by subsampling four inflorescences and counting florets in six spikelets, two at the top, middle, and bottom of each inflorescence.

Seed yield as determined by swathing the total plot area with a commercially built McCormick 63 swather, modified to a cutting width of 2.4 meters. Swathing time for each species was determined by the method of Klein and Harmond (1971). Windrows were allowed to air-dry in the field for 10-14 days before combining. Plots were combined, using a Wintersteiger Seedmaster Universal plot harvester. Seed was cleaned on an M2-B clipper cleaner and weighed. The final year of seed harvest was 1982; thus, treatment effects were evaluated over four years on perennial ryegrass and three years on fine-leaf fescue and bluegrass.

Data were subjected to a split-plot analysis of variance and least significance difference test to determine differences among treatment means.

RESULTS AND DISCUSSION

Perennial Ryegrass

Visual observations made each fall (September-November) confirmed burning as the only treatment capable of complete residue removal, and the only treatment capable of destroying non-reproductive tillers formed in the late stages of reproductive growth from the previous crop. Increased amount of residue and the presence of surviving tillers have been shown to reduce auxillary tiller development in the fall (Chilcote et al., 1978). All other treatments appeared less vigorous due either to the inhibition of new tiller growth or reduced control of volunteer crop or weed plants.

Fertile tiller number at harvest was not significantly reduced by close-clipping of residue when compared to burning (Table 1). Other non-burn treatments generally had lower fertile tiller density. There were no significant differences in the number of spikelets per spike or weight per 1000 seeds (data not presented). Florets per spikelet were reduced in 1981 when residue was removed by flail-chopping at the early or late date, or close-clipping of stubble at the later date (Table 2). No main plot effects (residue collection at harvest) were observed. Thus, residue collection at the time of seed harvest did not significantly influence yield components.

Table 1. Fertile tillers 0.1 m^{-2} for residue removal treatments in perennial ryegrass, 1980-82.

Treatment	1980	1981	1982	Mean
Close-clip	185	174	184	181
Burn	181	173	194	183
Flail-chop	157	151	172	160
Late close-clip	142	122	170	144
Late flail-chop	174	108	193	158
LSD .05	30	29	N.S.	16

Table 2. Florets per spikelet for residue removal treatments in perennial ryegrass, 1981.

Treatment	Florets per spikelet
Close-clip	8.24
Burn	8.89
Flail-chop	7.94
Late close-clip	7.09
Late flail-chop	8.22
LSD .05	0.88

Continuous burning was the only treatment capable of maintaining seed yield over several years in perennial ryegrass (Table 3). The average yield decline over four years was 15% for all non-thermal treatments when compared to continuous burning. Furthermore, the average yield reduction due to close-clipping was not significantly different from early flail-chop or the later residue removal treatments. However, the yield decline of close-clip treatments from yield component analysis remains unexplained. It may have been due to greater seed loss at harvest or in seed conditioning from these treatments because of more light seed. Later tiller initiation in the fall in non-thermal residue removal treatments may result in reduced plant vigor and reduced seed filling.

Treatment effects on seed quality shown in Table 4 are averaged over four years. In each year the crop from the burned plots consistently have a slightly higher percent pure seed. These improvements in seed quality are the result of a slight reduction in percent weed seed and inert matter (straw, soil and chaff). Treatments where stubble was close-clipped were intermediate in their effect on seed quality components.

Table 3. Seed yield (kg ha^{-1}) for perennial ryegrass, 1979-82.

Treatment	1979	1980	1981	1982	Mean
Close-clip	662	435	657	634	597
Burn	816	519	910	608	713
Flail-chop	770	358	548	678	588
Late close-clip	738	388	610	646	595
Late flail-chop	740	416	612	642	603
LSD .05	90	54	172	N.S.	56

Table 4. Four-year mean of selected quality components of harvested seed from perennial ryegrass, 1979-82.

Treatment	Pure seed	Weed seed	Inert matter
	(%)		
Close-clip	88.87	2.17	8.91
Burn	90.08	1.53	8.32
Flail-chop	87.72	3.22	9.12
Late close-clip	85.82	4.68	9.50
Late flail-chop	87.50	3.44	9.06
LSD .05	1.97	0.84	N.S.

Fine-leaf fescue

Crop residue removal treatments significantly altered the stand appearance after several years of treatment. Plants in burned plots are "pruned" back annually, which allows new tiller growth to expand radially from the crown. However, mechanical removal treatments, particularly the close-clip stubble removal, developed a more prostrate or creeping growth habit. The lack of removal of vegetative

tillers by burning contributed to this growth pattern. More crop and weed seedlings became established in the unburned plots and increased plant population. This was particularly evident in the late close-clip stubble treatment (Table 5).

Fertile tiller number at harvest was unchanged until the third year (Table 6). Continued stubble accumulation in and around the unburned plant crowns appeared to have contributed to this decline; however, a stimulus by the late close-clip treatment may have helped to overcome the inhibition of tillering. More panicles were present when straw and chaff were collected during the combining operation only in the first year of study (Table 7). However, no additional evidence of yield component compensation was observed.

The close-clip treatment has been successful in maintaining seed yield in fine-leaf fescue through three years of study, regardless if used early or late in the post-harvest period (Table 8). Furthermore, seed quality was not significantly affected by residue removal treatment. Residue collection after combining had no effect on seed yield.

Table 5. Volunteer seedlings in fine-leaf fescue, 1981.

Treatment	Number of plants (m^{-2})
Close-clip	4.88
Burn	3.29
Flail-chop	5.79
Late close-clip	46.54
Late flail-chop	4.75
LSD .05	6.76

Table 6. Fertile tillers 0.1 m^{-2} for residue removal treatments in fine-leaf fescue, 1980-82.

Treatment	1980	1981	1982	Mean
Close-clip	297	192	197	228
Burn	297	210	262	257
Flail-chop	280	225	173	226
Late close-clip	273	208	255	245
Late flail-chop	262	226	209	232
LSD .05	N.S.	N.S.	33	23

Bluegrass

Changes in growth habit of bluegrass plants were apparent from the onset of vegetative growth (October) until late April. In burned plots, tiller development was in direct contact with the soil and growth was compact while unburned treatments were elongated. Flail-chop and late flail-chop plots were similar in appearance; both had etiolated tiller growth emerging from approximately 7.5 cm of stubble which remained after post harvest treatment. Similarly, early and late close-clip treatments did not appear to differ greatly; however, new tiller development was less etiolated than the flail-chop treatments. Growing conditions following burning will favor a longer period of tiller development and improved conditions for vernalization and induction.

Table 7. Mean of several components of seed yield in fine-leaf fescue, 1980.

Treatment	Panicles 0.1 m^{-2}	Spikelets per panicle	Florets per spikelet
Chaff collected	299.9	22.7	5.3
Chaff not collected	265.4	23.3	4.9
LSD .05	26.1	N.S.	N.S.

Table 8. Seed yield (kg ha^{-1}) for residue removal treatments on fine-leaf fescue, 1980-82.

Treatment	1980	1981	1982	Mean
Close-clip	440	188	268	298
Burn	445	186	284	305
Flail-chop	358	167	257	261
Late close-clip	424	282	277	328
Late flail-chop	396	183	255	278
LSD .05	N.S.	30	N.S.	44

Maximum fertile tiller number at havest was maintained through the third year of the study only by post-harvest burning (Table 9). Seed yield increased with increases in fertile tiller number (Table 10). Furthermore, processed seed quality was not affected by treatment (data not presented). Thatch accumulation over time in the non-burn plots reduced fertile tiller number for early and late close-clip treatments most severely in the final year. Flail-chop and late flail-chop treatments severely limited tiller development in all years, with no significant compensation by other yield components.

Treatment effects on seed yield increased over the three years of the study. The adverse effect of not burning was first observed for the flail-chop and late flail-chop treatments in 1981. In 1982, however, both early and late close-clip stubble removal treatments showed reduced yield. Although the average seed yield for the close-clip treatments did not differ significantly from annual burning because of high yields in the first years of the study, mean seed yield of flail-chop and late flail-chop treatments was reduced.

Table 9. Fertile tillers 0.1 m^{-2} for residue removal treatments on bluegrass, 1980-82.

Treatment	1980	1981	1982	Mean
Close-clip	446	227	321	332
Burn	502	319	467	429
Flail-chop	260	245	161	222
Late close-clip	684	316	362	354
Late flail-chop	294	207	183	228
LSD .05	75	37	32	34

Table 10. Seed yield (kg ha^{-1}) for bluegrass, 1980-82.

Treatment	1980	1981	1982	Mean
Close-clip	1083	845	556	828
Burn	863	853	678	798
Flail-chop	869	736	470	692
Late close-clip	884	930	602	806
Late flail-chop	917	772	437	709
LSD .05	104	92	77	51

SUMMARY

In perennial ryegrass, continuous burning was the only treatment capable of maintaining seed yield over several years. The mean yield reduction for all non-thermal treatments was 15 percent after four years, and no advantage for the close-clip stubble removal treatment over other systems of residue removal was noted.

In fine-leaf fescue, the close-clip stubble removal system maintained seed yield through three years of study, whether used early or late in the post-harvest period. However, these treatments altered stand density, resulting in a more prostrate growth habit and the establishment of volunteer seedlings which could cause rejection of the field by certification officials.

In bluegrass, the close-clip treatment maintained seed yield equal to burning when averaged over three years, and was superior to flail-chop residue removal. However, seed yield and fertile tiller number decreased in the third year, suggesting that the close-clip treatment is not an effective replacement to burning for more than two years.

With the exception of an increased number of panicles in fine fescue following the first year of use, no significant effects were attributed to the collection of straw and chaff during the combining operation.

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