

The influence of autumn cutting treatments on canopy structure and seed production of first-year crops of *Poa pratensis* L. and *Festuca rubra* L.

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Abstract

Poa pratensis and *Festuca rubra* seed crops were sown under winter wheat cover crops. Immediately after wheat harvest, or 4-6 weeks later, close cuts were made with a rotary mower. In most experiments, cutting treatments increased production of inflorescences, resulting in an almost proportional increase in seed yield. No interaction was found with various nitrogen applications. No consistent relation was observed between stimulation of autumn tillering by cutting treatments and higher seed production. Tillers that developed after autumn cutting had shorter leaves and much less dead residue was found in the cut crops. As a result in spring, from the onset of stem elongation until flowering, more light penetrated to lower levels in the cut crops. It is concluded that the higher production of fertile tillers in response to autumn cutting can largely be attributed to better illumination and increased survival of mainly the late elongating reproductive tillers. This mechanism could explain most of the effects of autumn treatments in older stands too.

Introduction

In the Netherlands, most *P. pratensis* and *F. rubra* crops are sown under a winter wheat cover crop. After the cover crop has been harvested, the grass crop is often weak and partly covered and shaded by the wheat stubble and by some straw and chaff remnants. The grass tillers are often thin and elongated. Young leaves and new tillers have to pass through the more or less elongated, dead and living leaf sheaths and through that intermingled layer of cover crop residue and old grass till-

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ers. Hardly any information is available on cuts in the autumn preceding the first harvest year. Preliminary trials with autumn cuttings in 1975 in the Netherlands were not conclusive. In a series of 14 experiments, Nordestgaard (1976) found no consistent effect of autumn cuttings in first-year *F. rubra* crops either. In the UK, Lambert (1966) found inconsistent yield responses to late autumn and early spring cuttings in first-year cocksfoot, although the fertility of tillers was improved.

More extensively studied are the effects of autumn treatments in older stands. The perennial nature of *Poa pratensis* and *Festuca rubra* allows seed crops to be harvested for several years. However, after each harvest the layer of grass stubbles and dead and living crop residue must then be cut, burnt or otherwise removed, to maintain seed yields of subsequent crops. Although often the tiller density of older stands will be higher than of first-year crops, and the accumulated layer of crop residue much denser, the mechanism of how autumn cutting affects subsequent seed production is expected to be identical. Chilcote et al. (1980) reviewed studies on how burning and mechanical removal affects plant growth and the subsequent seed production of older stands. They suggest that the more open canopy after burning or close cutting allows for more and more vigorous tillering, better flower induction and therefore many more panicles in spring. Hickey & Ensign (1983) proposed an additional mechanism in *P. pratensis*: burning or mechanical thinning of the crop could release the rhizome system from apical dominance, resulting in an increase in tillering and in subsequent panicle production. In species without rhizomes, the latter mechanism cannot explain the effects of autumn treatments.

This paper reports on how cutting treatments after the wheat cover crop harvest influence the seed production of *P. pratensis* and *F. rubra* crops. In these species, panicle production strongly depends on autumn tillering (Meijer, 1984). Because tillering is stimulated by nitrogen fertilization and because part of the nitrogen temporary is fixed in the cut leaves, these treatments were combined with various nitrogen applications. Subsequently, the influences of cuts in cultivars with an open crop type were compared with the influences in densely tillering, leafy types. Furthermore, the responses of grass crops that were allowed to develop weakly or strongly under the cover crops were compared. In addition, in a small-scale experiment, normal residue after cover crop harvest was replaced by an artificial stubble, to study the effect on tiller growth and on panicle production.

Materials and methods

P. pratensis and *F. rubra* were sown in October or November on the same date as the wheat cover crops. Management of the wheat crops was adapted to favour growth of the undersown grasses. A late-closing wheat cultivar (Arminda) was chosen. It was sown at a 20 % lower rate than usual (115 kg ha^{-1}). In spring, nitrogen dressing was split applied to the wheat: 140 kg ha^{-1} nitrogen minus the mineral N in the soil (0-60 cm) at Feekes stage 3 and 60 kg ha^{-1} at stage 7. The wheat was combine-harvested during the last 10 days of August at 10-20 cm stubble height and the straw was baled.

Cutting treatments were made using a rotary cutter. This type of mower does not

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Table 1. Summary of experiments and treatments. 'Early' refers to cuts and dressings immediately after wheat harvest. 'Late' treatments were carried out 4 weeks later in *Festuca rubra* and 6 weeks later in *Poa pratensis*.

Harvest year	Number of experiments	Cultivars (number of exp.)		Cutting treatments	Autumn dressing (kg ha ⁻¹ nitrogen)	Other factors
		<i>P. pratensis</i>	<i>F. rubra</i>			
1981-84	4	Parade (2) Enprima Geronimo	Dawson (4)	untreated early late	60 early 60 early + 45 late	
1983-84	2	Baron (2) Kimono (2)	Koket (2) Agram (2)	untreated early late	60 early 60 late	dense cv. open cv.
1986	1	Entopper	Dawson	untreated early late	60 early 60 late	weak crops strong crops
1985	1	Delft	Dawson	untreated early early + artificial stubble until 1 December early + artificial stubble until 1 April early + artificial stubble until harvest		

remove the residue but spreads it out evenly. With *P. pratensis*, cuts were made as low as evenness of the field allowed, aiming at an average stubble length of 2 cm. *F. rubra* often exhibits a certain degree of vegetative stem elongation. Close cuts would have removed many apices. Cuts in that species were therefore somewhat higher, at 5 cm above ground. In this paper, cutting treatments immediately after wheat harvest, at the end of August, are referred to as 'early'. The 'late' cuts were carried out 4 weeks later in *F. rubra* and 6 weeks later in *P. pratensis*. The late date corresponds with the recommendations for autumn treatments in older stands in the Netherlands.

The autumn nitrogen dressing treatments in the experiments are shown in Table 1. The time of the 'early' and 'late' autumn dressings corresponds with the cutting treatments. In February the spring dressing was applied. *P. pratensis* and *F. rubra* received a dressing equivalent to 90 kg N ha⁻¹ and 70 kg N ha⁻¹, respectively.

Experiments are referred to according to their year of harvest, even though the treatments were applied in the preceding autumn. Four types of experiments were conducted (Table 1). An identical experiment was carried out each year on both species from 1981-1984. In this the effects of early and late cuts and the influence of an additional nitrogen dressing applied on the late cutting date were studied. A second series of two experiments in 1983 and 1984 was designed to examine the influence of cutting on two diverging cultivars. With *P. pratensis* the response of a leafy and fast growing cultivar (Kimono) was compared with the effect on a short and more open growing type (Baron). The differences between the two *F. rubra* culti-

vars are less pronounced: Agram, a more densely tillering type, was compared in its response with Koket. In the third type of experiment, conducted in 1986, the effects of cutting on weakly and strongly developed grass crops of one cultivar were studied. A weaker grass crop was attained by forcing the wheat cover crop to early closing by denser sowing (seed rate 180 kg ha^{-1}) and early application of total spring dressing (200 kg ha^{-1} minus soil nitrogen at stage 3) (Meijer, 1987). In 1985 in a small-scale experiment, an artificial stubble of bamboo sticks was inserted on 0.5 m^2 plots after cutting. About $1100 \text{ sticks m}^{-2}$, 0.4 cm thick, created an artificial stubble $15\text{-}17 \text{ cm}$ in height. The number of sticks per area was almost twice the number of wheat stems because the grass tillers in the uncut plots were additionally covered by chaff, leaf and straw remnants. At ground level, light intensity was comparable: 70% of full light. At 5 cm height, above the layer of straw and chaff remnants, shading in the wheat stubble was less: 85% of full light compared with about 75% in the artificial stubble. That stubble was removed again on 30 November or 1 April, or it was left until flowering. In spring the leaf length and number of reproductive tillers at flowering were determined, but not the seed yield.

All experiments were replicated four times. Seed production data were obtained by harvesting 21 m^2 per plot. Vegetative and reproductive tiller numbers and dry weight of the green crop and of the dead residue were obtained from 0.125 or 0.25 m^2 sample areas. Leaf length was determined as the length of leaf sheath and lamina at the youngest full-grown leaf of 24 random tillers per replicate. The percentage of light transmission to the crop base at a height of about 5 cm above ground was measured with a line sensor (dimensions $100 \times 0.4 \text{ cm}$, measuring $400\text{-}800 \text{ nm}$).

Results and discussion

Influence of nitrogen dressings

Except in the 1986 experiment with *P. pratensis*, no interaction was found between cutting treatments and nitrogen applications. The additional 45 kg ha^{-1} nitrogen applied late in the 1981-1984 series (Table 1) tended to act positively in the drier seasons (1983 and 1984) but had no effect in the wetter harvest years (1981 and 1982). Probably in the predominantly dry years the spring dressings limited seed production and therefore the additional nitrogen applied late in autumn was beneficial. In most experiments, yields were highest with the early applied 60 kg ha^{-1} nitrogen. Delaying the autumn dressing until the late date only appeared to be positive in vigorously developed *F. rubra* crops. Possibly, such vigorously developed first-year crops have to be treated like older stands, for which it is commonly recommended to apply the autumn dressing in late September. In a series of experiments on *F. rubra*, Nordestgaard (1976) found no consistent effect of cutting, but delaying the nitrogen application until mid-September gave highest yields. His crops were grown under early-harvested summer barley and therefore probably also developed vigorously.

This paper concentrates on the effects of cutting. It appeared that the effect of cutting was usually not influenced by fertilization; furthermore, on average the 60

kg ha⁻¹ nitrogen applied early gave the highest yields. Therefore, in the following sections only data from that treatment are discussed.

Influence of cutting on seed production

In an identical experiment in both species repeated annually from 1981-1984, cutting always gave higher yields compared with the uncut control. The difference was significant (Tukey, 0.05) in three experiments with *P. pratensis* and in two experiments with *F. rubra*. In Table 2 the results are presented as averages of the four experiments. The yield increase results from a larger number of inflorescences. Average seed weight was not affected. Cutting tended to decrease the calculated yield per panicle: this suggests that the extra panicles produced were smaller on average. No significant differences were found between early and late cuts.

This series of experiments was conducted with only one cultivar of *F. rubra* and with 3 cultivars of *P. pratensis* that are very similar in growth habit. All these crops developed sufficiently or rather vigorously under the cover crop. Cutting was subsequently studied on different crop types. The effects on cultivars with an open or dense crop type were examined (Table 3) and the effects on strongly or weakly developed crops of one cultivar were compared (Table 4).

Because of frost damage to the wheat crops during the '81-'82 winter, the growth of the undersown grass crops in 1982 was excellent, even excessive. At the end of autumn growth there were many tillers (Table 3). In that 1983 experiment, cutting vigorous crops had no significant effect on autumn tillering. But cutting increased the seed yield of the vigorous *P. pratensis* crops, especially of the leafy and fast-growing cv. Kimono. Results of 1984 deviated from those of the previous year: cutting improved tillering of the relatively weak *P. pratensis* crops, but yields were unaffected. These results with *P. pratensis* demonstrate that yield increases because of autumn cuttings not always are related to stimulation of autumn tiller growth. In both years the two *F. rubra* cultivars reacted similarly. However, the effect of cutting deviated from *P. pratensis*: no effect on yield in the strong 1983 crops and a moderate but significant increase in the weaker crops of 1984. In the dense 1983 *F. rubra* crops, many tillers showed vegetative stem elongation. Although cuts were made at about 5 cm above the ground, possibly the removal of part of the apices has hampered seed yields.

In the 1986 experiment, crop development was characterized by determining tiller density two weeks after the wheat harvest (Table 4). In both species, early cuts increased seed yield in the better-developed crops. Early cutting was also beneficial in the weak *P. pratensis* crop, but not in the less-developed *F. rubra* crop. In these trials, late cuts resulted in seed yields that were lower than those after early cuts. This might have been because autumn growth stopped early as a consequence of an unusually early drop in temperature in mid-November. Nordestgaard (1976) found no consistent effect of autumn cutting in first-year *F. rubra* crops. All his treatments started late, from mid-October onwards. Possibly a certain recovery and regrowth period is needed after autumn cuts.

From autumn cuts in older stands of various perennial grass species also in-

Table 2. The influence of autumn cutting on first-year production of *Poa pratensis* and *Festuca rubra* seed crops. Averages of 4 experiments, 1981-1984.

	<i>Poa pratensis</i>			<i>Festuca rubra</i>		
	not cut	early cut	late cut	not cut	early cut	late cut
Seed yield (kg ha ⁻¹)	1092	1350	1346	1243	1320	1325
Panicles m ⁻²	2248	3017	2914	2609	2909	2949
1000-seed weight (g)	0.353	0.350	0.344	0.806	0.806	0.806
Mg seed panicle ⁻¹	48.6	44.7	46.2	47.6	45.3	44.9

Table 3. The influence of a short cut after cover crop harvest on autumn tiller growth and on subsequent seed production of two distinct cultivars of *Poa pratensis* and *Festuca rubra*. 2 Experiments, 1983 and 1984.

	Tillers m ⁻² , December			Seed yield (kg ha ⁻¹)		
	not cut	early cut	LSD 0.05	not cut	early cut	LSD 0.05
<i>Poa pratensis</i>						
1983 Baron	4380	4446	n.s.	935	1385	197
Kimono	5080	5112	n.s.	365	990	197
1984 Baron	2612	3068	325	1610	1540	n.s.
Kimono	2602	3280	325	840	990	n.s.
<i>Festuca rubra</i>						
1983 Koket	8392	8120	n.s.	1530	1535	n.s.
Agram	7960	8832	n.s.	990	940	n.s.
1984 Koket	5225	6415	751	1550	1630	75
Agram	5440	5780	n.s.	1240	1370	75

Table 4. The influence of short cuts after cover crop harvest on seed production of strongly or weakly developed grass crops. Tiller density 10 September 1985, seed yield 1986.

	Tillers m ⁻²	Seed yield (kg ha ⁻¹)			
		not cut	early cut	late cut	LSD 0.05
<i>Poa pratensis</i> crops					
strong	1770	998	1302	1012	149
weak	1230	1011	1235	930	149
<i>Festuca rubra</i> crops					
strong	2580	1144	1299	1134	131
weak	1640	1026	1044	896	131

creased inflorescence production has been reported, resulting in higher seed yields (Fulkerson, 1980; Ensign et al., 1983; Hickey & Ensign, 1983; Young et al., 1984; Nordestgaard, 1987). Some authors have also tried to explain the beneficial effects of post-harvest residue removal. In most of the proposed explanations the positive effects are related to improved tillering and the development of more large tillers in autumn (Canode & Law, 1979; Chilcote et al., 1980; Ensign et al., 1983; Hickey & Ensign, 1983). The stimulation of tiller growth in autumn could explain most of the beneficial effects in under-developed crops. Indeed, in some of our trials, higher tiller numbers were found at the end of autumn growth in cut plots. But that effect was not consistent and there was no clear relation between improved tillering and higher seed production (Table 3). Moreover, in our experiments the largest yield increases and the most consistent effects of cuts were found in vigorously developed crops. It is therefore unlikely that all or most of the favourable effects of autumn cuts can be attributed to stimulation of autumn tiller growth. In some experiments therefore, the effect of cutting on tiller growth and canopy structure were also studied in next spring, in the period from reproductive stem elongation until harvest.

In grass seed crops, minor reductions in fertile tiller numbers are often observed after heading. Probably more important, although scarcely examined, is the death of fertile tillers before heading. From his data on a perennial ryegrass crop, Wright (1978) calculated that 30 % of the fertile tillers died before maximum ear emergence. Furthermore, in well-developed *P. pratensis* and *F. rubra* crops many more fertile tillers are produced than ultimately flower. In such crops, actual inflorescence production is strongly affected by crop density and is probably determined mainly by the fierce competition during the period of stem elongation (Meijer, 1984). Autumn treatments in older stands have been reported to result in the development of shorter and more prostrate tillers, giving a more open canopy which lasts until spring (Lambert, 1966; Chilcote et al., 1980; Ensign et al., 1983) These effects were also noticed after autumn cuts in our first-year crops. A more open canopy in spring during the stem elongation phase, resulting in decreased light competition and higher survival of fertile tillers, could possibly explain the greater inflorescence production after cutting.

Influence of cutting on canopy structure

In the 1984 crops the composition of the early cut and the untreated crops was determined at the beginning of stem elongation (Table 5). Cutting stimulated tillering in these crops. Comparison with tiller numbers in Table 3 shows that the effect lasted until in spring. Tillers that developed after a cutting treatment had shorter leaves. Average tiller weight was lower, but because of higher numbers, total green mass of the crops was about equal to that of the uncut crops. As a result of autumn cutting, considerably less dead residue was present in the canopy in spring. Together, these differences resulted in a deviating canopy structure. The cut crops were shorter and more open and this difference was visible until the beginning of flowering. Table 5 shows that seed yield responses were related to crop length and total crop mass.

Table 5. The influence of autumn cutting on tiller density, leaf length, tiller weight and residue removal (at the onset of stem elongation) and on seed yield. 3 cultivars, 1984.

	Tillers m ⁻²	Leaf length (cm)	Tiller weight (mg)	Dry weight (kg ha ⁻¹)		Seed yield (kg ha ⁻¹)
				green parts	dead residue	
<i>Poa pratensis</i>						
Geronimo						
early cut	7990	13.3	54	4310	1660	1520
not cut	6700	22.1	72	4800	2960	1170
Baron						
early cut	8160	7.6	33	2690	850	1540
not cut	6000	11.1	45	2700	1700	1610
Kimono						
early cut	8960	9.6	35	3140	1040	990
not cut	6560	12.3	49	3210	1960	840
<i>Festuca rubra</i>						
Dawson						
early cut	9625	15.0	50	4810	2880	1350
not cut	8750	25.0	67	5860	4630	1250
Koket						
early cut	10780	17.3	45	4850	1570	1630
not cut	9570	18.4	47	4500	2080	1550
Agram						
early cut	11900	12.5	35	4170	1150	1370
not cut	10950	14.7	37	4050	1800	1240

From the onset of stem elongation until flowering, light penetration to lower levels in these crops diminishes rapidly. During that period, 25-50 % higher light intensity was measured in the cut crops at 5 cm above the ground. Similar results were found from measurements in the 1986 experiments (Fig. 1).

In these grasses, stem elongation is spread over several weeks. For first generations fertile tillers to elongate, light will not be limiting. But subsequently later elongating tillers are increasingly shaded. It seems that the higher production of fertile tillers and the increased seed yields in response to autumn cutting in our experiments can largely be attributed to better light penetration to and increased survival of the later elongating reproductive tillers. This explanation is consistent with the lower seed production per panicle after cutting in Table 2, because, on average, the later appearing inflorescences produce less seed. The explanation is also consistent with the strong effects of cuts in vigorously developed crops (Tables 3 and 4).

From studies in older stands too is reported that autumn cutting or burning often results in a more open canopy that lasts until spring. Notwithstanding this, beneficial effects are expected to occur in autumn (Lambert, 1966; Chilcote et al., 1980; Ensign et al., 1983). The similarity of the described effects in older stands with our

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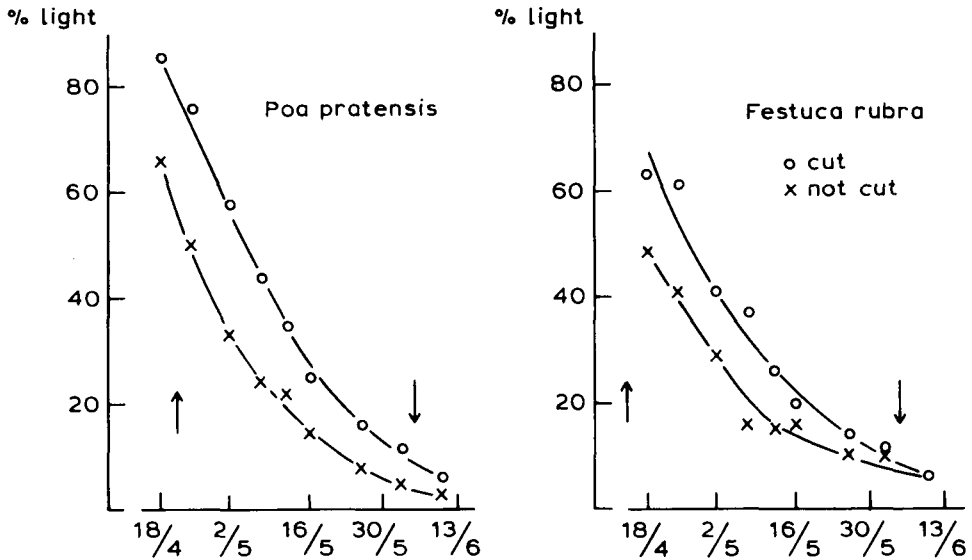


Fig. 1. The influence of autumn cutting on percentage light transmission to the crop base during stem elongation phase. Averaged data for weakly and strongly developed crops, 1986 experiments. ↑ beginning of stem elongation; ↓ first anthesis.

observations in firmly established first-year crops suggest that decreased competition for light during stem elongation could explain most of the effects in older crops too. Lambert (1966) found that autumn and early spring cuts caused a large increase in the penetration of light in third-year cocksfoot crops. But this had few beneficial effects on reproduction. In that species, tiller density is relatively low, and in his gapped crops most tillers originated from early autumn growth. The lack of effect might be explained by a lower competition level and a more synchronous elongation of fertile tillers.

In our crops the elongated leaf and tiller type had often already developed under the cover crops. Harvesting the cover crop left these tillers almost unimpaired. In a small-scale experiment in 1984-1985 it was examined whether the elongated crop type is brought about because new tillers must traverse through the elongated leaf sheaths, or because of shading by the cover crop stubble. After an early cut and removal of residue, an artificial stubble of bamboo sticks was inserted. The artificial residue redressed the cutting effect, and compared with the untreated crops the tillers were more elongated and panicle production was lower (Table 6). The effect was stronger if the residue was kept until spring.

The effect of cutting leading to shorter tillers was described by Davies & Simons (1979) for perennial ryegrass in grassland. Davies et al. (1983) obtained long tillers both by artificial base-shading and from tillers surrounded by their natural dead sheaths. They concluded that close defoliations caused grass swards to return to conditions less favourable to elongation of tillers. Wilson & Laidlaw (1985) showed

Table 6. The influence of an early cut and of artificial residue on leaf length (at the onset of stem elongation) and on panicle production (at flowering).

	Not cut	Early cut	Early cut + artificial residue		
			until 1 Dec	until 1 April	until harvest
<i>Leaf length (cm)</i>					
<i>Poa pratensis</i>	12.9	10.3	11.7	15.1*	14.9*
<i>Festuca rubra</i>	23.0*	14.1	15.9	21.3*	24.8*
<i>Panicles m⁻²</i>					
<i>Poa pratensis</i>	1570	1770	1280*	1360	1030*
<i>Festuca rubra</i>	2680*	3570	2910	2650*	2410*

* Significantly different from early cut, Tukey 0.05.

that long leaves developed from long natural, or from artificially extended, sheath tubes and they concluded that the sheath tube has a morphogenic influence on the development of subsequent leaves. These findings and our results with artificial residue suggest that the elongated tiller growth under cover crops and also crop residue can both induce subsequently appearing tillers to elongate. Early cutting and removal of residue can stop this auto-catalytic cycle, resulting in improved light penetration into the crops in the elongation phase and higher survival of reproductive tillers.

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