Maximising Seed Yield of Tetraploid Hybrid Ryegrasses (*Lolium x boucheanum* Kunth.)

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ABSTRACT

Tetraploid hybrid ryegrasses (*Lolium x boucheanum* Kunth.) are bred to combine the persistency and winter hardiness of perennial ryegrass (*Lolium perenne* L.) with the high dry matter yield and quality of Italian ryegrass (*Lolium multiflorum* Lam.). The effect of spring defoliation on the seed yield and seed yield components of three hybrid ryegrass cultivars of comparable heading date but differing perenniality was studied in two separate harvest years. Cv. Augusta (Italian type) had lower seed yields than the other cultivars and produced highest seed yields when cut in mid and late April. The perennial type (cv. AberExcel) showed the greatest response to defoliation, as all cutting treatments significantly reduced seed yield compared to the uncut control. Cv. AberLinnett (intermediate type) showed a response to defoliation between the perennial and Italian type. The effects of cutting date on the seed yield components and consequences for seed and forage production are discussed.

Additional index words: hybrid ryegrasses, *Lolium x boucheanum* Kunth., defoliation, seed production.

INTRODUCTION

Tetraploid hybrid ryegrasses are bred to combine the persistency and winter hardiness of perennial ryegrass (*Lolium perenne* L.) with the high dry matter yield and quality of Italian ryegrass (*Lolium multiflorum* Lam.) (Jones and Humphreys, 1994). The hybridisation of Italian ryegrass with perennial ryegrass enables the production of hybrids with a wide range of mean inflorescence date that in terms of agronomic performance can resemble the Italian ryegrass or perennial ryegrass parent, or be intermediate in type. The objective is to produce cultivars which increase the flexibility of use of ryegrasses providing high quality forage for both conservation and grazing over an extended number of years, providing options for UK grassland agriculture (Jones and Humphreys, 1994). Early hybrid cultivars resembled the Italian ryegrass parent but more recently developed hybrid cultivars contain a higher proportion of the perennial ryegrass genome (Jones and Humphreys, 1993).

Seed yield potential is also an important agronomic trait that can influence the commercial success of a cultivar. The early hybrids to emerge from the plant breeding programme at IGER resembled the Italian ryegrass parent (Jones and Humphreys, 1993). Seed crop management guidelines suggested that they should be treated like an Italian ryegrass (Bean, 1978) so that spring defoliation could safely take place up to the second week of April without a reduction in seed yield. The objective of this defoliation is to remove excessive spring growth so as to avoid lodging before defoliation that can result in poor pollination and seed set. On farms with livestock the forage removed at defoliation is also used to make high quality silage. Perennial ryegrasses do not have the inherent capacity to produce high numbers of reproductive tillers following spring defoliation. Recent research (Hides, Marshall and Jones, 1996) has shown that new hybrid cultivars, which contain a higher proportion of the perennial ryegrass genome, need to be treated like a perennial ryegrass as they can incur higher than acceptable seed yield losses if managed in the manner devised for Italian ryegrass (Hides *et al.*, 1996). However perennial and Italian type hybrids can also differ in heading date from early (up to 11 May), intermediate (12 to 22 May) to late (after 22 May) types which can confound the effect of spring defoliation. This present paper reports the results of a field study to assess the seed yield response to spring defoliation of hybrid ryegrasses of similar heading date but which ranged in type from the Italian to the perennial parent.

MATERIALS AND METHODS

A field trial was carried out at the Institute of Grassland and Environmental Research, on soil of the Denbigh series. Three cultivars of hybrid ryegrass (*Lolium x boucheanum* Kunth.) (Table 1) were sown in August in each of two years (1993 and 1994) in plots measuring $5m^2$, at a seed rate of 15 kg ha^{-1} with 15cm between the rows. The experimental plots were randomized in four replicates and given four defoliation managements in the spring of each of the harvest years (1995 and 1996). In the spring of 1995 and 1996 plots were either not defoliated (C0) or defoliated to a height of 5cm on one of four dates (Table 2).

The experiment, which consisted of 3 cultivars x 4 defoliation treatments x 4 replicates, was analysed in a factorial design. Management inputs consisted of the application of 200 kg ha^{-1} compound fertiliser (36.4 kg N, 17.6 kg P and 33.2 kg K) applied to the seed bed. In the spring (16/2/94; 21/2/95), 200 kg ha^{-1} of nitro-chalk (54 kg ha^{-1} N) was applied to all plots and a further 200 kg ha^{-1} (54 kg ha^{-1} N) applied after each defoliation. Uncut plots were given a second application on the same date as the C1 defoliation. The following characteristics were measured in each plot:

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Table 1. Description of the hybrid ryegrass cultivars sown in the experiment.

Cultivar	Heading date	Description
Augusta	20 May	Italian ryegrass type
AberLinnett	15 May	Intermediate between Italian and perennial ryegrass
AberExcel	20 May	Perennial ryegrass type

Table 2. Date of defoliation treatments in each of the two harvest years.

Treatment	1994	1995
C0	-	-
C1	18 April	15 April
C2	26 April	26 April
C3	3 May	3 May
C4	16 May	16 May

Seed crop development
In the spring of each year, the height of the growing point above ground level was determined at each cutting date by sampling ten tillers per plot and exposing the developing apex using a scalpel.

Seed yield components and seed yield
After anthesis, a 450cm^2 quadrat was placed at random along a drill row in each plot, and all tillers within the quadrat removed about two weeks before harvest and before shedding had commenced. The number of reproductive tillers, spikelets per tiller and seeds per inflorescence were determined as described previously (Hides *et al.*, 1996).

The timing of harvest was determined by monitoring the development of seed maturity of the cultivars using an infra-red moisture meter. All plots were harvested when the seed moisture content had reached approximately 45%. Plots were harvested by hand by harvesting an area of 2.5m^2 within each plot with hand shears and placing the cut material in a linen bag. Harvested material was dried on a cold air floor drier until the moisture content had reached 12-14%, then threshed in a static thresher. Dried seed samples were then cleaned on a Seven L seed cleaner and clean seed weight determined. The moisture content of all seed samples was then determined using the approved ISTA method (ISTA, 1993), and clean seed yields corrected to 10% moisture content.

Weather
Table 3 shows monthly averages for 1994 and 1995 and the overall means for the 25 years (1968-1993) for the Institute of Grassland and Environmental Research, Aberystwyth.

RESULTS

Apical development
The height of the developing growing point of each hybrid at the time of spring defoliation in the two years of the experiment is shown in Table 4. Although there were some

Table 3. Weather data (monthly means) during the experiment in 1994 and 1995 and 25 year average (1968–1993).

	March	April	May	June	July	August	Total
Min. temperature (°C)							
1994	5.5	4.2	7.4	9.9	12.1	11.9	-
1995	2.3	4.6	6.9	9.3	13.9	13.2	-
1968-1993	2.8	4.0	6.8	9.6	11.8	11.6	-
Max. temperature (°C)							
1994	9.9	11.6	14.9	16.5	20.2	18.5	-
1995	8.9	12.4	15.1	18.3	21.9	24.2	-
1968-1993	9.5	11.9	14.9	17.5	18.9	18.9	-
Rainfall (mm per month)							
1994	158.2	79.6	122.4	49.2	65.6	104.6	579.6
1995	66.6	36.6	31.8	39.6	48.0	4.8	227.4
1968-1993	73.9	59.1	62.1	70.7	80.5	89.7	436.0

differences between years the growing points of the three cultivars were all above the cutting height of 5cm in treatments C2, C3 and C4 in 1994 and in treatments C1, C2, C3 and C4 in 1995.

Seed yield

The effect of spring defoliation on seed yield of the hybrids was similar in both harvest years. Consequently seed yields (Fig. 1) are a mean of the two harvest years. There were significant differences among the hybrids as in the absence of defoliation, the perennial and intermediate type hybrids produced a significantly higher seed yield than the Italian type Cv. Augusta (Fig. 1). Generally seed yield declined with later defoliation though the response differed among the three cultivars. Cv. Augusta (Italian type) produced significantly higher seed yields when cut in the middle and end of April (C1 and C2) than the uncut treatment (C0) or when cut in early and mid-May (C3 and C4). The perennial type (cv. AberExcel) showed the greatest response to defoliation, as all cutting treatments significantly reduced seed yields compared to the uncut controls, with seed yield following the mid April (C2) cut comparable to the late April cut of Cv. Augusta and the early May (C3) cut of Cv. AberLinnett. Cv. AberLinnett (intermediate type) showed a response to defoliation somewhere between the perennial and Italian type as defoliation in May (C3 and C4) significantly reduced seed yield compared to the control.

Number of fertile tillers

The number of fertile tillers was significantly influenced by defoliation in both harvest years (Table 5). Defoliation initially tended to increase fertile tiller number, but defoliation treatments in early and mid-May (C3 and C4) decreased the number of fertile tillers. There were no significant cultivar differences in 1994 or 1995 or cultivar x defoliation interactions in 1994. In 1995, all cultivars had similar numbers of fertile tillers at C0 and C1 followed by a significant increase at C2. The number of fertile tillers of cv. Augusta decreased at C3 but remained relatively stable at C4, whilst those of cvs. AberLinnett and AberExcel decreased at C3 and showed a further significant decrease at the last cut (C4).

Spikelets per tiller

Generally, defoliation reduced the number of spikelets per tiller in both harvest years (Table 6). In 1994 there was a significant decline in spikelet number between treatments C1 and C3 and in 1995 a significant decline between treatments C0 and C1. There was no significant cultivar x defoliation interaction in either year.

Table 4. Height of the growing point (cm) (mean of ten tillers per plot) of three hybrid ryegrasses at four cutting dates in each of two harvest years (1994 and 1995).

Year	Treatment	Augusta	AberLinnett	AberExcel
1994	C1	2.7	3.6	2.7
	C2	7.9	6.9	8.3
	C3	30.0	15.6	18.2
	C4	42.5	26.3	37.2
1995	C1	13.7	14.2	12.8
	C2	19.3	12.4	16.7
	C3	23.7	24.8	29.4
	C4	71.0	50.8	61.9

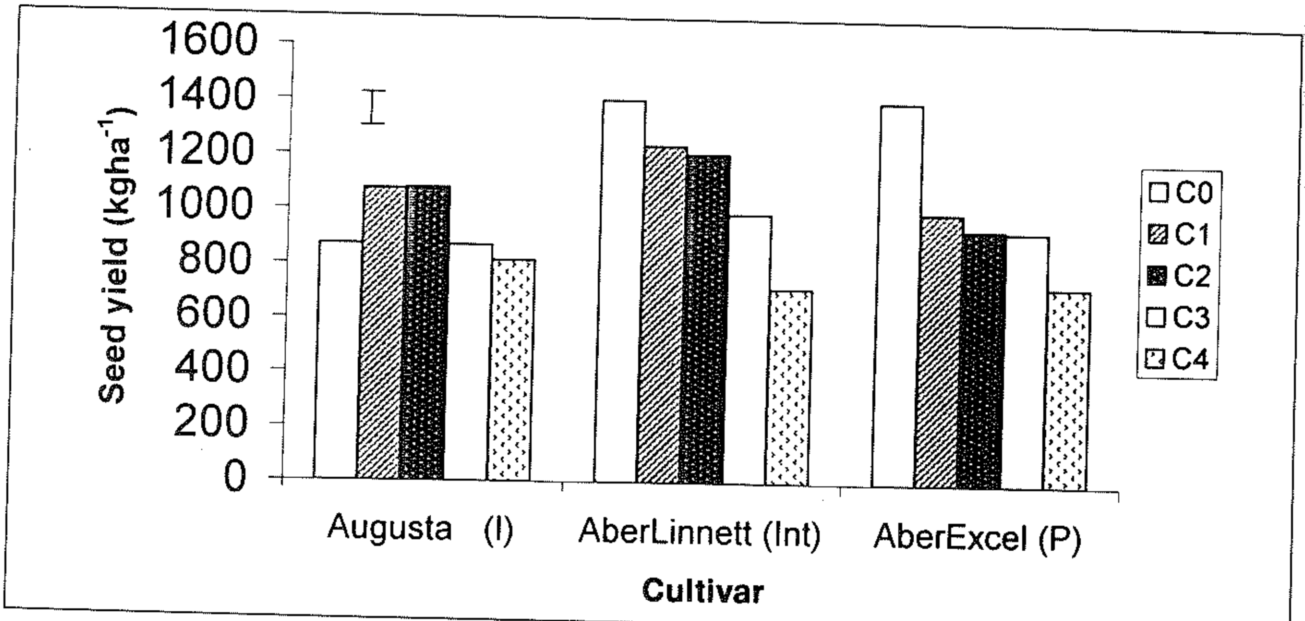

Figure 1. Effect of defoliation on seed yield of three hybrid ryegrass cultivars (data are a mean of two harvest years; 1994 and 1995). Vertical bar represents l.s.d. at p=0.05) C0=control; C1=18/4/94,15/4/95; C2=26/4/94,26/4/95; C3=3/5/94,3/5/95; C4=16/5/94,16/5/95.

Table 5. Effect of time of spring defoliation on the mean number of fertile tillers m^{-2} *of three hybrid ryegrass cultivars in 1994 and 1995.*

	1994				1995			
Treatment	**Augusta**	**AberLinnett**	**AberExcel**	**Mean**	**Augusta**	**AberLinnett**	**AberExcel**	**Mean**
C0	2693	2819	2258	2590	2169	2293	2042	2168
C1	2782	2990	2768	2847	2213	2242	1925	2127
C2	2791	2673	2857	2774	2486	2567	2746	2600
C3	2648	2220	2309	2392	2489	2249	2480	2406
C4	2242	1820	1814	1959	2198	1969	1931	2033
Mean	**2631**	**2504**	**1950**		**2311**	**2264**	**2225**	

s.e. means and significance level	1994	1995
cultivars	169.2 NS	145.9 NS
defoliation	168.2***	118.1***
cultivars x defoliation	310.8 NS	233.9**

P<0.05, **P<0.01, ***P<0.0001, NS Not significant

Table 6. Effect of time of spring defoliation on the mean number of spikelets per inflorescence of three hybrid ryegrass cultivars in 1994 and 1995.

Treatment	1994 Augusta	1994 AberLinnett	1994 AberExcel	1994 Mean	1995 Augusta	1995 AberLinnett	1995 AberExcel	1995 Mean
C0	23.4	23.5	21.8	22.9	27.7	28.9	24.3	26.9
C1	23.2	22.3	21.9	22.5	20.2	20.6	19.8	20.2
C2	20.6	22.4	19.4	20.8	21.2	18.4	18.0	19.2
C3	19.6	20.1	18.7	19.5	17.4	18.2	16.4	17.4
C4	13.9	17.1	16.9	16.0	17.2	18.6	17.9	17.9
Mean	**20.2**	**21.1**	**19.7**		**20.7**	**20.9**	**19.3**	

s.e. means and significance level

	1994	1995
cultivars	1.01 NS	0.36 NS
defoliation	1.12***	0.70***
cultivars x defoliation	2.00 NS	1.14 NS

P<0.05. **P<0.01. ***P<0.0001. NS Not significant

Table 7. Effect of time of spring defoliation on the mean number of seeds per inflorescence of three hybrid ryegrass cultivars in 1994 and 1995.

Treatment	1994 Augusta	1994 AberLinnett	1994 AberExcel	1994 Mean	1995 Augusta	1995 AberLinnett	1995 AberExcel	1995 Mean
C0	51.4	67.6	72.8	63.9	96.9	87.5	88.0	90.8
C1	42.1	48.1	69.5	53.2	56.8	58.7	60.4	58.6
C2	58.5	75.5	67.1	67.0	55.5	54.9	67.9	59.4
C3	49.5	65.8	68.3	61.2	56.3	45.4	30.9	44.2
C4	46.8	59.8	64.4	57.0	52.3	64.1	63.7	60.0
Mean	**49.7**	**63.4**	**68.5**		**63.6**	**62.1**	**62.2**	

s.e. means and significance level

	1994	1995
cultivars	4.46**	5.67 NS
defoliation	6.47 NS	4.59***
cultivars x defoliation	10.97 NS	9.09 NS

P<0.05. **P<0.01. ***P<0.0001. NS Not significant

Seeds per inflorescence

The effect of defoliation on the number of seeds per inflorescence differed between years (Table 7). In 1994 cvs. AberLinnett and AberExcel had significantly more seeds per inflorescence than Cv. Augusta but there was no significant effect of defoliation or a cultivar x defoliation interaction. In 1995 there were no cultivar differences but defoliation significantly reduced the number of seeds per inflorescence from 90.8 at C0 to 60.0 at C4.

DISCUSSION

Relatively little work has been carried out on the reproductive growth of hybrid ryegrasses. Management guidelines for the production of seed of hybrid ryegrasses have been based on cultivars developed in the 1960s and '70s such as Sabrina, Sabel and Augusta (Williams, 1973; Roberts, 1977; Bean, 1978). These tended to resemble the Italian ryegrass parent and research suggested that they should be treated like Italian ryegrass when being grown for seed. This enabled seed producers with livestock to cut seed crops up to the first week of May with no detrimental effect on seed yield, allowing the production of high quality forage with reasonable seed yields. Preliminary research by Hides *et al.* (1996) has shown that newer hybrid ryegrass cultivars, which have more of the perennial ryegrass genome, may require somewhat different managements to maximise seed yield, and that a careful balance between the need for forage and the effect on seed yield was necessary. However, that study used cultivars of different heading date and so the response of the cultivars to spring defoliation was confounded by this difference. In the present experiment, the three cultivars examined had similar intermediate heading dates, but ranged from the perennial to the Italian type (Jones, pers. comm.) and consequently any difference in response to defoliation can be directly related to their morphological type.

The three cultivars differed in their seed production potential. Cvs. AberExcel and AberLinnett produced significantly higher seed yields than cv. Augusta in the uncut treatment. There were few differences in the number of fertile tillers or spikelets per tiller among cultivars but Augusta had fewer seeds per inflorescence than the other cultivars in one of the two years. Italian ryegrasses (*Lolium multiflorum*) normally have higher seed yields than perennial ryegrasses (*L. perenne*) and therefore it was surprising that seed yields of cv. Augusta, the Italian type hybrid were low compared to the perennial and intermediate type hybrids, despite having relatively high numbers of reproductive tillers. The low number of seeds per inflorescence in 1994 may be one contributing factor. It may also reflect the fact that selection of plants with high seed yield was an important part of the breeding of cvs. AberExcel and AberLinnett but was not part of the breeding programme of cv. Augusta (Jones, pers. comm.).

The cultivars also differed significantly in response to defoliation. Cv. Augusta (Italian type) maintained a similar seed yield even after relatively late spring defoliation (16 May), whilst any defoliation significantly reduced seed yields of cv. AberExcel, the perennial type hybrid, even when defoliated in the third week of April. Cv. AberLinnett, the intermediate type hybrid, showed a response somewhat between the other cultivars with reasonably high seed yields maintained until the beginning of May, whereupon defoliation significantly reduced seed yield. These results were obtained on cultivars that were comparable in terms of heading date and apical development when they were defoliated. As perennial ryegrass does not have the inherent capacity to produce high numbers of reproductive tillers after late spring defoliation (Bean, 1978), the low seed yields of perennial type hybrids after spring defoliation has been attributed to the perennial ryegrass genome (Hides *et al.*, 1996). This was to some extent confirmed by this present study as tiller numbers of both Cvs. AberExcel and AberLinnett were reduced by the late (16 May) defoliation and for this treatment were lower than that of cv. Augusta.

Generally, the other measured components of seed yield tended to show similar responses to defoliation in all three cultivars with no significant cultivar x defoliation interactions. Late defoliation reduced the number of spikelets per inflorescence of all cultivars in both years. In 1995 the number of seeds per inflorescence of all cultivars tended to be reduced by later defoliation, and there was a general trend that this was greater in cvs. AberLinnett and AberExcel than in cv. Augusta. However there was no evidence of this trend in 1994. This may reflect the difference in the climatic conditions between the two harvest years. In 1994 there was higher than average rainfall with May having almost twice the average rainfall after defoliation. In contrast, 1995 was a very dry year with May having half the average rainfall. These differences in rainfall between harvest years are likely to have had a significant effect on the regrowth of the hybrids after defoliation, particularly in 1995, where low rainfall after defoliation may have had a detrimental effect on regrowth and consequently on seed yield.

These results confirm there is a considerable danger of a reduction in seed yield potential if all hybrids are treated the same and that the spring managements suitable for Italian type hybrids appear unsuitable to maximise seed yields of perennial type hybrids. However the effect of defoliation date on seed yield was less dramatic than in previous research. Hides *et al.* (1996) reported harvested seed yields of only 40% and 24% of the uncut control for intermediate type hybrids and 42% and 20% for perennial types when cut on the 7th and 20th May. These cultivars were both early types, with a heading date of the 11th May, some 7 days earlier than cv. Augusta and 9 days earlier than cv. AberExcel, the two cultivars used in this present study. This suggests that later defoliation may have a greater detrimental effect on the seed yield of the early heading intermediate and perennial types than the intermediate heading types used in this present study. Farmers therefore need to be careful in the choice of hybrid ryegrasses where the production of silage is an integral component of the seed production system. As future breeding of hybrid ryegrasses seeks to produce hybrids with more of the characteristics of perennial ryegrass (Jones and Davies, 1995), careful consideration needs to be given to the appropriate seed crop management system suitable for the type of hybrid and its heading date.

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