

Delay of harvest effects on forage yield and regrowth in spring and winter cereal mixtures

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Baron, V. S., de St Remy, E. A., Salmon, D. F. and Dick, A. C. 1995. Delay of harvest effects on forage yield and regrowth in spring and winter cereal mixtures. Can. J. Plant Sci. 75: 667-674. Spring-planted mixtures of spring and winter cereals extend the grazing season and maximize dry matter yield if the initial defoliation is delayed until the milk stage of kernel development of the spring cereal component. However, fall regrowth may be less than spring-planted winter cereal monocrops. Research was conducted at Lacombe, Alberta to determine the effect of time of initial cut and winter cereal species on initial yield, regrowth yield and factors affecting regrowth (tiller density, water-soluble carbohydrate (WSC) and etiolated regrowth immediately post-cutting) of the winter cereal component of spring-seeded monocrops of fall rye (*Secale cereale* L.), winter triticale (\times *Triticosecale* Wittmack) and winter wheat (*Triticum aestivum* L.) and in binary mixtures with spring barley (*Hordeum vulgare* L.). Treatments were planted in early May and harvested initially when the barley reached the boot (B), heads emerged (H), H + 2 wk, H + 4 wk and H + 6 wk stages. Three weeks after the initial cut a regrowth harvest was conducted. Initial yields of both mixtures and monocrops increased until approximately H + 4 wk and H + 6 wk respectively, with no differences due to species in the mixture. The effect of crop stage at initial harvest on regrowth was much larger than the species effect. Monocrop regrowth decreased almost linearly with delay of defoliation, while that of the mixture (winter and spring components combined) declined at a faster rate. Tiller density, WSC and etiolated regrowth also followed decreasing trends with time of initial cut in the monocrops and mixtures. These trends were due directly or indirectly to very low light intensities in the lower levels of the canopies of both cropping systems after H + 2 wk. Both initial and regrowth yields of the winter cereal component of mixtures involving rye and triticale were generally superior to those involving wheat. The ability of the winter cereal component to regrow in mixtures may be related to plant size and therefore ability to compete during initial growth. In general, the initial harvest of the mixture should occur no later than H + 2 wk of the spring cereal component in order to allow sufficient time for recovery of the winter cereal component after harvest. Otherwise, a spring-seeded winter cereal would be a better alternative for fall pasture.

Key words: Delayed harvest, spring and winter cereals, forage yield, regrowth

Baron, V. S., de St Remy, E. A., Salmon, D. F. et Dick, A. C. 1995. Effets du retard à récolter sur le rendement fourrager et sur la repousse des associations de céréales de printemps et d'hiver. Can. J. Plant Sci. 75: 667-674. Les associations, en semis de printemps, de céréales de printemps et de céréales d'hiver permettent d'allonger la saison de pâturage et de maximiser le rendement de matière sèche, pour autant que la première coupe ne se fasse pas avant le stade grain laiteux de la céréale de printemps. Par ailleurs, la repousse en automne risque d'être moindre que celle de la céréale d'hiver semée seule au printemps. L'objet de nos recherches, réalisées à Lacombe (Alberta), était de déterminer l'effet du stade de croissance à la première coupe et de l'espèce de céréale d'hiver utilisée, sur le rendement de premier cycle et à la repousse, ainsi que sur les facteurs gouvernant la repousse (densité des talles, teneurs en glucides hydrosolubles et croissance étiolée) du seigle d'automne (*Secale cereale* L.), du triticale d'hiver (\times *Triticosecale* Wittmack) et du blé d'hiver (*Triticum aestivum* L.), combiné en associations binaires avec l'orge de printemps (*Hordeum vulgare* L.). Les essais étaient installés au début de mai et récoltés pour la première fois lorsque l'orge atteignait les stades du gonflement (G), de l'épiaison (E) et de E + 2, plus 4 et + 6 semaines. Une seconde coupe était prélevée trois semaines après la première. Les rendements initiaux des associations et des semis purs augmentaient jusqu'à, respectivement, les stades E + 4 et E + 6 semaines, indépendamment des espèces composant l'association. L'effet du stade de croissance à la première coupe sur le regain était beaucoup plus important que celui de l'espèce. La repousse des céréales en semis purs diminuait presque linéairement à mesure qu'on retardait le premier prélèvement, tandis que celle de l'association diminuait plus rapidement encore. La densité de talles, les concentrations de glucides hydrosolubles et la repousse étiolée (à l'obscurité) suivait également une courbe décroissante selon le temps de la première coupe, tant en semis purs qu'en mélanges. Ces tendances étaient attribuables, directement ou indirectement, aux très faibles intensités lumineuses observées dans le bas du couvert végétal dans les deux systèmes de culture après le stade E + 2 semaines. Le rendement de première coupe et à la repousse du seigle et du triticale d'hiver dans les associations était généralement supérieur à celui du blé. La meilleure repousse de la céréale d'hiver dans les associations serait reliée à la taille des plantes et, partant, à leur aptitude à la concurrence durant le premier cycle de croissance. On peut dire en général que la première coupe des associations ne devrait pas avoir lieu plus tard que le stade E + 2 semaines chez la céréale de printemps, afin d'accorder suffisamment de temps à la céréale d'hiver pour produire une bonne repousse. Sinon, on serait mieux d'utiliser une céréale d'hiver en semis de printemps pour le pâturage d'automne.

Mots clés: Retard de la récolte, céréales de printemps et d'automne, rendement fourrager, repousse

Abbreviations: B, boot stage; H, heads emerged stage; LAI, leaf area index; PAR, photosynthetically active radiation; PPFD, photosynthetic photon flux density; WSC, water-soluble carbohydrates

In the Parkland of the Canadian prairies, cultivated crop production occurs from early May to early September. The frost-free period is short, about 93 d (Campbell et al. 1990), consequently the duration of crop growth is also short. Including winter cereals in a crop rotation or sequence extends productivity beyond the frost-free period. The potential of winter cereals for pasture provides incentive to adopt new cropping techniques which enhance sustainability through more efficient land use.

Previous research has shown that it is feasible to extend the grazing season until mid-October using spring-planted winter cereals or mixtures of spring and winter cereals (Baron et al. 1993a). Seasonal dry matter production can be maximized for the spring-planted mixtures when initial harvest is delayed until the late milk to early dough stage of kernel development of the spring cereal component. The winter cereal regrows providing fall pasture (Baron et al. 1990, 1994). At the dough stage, the silage/pasture system provides a high-yielding feedstuff which is higher in forage quality than the spring cereal grown alone (Baron et al. 1992b). However, at the silage stage the mixture yielded 80–113% of the spring cereal monocrop (Baron et al. 1992b), while regrowth yields varied from 50 to 75% of the winter cereal grown alone, depending on early vs. late planting date, respectively (Baron et al. 1994). Thus the yield of mixtures may be less than either a spring cereal or winter cereal monocrop at a given harvest, depending on cropping methods and climatic conditions, but the total seasonal dry matter is greater than either monocrop (Baron et al. 1990). By maximizing silage yield, the quantity of fall pasture supplied by the mixture may be too low to supply intended requirements. Where fall pasture is the primary objective (not silage, then pasture) a winter cereal monocrop may be a better option.

Intercrop competition has little effect on the spring cereal in the silage/pasture system (Baron et al. 1994). Therefore the success of the cropping system depends on regrowth of the winter cereal. Baron et al. (1993a) found that the winter cereal in a mixture did not recover to levels similar to the winter cereal monocrop until 3 mo after initial cutting occurred at the boot stage in mid-June. The advantage of the mixture in that case was earlier grazing. Regrowth or establishment of a slower-growing mixture component is enhanced by defoliation, but if suppressed for long periods of time it will lose the ability to compete (Donald 1963). Davies (1988) summarized factors influencing regrowth in perennial grasses which included an interaction of carbon reserves in the stubble, residual leaf area and tiller development during early stages; and tiller density, extent of tissue loss, leaf area expansion and dry matter partitioning at later stages. Past research has indicated that fall rye (*Secale cereale* L.) and triticale (\times *Triticosecale* Wittmack) provided more stable and slightly higher regrowth yields than winter wheat (*Triticum aestivum* L.) when grown in mixture with spring cereals, especially in a silage/pasture system (Baron et al. 1994). The reasons for these differences are unclear.

Regrowth potential of the winter cereal component of the spring/winter cereal mixture is complicated by the predefoliation environment. The effects of competition in mixtures

and the resulting condition of the winter cereal prior to defoliation must be considered in managing for regrowth and fall pasture. The objective of this study was to compare the initial and regrowth yields of three spring-planted winter cereal species grown in binary mixtures with spring barley (*Hordeum vulgare* L.) and as monocrops when defoliated at successive stages of spring barley development.

MATERIALS AND METHODS

Norstar winter wheat, Wintri winter triticale and Muskeeter fall rye were planted alone and in binary mixtures with Leduc barley on Ponoka clay loam soil at Lacombe, Alberta. The plots were established on barley stubble on 9, 10 and 4 May during 1990, 1991 and 1992, respectively. Treatments were arranged in a randomized complete block design within harvest times using four replicates. The plots were seeded with a six-row plot seeder with a 25-cm row width (1.5 m). Seeding was done in two passes such that each plot consisted of twelve 12.5-cm rows. All treatments were planted at a total seeding rate of 300 seeds m^{-2} with mixture components in a 1:1 ratio. Prior to planting each year a blanket application of 14 (N), 56 (P_2O_5) and 54 (K_2O) kg ha^{-1} was broadcast and soil incorporated. An additional 75 kg N ha^{-1} was broadcast in three equal split applications between planting and early July.

Prior to planting of the plots, 4-L plastic pails with perforations in the bottoms for drainage were filled with soil from an area adjacent to the plots and fertilized identically to the plot area. Approximately five seeds of the respective winter cereal species were planted into the pails on the same day as the plots were seeded. After seedlings emerged, they were thinned to two plants per pail. The pails were dug into the plots 1.3 m from the front after the seedlings in the plots emerged, to avoid destruction of the existing plants.

Time of harvest was randomized within replicates. Five initial harvests or cuts were carried out at the B, H, H + 2, H + 4, and H + 6 wk of the barley component in the mixture. Regrowth harvests occurred 3 wk after the initial cuts occurred.

Measurements of light (PAR) intensity were made above the canopy, above the winter cereal (about mid-canopy) and at the bottom of the canopy the day prior to each cut. The measurements were made with a 1.0-m line quantum sensor (LI-189 Li-Cor Ltd. Lincoln, NE) at one location in the mid-portion of each plot, perpendicular to the plot rows, between 11:00 and 13:00 h Mountain Standard Time. The measurements above the winter cereal canopy in the mixtures and at the bottom of the canopy were represented as a percent of incoming PAR (above the canopy) intercepted.

Prior to initial harvest two random areas of each plot totalling 0.075 m^{-2} , were removed at 5 cm above ground level. Barley and winter cereal tillers were separated and dried at 60°C for 3 d and weighed to determine percent composition of the mixture stands. Plot yields were assessed by cutting an area 1.0 \times 3.9 m with a flail mower to a height of 5 cm. A 0.25-kg subsample was dried at 60°C for 3 d. Yields of total dry matter and species component dry matter were determined. The pails were removed and tillers were counted in each pail. Other data collected from these plants will be reported in a subsequent publication.

During 1990 and 1991, prior to each initial cut, winter cereal plants were removed from the front 1.3 m of the plot area. Crowns, including 2.5 cm of stubble (crowns) were washed, weighed fresh after brief air drying, frozen in liquid nitrogen, then dried at 80°C until constant weight. The dry weight of crowns was used to calculate percent dry matter of crowns used in measurement of etiolated regrowth. The dried material was then ground and used to determine percent WSC in the crowns according to Thomas (1977) using the phenol-sulphuric method for colorimetric assessment of reducing sugars. Ten crowns of each treatment were washed, weighed and placed in styrofoam root trainers (vent block 45, Beaver Plastics, Edmonton, AB), that had been previously filled with moistened vermiculite. After filling the root trainers, they were placed into insulated plywood boxes to exclude light and maintain a constant temperature (18°C). Regrowth was removed from the crowns every second day until no more appeared. This lasted no longer than 10 d. Accumulated regrowth was dried at 80°C in a forced air drier to a constant weight and weighed. The dried etiolated regrowth was expressed as a percent of crown dry weight.

Field plots were set up in a split-plot design with years and cuts as the main plots and cropping systems (monocrop vs. mixture) and species as subplots using four replicates. Data were first analyzed within cuts (stages), then tested for homogeneity of error (Gomez and Gomez 1984). Almost all variables showed evidence of error heterogeneity with respect to harvests. These variables were transformed to log base 10 ($x + 1$) prior to running ANOVA with cuts included. The means shown in the tables are detransformed.

RESULTS AND DISCUSSION

Generally, near average temperatures prevailed during May, June and July and above average temperatures during August (Table 1). Precipitation was above average during May and June of 1990 and 1991, but was close to average in 1992. Above-average rainfall during the early season of 1991 resulted in very heavy stands of barley in the mixtures.

Light Interception

No difference was detected among species for amount of incoming PAR intercepted at the surface of the winter cereal canopy. Averaged over the 3 yr 61.9, 80.0, 85.0, 80.6, and 68.0% of PAR was intercepted by the barley component at the B, H, H + 2, H + 4 and H + 6 wk stages, respectively. On average the PPFD at the surface of the winter cereal

canopy in the mixtures was 494, 291, 195, 187 and 448 $\mu\text{E m}^{-2} \text{s}^{-1}$ at the respective stages. At the bottom of the canopy, the mixtures intercepted more light than the monocrop until H; by H + 2 wk all treatments were similar ($P > 0.05$) and over 95% of incoming PAR was intercepted by all treatments. Average PPFD at the canopy base for the monocrops and mixtures at B was 600 and 140 $\mu\text{E m}^{-2} \text{s}^{-1}$, respectively and never exceeded 100 $\mu\text{E m}^{-2} \text{s}^{-1}$ thereafter, for either cropping system.

According to Austin (1989), the light compensation point for wheat is approximately 150 $\mu\text{E m}^{-2} \text{s}^{-1}$. Therefore much of the winter cereal foliage in the mixtures existed below the light compensation point after the barley headed.

Initial Yield

Combined yields of mixtures were always higher than monocrops (Table 2). Differences among species were evident in the monocrops, but not in the mixtures within harvests. In the monocrops, rye and triticale had higher yields than wheat at the boot stage with the difference diminishing by H + 2 wk. The higher yield of the rye monocrop compared with the other species at H + 4 wk and H + 6 wk was due to the development of floral tillers. Yield generally continued to increase until H + 6 wk in the monocrops, but it maximized at about H + 4 wk in the mixtures. The time of maximum yield for the mixtures was in general agreement with Baron et al. (1992a) for pure stands of barley harvested as whole-plant silage — an indication that barley development was unaffected by the mixture. The mixtures could have been grazed earlier than the winter cereal monocrops which would be advantageous from a grazing perspective (Baron et al. 1993a). The rye monocrop produced sufficient forage for grazing earlier than the triticale which was in turn earlier than the wheat.

Performance of the winter cereal component of the mixtures varied from year to year between cuts, contributing to a species \times cropping system \times stage \times year interaction. However, the winter cereal species generally differed by degree from year to year within cut, so means were averaged over years (Table 3). The variability of the winter cereal component was increased due to the dominance of the spring component. In the mixtures, yields of the rye and triticale components were greater than wheat for all initial cuts (Table 3). Because the winter cereal component was planted at half the rate of the monocrop, dry matter yields of the component should have equalled 50% of the monocrop in

Table 1. Monthly mean temperatures and monthly precipitation during the experimental period at Lacombe, Alberta

Month	Mean daily temperature				Monthly precipitation			
	1990	1991	1992	83-yr Mean	1990	1991	1992	83-yr Mean
	(°C)				(mm)			
April	3.7	6.0	6.0	3.7	46.2	32.9	27.2	27.7
May	9.6	9.8	8.7	9.8	85.1	86.3	62.0	49.7
June	13.8	13.1	14.5	13.8	151.4	122.7	51.9	81.5
July	15.5	15.9	14.2	16.1	82.9	114.2	73.7	77.2
August	16.0	17.2	13.6	14.8	41.5	86.3	18.4	63.8
September	12.5	11.0	8.6	10.0	1.4	25.5	59.2	41.8
October	3.4	0.2	4.2	4.6	21.8	41.8	17.5	19.2

the absence of competition. At B the component yield ranged from 106% for wheat to 60% for rye relative to the corresponding monocrops. The lower percentage for the rye reflected a high monocrop yield for rye, not a low mixture component yield. From H to H + 6 wk of the mixtures, the rye component yield ranged from 35 to 22%, triticale ranged from 36 to 31% and wheat ranged from 23 to 15% of their respective monocrops. Therefore all winter species, but especially wheat, suffered from competition in the mixtures after B. The barley became much more dominant after B. Plant height of each component was not measured in this study, but barley was taller than the winter cereal, especially after B. Species with leaves at the top of the canopy have a competitive advantage, because they have direct access to sunlight (Trenbath 1974) and light attenuation in the canopy is logarithmically related to LAI from the top of the canopy (Donald 1963).

Regrowth in perennial grasses results from the development of new tillers from buds on existing tillers. When tiller

density is sparse, yield is closely related to tiller density, but when tiller density is constant, yield is more closely related to tiller weight (Zarrouh et al. 1983). Tiller number of winter cereal plants grown in pails inside the respective crop canopies peaked for the monocrops at H and for the mixtures at B (Table 4). Except for monocrop triticale a significant decline in tiller number occurred for all treatments with delayed initial harvest. After B tiller number for all mixtures was lower than all monocrops. At B rye, triticale and wheat in the mixture had 95, 88 and 68% of the tillers of their respective monocrop counterparts; by H + 2 wk they had thinned to 53, 47 and 42% of their respective counterparts. Baron et al. (1994), reported binary mixtures containing oat at the early milk stage, with fall rye, triticale and wheat having tiller densities of 39, 42 and 52% of their respective winter cereal monocrops. In that study the tiller densities were determined from the plot, where seeding ratios were 1:1 (spring:winter cereals) and the seeding rate of each component was 50% of its respective monocrop. Tiller densities

Table 2. Initial dry matter yields (barley and winter cereal) of three winter cereal species grown as monocrops and mixtures with Leduc barley cut at five stages of barley development, averaged over 3 yr (1990–1992)

Winter cereal	Stage ²				
	B	H	H+2	H+4	H+6
	<i>Monocrop</i>				
	(t ha ⁻¹)				
Rye ³	1.26bD	2.95bC	4.36bB	5.89bA	6.61bA
Triticale	0.81cD	2.51bcC	3.63bB	4.36bB	4.56cA
Wheat	0.27dD	2.09cC	3.71bB	4.26cB	5.01cA
	<i>Mixture</i>				
	(t ha ⁻¹)				
Rye	2.34aC	5.75aB	8.51aA	9.77aA	9.77aA
Triticale	2.19aD	5.49aC	7.94aB	10.00aA	10.23aA
Wheat	2.04aD	5.75aC	8.51aB	10.23aA	10.00aAB

²B, H, H+2, H+4 and H+6 are boot, heads emerged, heading plus two, four and six weeks for Leduc barley, respectively.

³Musketeer fall rye; Wintri winter triticale; Norstar winter wheat.

a–c Means followed by the same letter within stage are similar ($P \leq 0.05$).

A–D Means followed by the same letter within rows are similar ($P \leq 0.05$).

Table 3. Three-year average initial dry matter yield of the winter cereal component of three winter cereal species grown as monocrops and in mixtures with Leduc barley and cut at five stages of barley development

Winter cereal	Stage ²				
	B	H	H+2	H+4	H+6
	<i>Monocrop</i>				
	(t ha ⁻¹)				
Rye ³	1.26aD	2.95aC	4.36aB	5.89aA	6.61aA
Triticale	0.81bC	2.51bC	3.63bB	4.36bAB	4.57cA
Wheat	0.27dE	2.09cD	3.71bC	4.26bB	5.01bA
	<i>Mixture</i>				
	(t ha ⁻¹)				
Rye	0.76cC	1.05dBC	1.15cB	1.44cA	1.51cA
Triticale	0.56cD	0.91dC	1.15cB	1.32cBA	1.41cA
Wheat	0.29dC	0.49eB	0.76dA	0.98dA	0.78dAB

²B, H, H+2, H+4 and H+6 are boot, heads emerged, heading plus 2, 4 and 6 wk for Leduc barley, respectively.

³Musketeer fall rye; Wintri winter triticale; Norstar winter wheat.

a–d Means followed by the same letter within cut are similar ($P \leq 0.05$).

A–E Means followed by the same letter within rows are similar ($P \leq 0.05$).

in this experiment were derived from the same number of plants (two) in each cropping system. Despite this, the relative numbers of tillers (monocrop vs. mixture) was generally the same in both studies.

For a given amount of shade, grass communities converge towards a common tiller weight:tiller density ratio independent of initial sowing density, but dependent upon sward structure (Kays and Harper 1974). Tiller density at the onset of regrowth in this study was a function of the sward structure in the mixture and the resultant light quality and quantity relationships (Davies 1988). The general decline in tiller density of the monocrops and mixture components with delayed harvest was likely due to self-thinning (Kays and Harper 1974). Hart et al. (1971) observed reduced tiller density as harvest was delayed in tall fescue and orchardgrass.

Regrowth

Regrowth yields (Table 5) are only for the 3 wk immediately after cutting. Although the duration of regrowth was arbitrary, it appeared to be the rest period required between clippings and grazings for a winter cereal monocrop at its peak in midsummer. If the winter cereal component in the mixture is to produce a significant pasture yield by fall, it must make a substantial recovery over this period. There was

a general decline in combined regrowth yield as the initial harvest was delayed in both monocrops and mixtures (Fig. 1) for all winter cereal species. Barley accounted for 36, 42, and 21% of the mixture regrowth yield for the 3 wk following the boot stage, H and H + 2 wk, but was negligible after the remaining stages. Fewer barley tillers capable of regrowth remained following the later harvests. After floral apices are removed the tillers die and must be replaced by vegetative ones (Jewiss 1966). Regrowth yield of the mixtures decreased from 51 to 3% of the monocrops from the boot stage to H + 4 wk; in effect the mixtures regrowth declined faster with delay of cut than the monocrops. The most rapid decline in the short-term regrowth rates of the mixtures occurred when harvest was delayed up to 4 wk after the B stage (Fig. 1).

Regrowth of the winter cereals in monocrops and mixtures was affected by the species × cropping system × stage × year interaction. Generally, however, trends shown by the means averaged over years were similar to those within years. There was a general decline in regrowth yield of the winter cereal component when initial cutting was delayed past heading in both the mixtures and monocrops (Table 5). In the monocrops triticale had higher, but not necessarily significantly ($P > 0.05$) higher, regrowth yields than the

Table 4. Tiller number of winter cereal plants grown in pails inside monocrops and mixture canopies, sampled at five stages averaged over 3 yr

Winter cereal	Stage ²				
	B	H	H+2	H+4	H+6
	<i>Monocrop</i>				
Rye ³	41.7aAB	55.2aA	33.7aBC	27.7abC	32.9aBC
Triticale	29.9aA	41.7aA	32.9aA	27.2aA	29.2aA
Wheat	37.9aAB	59.3aA	41.7aAB	12.4abcC	31.4aC
	<i>Mixture</i>				
Rye	397aa	33.7bcA	18.1bB	13.1cdB	19.9bcB
Triticale	26.5aA	23.6cA	15.6bAB	10.5dB	12.8cdB
Wheat	25.9aA	22.4cAB	17.6bAB	15.6bcdB	11.9dC

²B, H, H+2, H+4 and H+6 are boot, heads emerged, heading plus 2, 4 and 6 wk for Leduc barley, respectively.

³Musketeer fall rye; Wintri winter triticale; Norstar winter wheat.

a-d Means followed by the same letter within cut are similar ($P \leq 0.05$).

A-C Means followed by the same letter within rows are similar ($P \leq 0.05$).

Table 5. Three-week regrowth yield of the winter cereal component grown in the monocrops and mixtures after harvest at five stages of spring barley development averaged during 3 yr

Winter cereal	Stage ²				
	B	H	H+2	H+4	H+6
	<i>Monocrop</i>				
	(t ha ⁻¹)				
Rye ³	2.04aA	1.66aA	1.02aB	0.56aC	0.14bD
Triticale	1.90aA	1.74aA	1.25aA	0.83aB	0.32aC
Wheat	2.34aA	1.51aAB	0.95aB	0.69aC	0.26aD
	<i>Mixture</i>				
	(t ha ⁻¹)				
Rye	0.87bA	0.55bA	0.23bcB	0.02cBC	0.01dC
Triticale	0.71bA	0.54bA	0.26bB	0.03bB	0.02cB
Wheat	0.64bA	0.33cB	0.16cC	0.04bB	0.01dC

²B, H, H+2, H+4 and H+6 are boot, heads emerged, heading plus 2, 4 and 6 wk for Leduc barley, respectively.

³Musketeer fall rye; Wintri winter triticale; Norstar winter wheat.

a-d Means followed by the same letter within cut are similar ($P \leq 0.05$).

A-D Means followed by the same letter within rows are similar ($P \leq 0.05$).

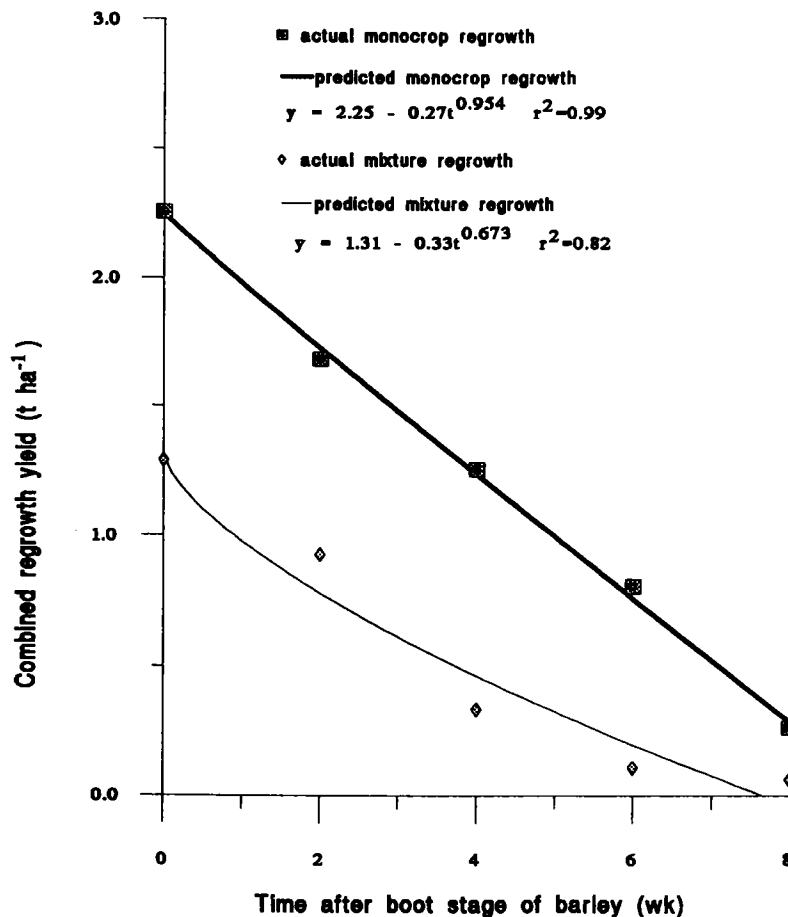


Fig. 1. Regrowth yield (3 wk) of monocrop and mixture treatments averaged over species and years after cutting initially at the B, H, H + 2 wk, H + 4 wk and H + 6 wk. Includes barley and winter cereal dry matter in the mixture.

other two species after H. In the mixtures, regrowth yield of rye and triticale were superior to wheat following H and H + 2 wk. After that time regrowth during the three week period was small for the mixtures. Regrowth yields of the winter cereal component of the mixtures were always less than 50% of the monocrop and diminished to less than 10% when the initial cut was delayed beyond H + 2 wk. Following cuts at B and H + 2 wk, regrowth yields of rye and triticale in mixtures ranged from 43 to 21% of the respective monocrops, while that of wheat ranged from 27 to 16% of its monocrop. During a 6-wk regrowth period beginning at the early-milk and heading stages of an oat-winter cereal mixture the winter cereal component averaged 46% (0.9 t ha⁻¹) and 56% (1.22 t ha⁻¹) of the respective winter cereal monocrops (Baron et al. 1994). While the trend for recovery was the same as in the present study, the longer rest period may have allowed the winter cereal component to recover to a higher percentage of the monocrop. However as the season progresses, typically, lower temperatures and less rainfall (Campbell et al. 1990) should reduce regrowth rates in addition to the apparent effects of delay of harvest. Baron et al. (1993b) found that about 3 mo was required for tiller density of a winter cereal in a mixture to equal the monocrop following initial harvest, but the yield of the winter cereal component in the mixture was still only 80% of the monocrop.

Etiolated regrowth provided an index of regrowth potential from existing crowns at the onset of regrowth, separating the effects of current photosynthate and stored energy, (mostly in the form of soluble sugars) on regrowth (Busso et al. 1990). WSC are required to support regrowth for a short time (4 to 7 d) until basal leaves can sustain net growth through photosynthesis (Booyesen and Nelson 1975). Winter cereals from mixtures had lower etiolated regrowth than the monocrops at the B and H + 2 stages, and lower WSC concentrations than the monocrops at B (Table 6). Triticale had generally lower WSC concentrations than wheat at all stages and less etiolated regrowth at H + 2, H + 4 and H + 6 (Table 7). Rye had lower WSC and etiolated regrowth than wheat at H + 2, H + 4 and H + 6 stages. The correlations of WSC and etiolated regrowth with actual regrowth were 0.44 and 0.72, respectively. The correlations of WSC with etiolated regrowth in the monocrops and mixtures were 0.98 and 0.00, respectively. Both Davies (1988) and Busso et al. (1990) indicated that concentrations of non-structural carbohydrates required to effect regrowth are variable and hard to quantify. Busso et al. (1990) concluded that non-structural carbohydrates in roots and crowns facilitated regrowth when meristematic activity was high. Reduced tiller density of winter cereals and low PAR levels at crown level indicates that meristematic activity was generally relatively low.

The amount of basal leaf area on regrowing winter cereals was not measured. However, when cut at the 5-cm level almost no basal leaf material appeared to remain on the winter cereal plants remaining in the mixture. Because of the low light levels at the base of the canopy, the lower leaves likely could not be sustained and the winter cereal plants grew high in the canopy so almost all of the leaf material was removed by cutting.

SUMMARY AND CONCLUSION

This study showed that while initial yields of the mixtures and monocrops increased when initial harvest was delayed, the regrowth potential of the winter cereals as represented by a 3-wk regrowth yield declined rapidly (Fig. 1 and Table 5). Previous studies have shown the advantages of allowing the spring cereal in the mixture to approach the dough stage to maximize dry matter yield (Baron et al. 1990, 1994). Reduction in regrowth yield occurred in both monocrops and mixtures but the effects were larger in the mixtures. The reduction in regrowth was associated with the intense shade at the base of the canopies of both the monocrops and mixtures. Reduced winter cereal tiller densities occurred in both cropping systems, but was more severe in the mixtures. The tiller density prior to cutting was likely a function of light interception-sward structure relationships.

The trend towards reduced tiller densities probably reflected a lack of tiller initiation, so when defoliation occurred, few tiller buds were advanced enough to resume rapid growth. Because the winter cereal component in the mixtures decreased to a substantially lower density than in the monocrops, the lag in tiller number was more prolonged for the mixtures.

The effect of time of initial cutting greatly overshadowed species effects on regrowth. However fall rye and triticale in mixtures appeared more stable than wheat in terms of dry matter production during initial growth and regrowth relative to the monocrop. The relative performance of the winter cereal species for regrowth (Table 5) over this period reflects their initial yield (Table 3) in monocrops with rye and triticale yielding more than winter wheat. The potential among species for regrowth after the initial cuts appears related to aspects of growth, perhaps plant size, prior to the initial cut. Difference in plant size in a mixture provides advantages to the taller component and the competitive ability of a species is determined by the space occupied at the beginning of the season (Spitters and Vanden Burgh 1982).

Where the silage/pasture system is desired, a sacrifice in silage yield may be necessary to ensure adequate fall regrowth. The latest practical stage to make the initial cut is H + 2 wk in barley, which could result in a sacrifice of

Table 6. Percent etiolated regrowth and water soluble carbohydrate content from crowns of winter cereal grown as monocrops and mixtures with Leduc barley, averaged over winter cereal species and sampled at five stages of barley development

Cropping system	Stage ^z				
	B	H	H+2	H+4	H+6
<i>Etiolated regrowth (% dry wt)</i>					
Monocrop	10.8aA	6.2aB	4.6aBC	3.4aC	1.8aD
Mixture	6.4bA	4.1aAB	3.2aBC	1.6bD	2.1aCD
<i>Water soluble carbohydrate (% dry wt)</i>					
Monocrop	4.75aA	3.79aAB	3.68aAB	3.37aAB	2.98aAB
Mixture	2.89bA	3.07aA	2.80aA	2.39aA	2.80aA

^zB, H, H+2, H+4 and H+6 are boot, heads, emerged, heading plus 2, 4 and 6 wk for Leduc barley, respectively.

a-b Means followed by the same letter within cut are similar ($P \leq 0.05$) according to transformed LSD, 0.19 and 0.12 for etiolated regrowth and water soluble carbohydrate, respectively.

A-D Means followed by the same letter within rows are similar ($P \leq 0.05$).

Table 7. Etiolated regrowth and water soluble carbohydrate content from rye, wheat and triticale crowns averaged over cropping systems and sampled at five stages throughout the season

Winter cereal	Stage ^z				
	B	H	H+2	H+4	H+6
<i>Etiolated regrowth (% dry wt)</i>					
Rye ^z	7.3aA	5.0aA	2.6bB	1.5bBC	0.8bC
Triticale	7.5aA	4.0aB	3.8aBC	1.8bC	2.3aCD
Wheat	10.5aA	6.4aB	5.3aB	4.5aBC	3.1aC
<i>Water soluble carbohydrate (% dry wt)</i>					
Rye	4.4aA	4.0aAB	2.9bB	2.8abB	2.8abB
Triticale	3.0bA	2.9bA	2.9bA	2.2bA	2.3bA
Wheat	3.8abA	3.4abA	4.0aA	3.6aA	3.9aA

^zB, H, H+2, H+4 and H+6 are boot, heads, emerged, heading plus two, four and six weeks for Leduc barley, respectively.

^yMusketeer fall rye; Wintri winter triticale; Norstar winter wheat.

a-b Means followed by the same letter within cut are similar ($P \leq 0.05$) for etiolated regrowth and water soluble carbohydrate, respectively.

A-D Means followed by the same letter within rows are similar ($P \leq 0.05$).

17% of maximum silage dry matter yield. Seeding must occur early enough to allow barley development to the H + 2 wk stage before the initial harvest, and still leave sufficient time for the winter cereal component to recover for pasture. As stated previously, the winter cereal in the mixture will not likely recover to the level of the winter cereal monocrop when the initial cut is made at H + 2 wk, even with a longer recovery period than was used in the present study (Baron et al. 1994). Where substantial regrowth for fall pasture is required, it is recommended that the initial growth of a mixture be harvested as soon after heading as possible or consider a winter cereal monocrop as an alternative. Fall rye and triticale appeared best suited for growth in both mixtures and monocrops.

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