Early Establishment and Growth of Tall Fescue (*Festuca arundinacea* Schreb.) Seed Crops under Barley (*Hordeum vulgare* L.) Cover

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ABSTRACT

A three year experiment was conducted to examine best management options for companion cropping of tall fescue (cv. Grasslands Roa) and barley (cv. Triumph). Barley was sown at densities ranging from 37.5 to 200 kg ha^{-1} and either 15 or 30 cm row spacing. Tall fescue was cross drilled (30 cm row spacing, either 7.5 or 15 kg ha^{-1}) into the barley seedbed. Tillering and growth of both crops were monitored regularly until maturity of tall fescue. Measurements of nitrogen uptake and biomass of both crops and estimates of light interception by the barley cover provided information on the ability of the tall fescue to respond in the competitive environment. Barley grain yields were significantly reduced at sowing rates lower than 75 kg ha^{-1}, but there was little difference in yield at rates greater than 100 kg ha^{-1}. The relative timing of canopy closure (95% cover) of barley crops sown at rates greater than 75 kg ha^{-1} had little effect on tall fescue biomass, weight per tiller or tiller number per unit area. Tall fescue sowing rate had a significant effect on biomass, weight per tiller and shoots per unit area prior to barley anthesis but these differences were not apparent at barley harvest.

Additional index words: **companion cropping, competition, grain yield, light interception, seed production.**

INTRODUCTION

Tall fescue cv. Grasslands Roa is commonly grown for improved summer forage production (Brock, 1983). When grown for seed, both spring and autumn-sown crops require two growth seasons for optimum production. Companion cropping with cereals optimises land use in a system where tall fescue establishment is slow and tillers require vernalisation. The practice of pasture establishment under a cereal cover or as a companion crop is not new (Santhirasegaram and Black, 1965). However, there have been few successful attempts to establish tall fescue in spring under a barley cover in the lower North Island of New Zealand. Economic seed yields of both cereal and herbage crops, as well as light winter grazing, are possible in just over one year. The economic benefit from harvesting a high value short season crop, such as malting barley, and a herbage seed crop in one growth season is dependent on correct management of both species.

A number of strategies have been studied to improve the competitive ability of grasses such as *Festuca rubra* L. (red fescue), *Dactylis glomerata* L. (cocksfoot) and *Poa pratensis* L. (Kentucky bluegrass) under the more vigorous cereal cover (Chastain and Grabe, 1988, 1989a, 1989b; Meijer, 1987). Experimentation with increased row spacing and reduced cereal planting densities has provided an improved light environment to the lower canopy. These treatments affect the performance of the cereal crop and therefore its profitability. Meijer (1987) proposed that the best option for red fescue seed production under barley was to reduce the cover crop density by reducing sowing rates, as the cereal yield was reduced less.

An experiment was conducted over three seasons to evaluate the establishment of tall fescue under a barley cover crop. Malting barley performance was examined using standard monoculture management as well as reduced sowing rates and row spacings. The aim was to determine optimum sowing management and early establishment strategies for both tall fescue and barley and to minimise the adverse competitive effects between the two species. A second paper, in preparation, will detail the seed production responses of tall fescue in the following summer.

MATERIALS AND METHODS

Beginning in 1988/89, three trials in successive seasons were conducted at the Grasslands Aorangi farm, in the Manawatu, New Zealand (40° 23'S) on a Kairanga silt loam (quartzo-feldspathic silty alluvium). Each trial was conducted on a new site with treatment combinations of sowing rate and row spacing as given in Table 1.

Tall fescue (*Festuca arundinacea* Schreb., cv. Grasslands Roa) and a malting barley (*Hordeum vulgare* L., cv. Triumph) were sown on the same day. The barley was drilled at a depth of 5 cm and the tall fescue cross-drilled at 1 cm depth and 30 cm row spacing. All trials were randomised complete block designs with three replications.

A daily soil water balance (Kerr, de Ruiter and Hall, 1986) was calculated from inputs of daily mean air temperature, solar radiation and rainfall. This was used to derive soil water deficits throughout barley growth. Potential evapotranspiration (ET) was calculated using the Priestley and Taylor (1976) method and adjusted to actual ET on the basis of canopy cover development for the 150 kg ha^{-1} barley sowing treatment, and a reduced ET rate in a drying soil (Kerr *et al.*, 1986). The grass component contribution to ET was assumed to have a negligible effect

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Table 1. Row spacing and sowing rate treatments for barley, and sowing rate treatments for tall fescue.

Years 1 and 2		Year 3	
Tall fescue[a] (kg ha^{-1})	Barley (cm, kg ha^{-1})	Tall fescue[a] (kg ha^{-1})	Barley (cm, kg ha^{-1})
-[b]	15, 75		
		-	15, 100
-	15, 150	-	15, 150
		-	15, 200
7.5	-	7.5	-
		15	-
7.5	15, 37.5		
7.5	15, 75		
7.5	30, 37.5		
7.5	30, 75		
		7.5	15, 100
7.5	15, 150[c]	7.5	15, 150
		7.5	15, 200
		15	15, 100
		15	15, 150
		15	15, 200

[a] All fescue sown in 30 cm rows
[b] Indicates monoculture

on the overall soil water budget.

1988/89 and 89/90 (Years 1 and 2)

These trials were sown in successive seasons, on 30 September and 29 September, with treatments (Table 1) in 8 x 3 m (barley sown longitudinally) plots. In year 1, no fertiliser was applied at sowing but in year 2, 30% potassic super (0:7:15:8) was applied at 200 kg ha^{-1}. Urea was applied at 50 kg N ha^{-1} at barley GS5 (Large, 1954) in year 1 (30 November) and on 27 October in year 2 which coincided with tillering (GS3).

On 17 November in year 1, 2.16 kg ha^{-1} ai ha of 2,4-D was applied primarily for willow weed (*Polygonium* spp.) control, followed by a further application of dicamba (200 g ai ha^{-1}) and 2.16 kg ai ha^{-1} of 2,4-D 21 days later. In year 2, dicamba (480 g ai ha^{-1}) plus 2,4-D (430 g ai ha^{-1}) was applied for control of willow weed and other broad leaf weeds.

1990/91 (Year 3)

Tall fescue and barley were sown on 9 November. Treatments comprising two sowing rates for tall fescue and three barley sowing rates were designed to produce 200, 300 and 400 plants m^{-2} in the respective barley treatments (Table 1). Plots were 11 m x 3.5 m. A granular insecticide (phorate) was applied at 2 kg ai ha^{-1} prior to plant emergence to control aphids and therefore reduce the severity of Barley Yellow Dwarf Virus (BYDV). No fertiliser was applied at sowing. Soil nitrate at tillering indicated relatively high levels of mineral nitrogen (N) and therefore no fertiliser N was required.

Ten plants in each of the 'barley-alone' plots were leaf-tagged to determine final leaf numbers and rates of development. Estimates of canopy cover development were determined by infrared photographs (de Ruiter and Brooking, 1990) at two positions within each of the 'barley-alone' plots and returning to the same positions over time.

Photographs were taken at 4 days after emergence through to 75-80% ground cover. Paper positive (10 x 7 cm) images were captured and digitised by image processing software and determinations made of the relative proportions of leaf cover to bare soil. Estimates of barley cover above 75% were determined by difference between photosynthetically active radiation (PAR) detected at the soil surface by a 1 m line quantum sensor (Li-Cor) relative to a point quantum sensor (Li-Cor) positioned above the canopy.

Herbage sampling

In years 1 and 2, tall fescue plants were counted seven weeks after sowing, in six 1 m row lengths per plot. In year 3, tiller number, tiller dry matter (DM), N concentration and herbage N uptake were determined at three stages (17, 52 and 82 days after sowing) prior to barley anthesis (7 January). In all trials, DM and tiller numbers were counted following the barley harvest.

Duplicate 0.25 m^2 quadrats of barley were sampled from each plot at maturity (26 January - year 1; 6 February - year 2; 20 February - year 3). Determinations included plant and tiller counts, dry matter of grain and stubble (stem, dead leaf and chaff), and subsamples for N content by micro-Kjeldahl analysis (Haslemore and Roughan, 1976) on oven-dried plant material after grinding to pass a 1 mm screen. Nitrogen uptake for barley and tall fescue was calculated on a unit area basis.

One m^2 quadrats were sampled for barley grain yield. Grain was threshed by a stationary thresher and corrected to 14% moisture. Mean seed weight (g 1000^{-1} seeds) and seed number per unit area were determined on oven-dried subsamples.

Soil Nitrogen

In year 2, NO_3^--N and NH_4^+-N were determined by automated colorimetry. In year 3, NO_3^--N determinations were made using a nitrate electrode with adjustments made for soil bulk density.

RESULTS AND DISCUSSION

Sowing Rates and Germination

Persistence of tall fescue under a barley canopy was dependent on sowing rates of both species and a satisfactory environment in terms of water, light and nutrients. In years 1 and 2, the barley sowing rates chosen (Table 1) were less than the commercially recommended rate of 150 kg ha^{-1} for monocultures of feed or malting quality barley. Lower sowing rates were chosen to allow an improved response from the tall fescue within a partially closed canopy. Barley emergence was less than expected because of wet soil conditions. The conditions for germination were ideal in year 3 and initial plant populations were close to those intended (Table 2). Additional competitive pressure was imposed in this year by sowing barley at rates up to 200 kg ha^{-1} to determine whether tall fescue would survive and produce a seed crop in the following summer.

There was a significant difference between years in the number of fescue plants established at 7 weeks. Any long-term effects of emergence rate were negligible as the year effect on tiller numbers per unit area, and DM per tiller was not significant at barley harvest. However, total DM and plant numbers were different over years ($P < 0.01$).

Table 2. Barley and tall fescue plant populations at emergence and seven weeks after sowing, respectively.

	Sowing rate (kg ha^{-1})	Year 1	Year 2 (plants m^{-2})	Year 3
Barley	37.5	68.3 (17.5)[a]	63.2 (7.0)	–
	75	125.1 (29.1)	135.3 (16.2)	–
	100	–	–	217.2 (24.0)
	150	185.4 (30.2)	264.0 (19.3)	299.0 (35.4)
	200	–	–	387.6 (29.9)
Tall fescue	7.5	61.0 (13.9)	104.1 (10.4)	160.4 (25.9)
	15.0	–	–	301.0 (29.4)

[a] Values in parentheses are standard errors.

Growth Environment

Soil water deficits (Fig. 1) showed similar patterns in all three years. Spring soil conditions were favourable for early growth in the first two seasons. By barley anthesis, the soil deficits approached the 30% available water reserve level. The barley grain-filling period in both years 1 and 2 was relatively dry. In year 3, a combination of late sowing and adequate late spring and early summer rain resulted in good soil moisture conditions until barley maturity. Year 1 was the driest year, with soil moisture approaching stress conditions prior to stubble removal.

The effects of BYDV were more pronounced in years 1 and 2 when crops were sown at the lower density. During grain-filling, the 37.5 and 75 kg ha^{-1} treatments had incompletely closed canopies and there was ample light to support tall fescue growth. In year 3, differences in light interception due to barley sowing rate were detected within 42 days after emergence and until the crops intercepted greater than 90% of incident PAR (Fig. 2). In previous work with spring sown tall fescue and barley (Chastain and Grabe, 1989a), the canopy cover was less complete. In their study, as much as 34-38% of the incident light reached the developing fescue in spite of barley sowing rates of 117 kg ha^{-1}. In our study, sowing rates at or greater than 100 kg ha^{-1} developed a complete canopy cover. Half-closure was delayed by 100 degree days (base 0°C) in the low compared with the high barley sowing rate. This difference was not significant in terms of the overall time under a full barley cover. There was no difference in light interception due to barley sowing rate at barley harvest. Nevertheless, the radiation interception by the canopy at this time accounted for a significant proportion of the incident level. At 40 cm above ground level, an average of 67.8% (± 2.8) was intercepted compared with 93.8% (± 1.6) at the soil surface, 87.2% (± 2.0) at 20 cm and 80.2% (± 1.9) at 30 cm. Tall fescue leaves in the 100 kg ha^{-1} barley treatment extended to 40 cm height. Therefore, competition for light was severe right up to barley stubble removal. The fescue showed some etiolation of leaves. Chastain and Grabe (1989a) reported that etiolated leaves were higher in chlorophyll than the controls; however this trend was reversed when soil water was limiting. Reduction in growth under the barley has been shown to be related to low photosynthetic rates, but more directly to the low light environment (Woledge, 1971).

Initial mineral N levels, determined in year 2, were high. Nitrate-N levels were equivalent to 50 and 17 kg N ha^{-1}, respectively, for the 0-15 cm and 15-30 cm soil layers. Ammonium-N levels at sowing (0-30 cm) were also high (97.5 kg N ha^{-1}) and were indicative of active mineralisation and a cold dry late-winter. Therefore, it was assumed that there was no N limitation to early tall fescue growth other than as a direct result of competition for available N by the barley. In year 3, there was little systematic trend in soil nitrate levels in the one-month period following sowing but there were differences in tall fescue N uptake due to barley sowing rate in spite of high levels of soil mineral N. For example, nitrate levels were equivalent to 105 (± 26) kg N ha^{-1} and 42 (± 11) kg N ha^{-1} in the top 15 cm and 15-30 cm layers, respectively.

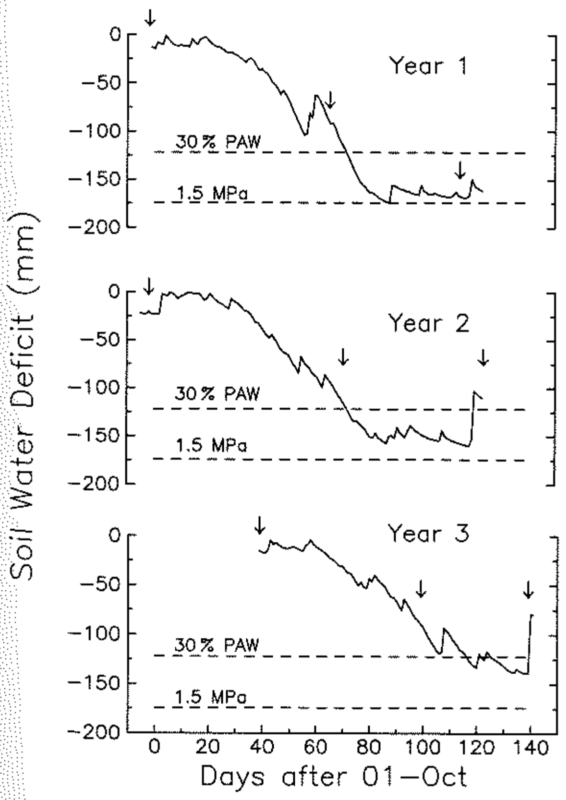

Figure 1.
Soil water balances for successive trials years. Dotted lines indicate levels for 30% plant available water (PAW) remaining and a 1.5 MPa soil water potential, (arrows indicate sowing, anthesis and maturity).

Tall Fescue Establishment

Effect of tall fescue sowing rate

Tall fescue sowing rate had a significant effect (P < 0.001) on both N uptake and DM production of tall fescue under barley at 17 days after sowing (DAS) but thereafter the effects were non significant (Tables 3 and 4). Differences in tiller numbers due to fescue sowing rate were significant until 52 DAS. There were no differences in the N percentage of leaf tissue or the dry weight per tiller at any growth stage whether sown at 7.5 or 15 kg ha^{-1}.

Effect of barley cover

There were marked differences in growth of tall fescue between the control (no barley) and under the barley cover. Differences in DM yield, tillers per unit area, and N uptake were apparent as early as 17 DAS and became greater with time (Tables 3 and 4) until 82 DAS. Similarly, dry weight per tiller and herbage N concentration were significant from 52 DAS. At 82 DAS in year 3, there was a six-fold reduction in fescue tiller numbers and a 14-fold reduction in DM when comparing the monoculture with companion cropped treatments (100 kg ha^{-1} sowing rate), (Table 3). By barley maturity, these effects were not as marked but there were still major differences between cover and no cover treatments (Table 5). When averaged over years, there was a three-fold difference in tiller number and DM per tiller and a nine-fold difference in total DM. In a comparison with earlier work, fescue tiller numbers under barley sown at 100 kg ha^{-1} were approximately half those

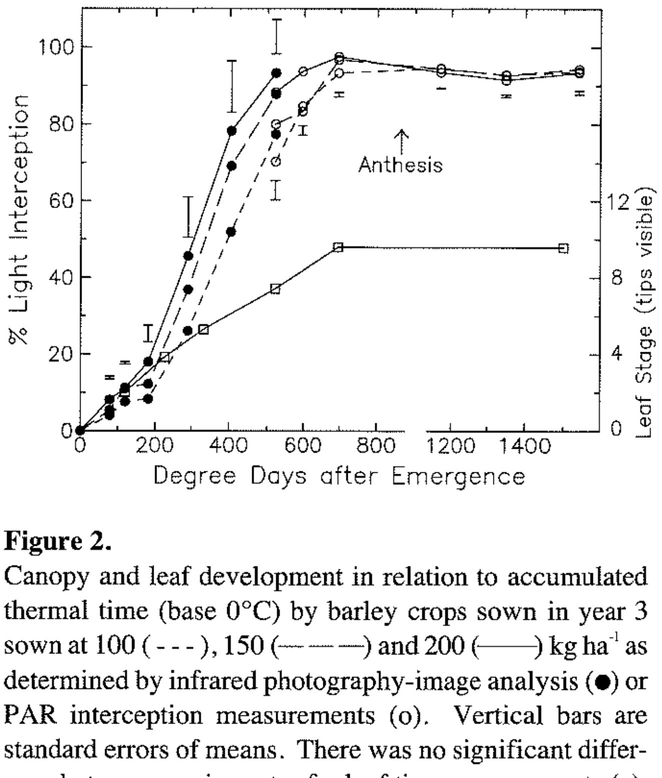

Figure 2.
Canopy and leaf development in relation to accumulated thermal time (base 0°C) by barley crops sown in year 3 sown at 100 (- - -), 150 (— — —) and 200 (———) kg ha^{-1} as determined by infrared photography-image analysis (●) or PAR interception measurements (o). Vertical bars are standard errors of means. There was no significant difference between sowing rates for leaf tip appearance rate (□).

reported by Chastain and Grabe (1989a), but were equivalent in the fescue controls. The difference can be explained by the better light environment for fescue growth in their study.

Barley sowing rate had no effect on early growth of tall fescue although linear contrasts between 100 and 200 kg ha^{-1} treatments indicated a significant difference ($P < 0.05$) in tall fescue dry weight per tiller at 82 DAS.

Barley Responses

The presence or absence of tall fescue had no significant effect on barley performance (data not shown), except for a significant ($P < 0.05$) effect on grain number per unit area. This may have resulted from the added competition for soil N from the fescue component. Grain number has been demonstrated to be one of the more sensitive yield components to environmental variation (de Ruiter, Brooking, Haslemore and Carran, 1988).

Differences in DM yield, DM per tiller, and N uptake per unit area were more pronounced in early growth. With the exception of DM yield, these differences were not present at 82 DAS.

Over all years, strong linear effects due to sowing rate were found in many barley growth variables at maturity (Tables 4 and 6). These included DM, grain yield, 1000 kernel weight, plant number, ear number, ears per plant, grains per unit area, and grain N yield. Variables which did not differ in response to sowing rate were harvest index and stubble N yield.

Table 3. Least squares means for tall fescue establishment responses under difference barley and tall fescue sowing rates in year 3.

Barley sowing rate (kg ha^{-1})	Days after sowing 17	52	82
		DM yield (g m^{-2})	
0	6.5	53.5	394.2
100	4.7	14.1	28.5
150	4.2	11.2	15.0
200	4.6	10.4	13.8
Contrasts[a]			
cover vs no cover	*	***	***
7.5 vs 15 rate – fescue[b]	***	ns	ns
100 vs 200 rate – barley	ns	ns	ns
		Tiller numbers (m^{-2})	
0	321	986	1882
100	255	314	310
150	273	269	235
200	241	270	206
Contrasts			
cover vs no cover	*	***	***
7.5 vs 15 rate – fescue[b]	***	**	ns
100 vs 200 rate – barley	ns	ns	ns
		DM per tiller (g)	
0	0.020	0.054	0.121
100	0.019	0.044	0.091
150	0.016	0.042	0.064
200	0.018	0.040	0.060
Contrasts			
cover vs no cover	ns	**	***
7.5 vs 15 rate – fescue[b]	ns	ns	ns
100 vs 200 rate – barley	ns	ns	*

[a] ns, *, **, ***, non significant and significant at $P < 0.05$, 0.01, and 0.001 respectively.

[b] excluding 'fescue-alone' control

Table 4. Least squares means for tall fescue and barley nitrogen response variables.

A: Tall Fescue (Year 3)

Barley sowing rate (kg ha-1)	Herbage N Concentration (%)			Plant N Uptake (g m^{-2})		
	17 DAS	**52 DAS**	**82 DAS**	**17 DAS**	**52 DAS**	**82 DAS**
0	4.66	4.06	3.28	0.30	2.16	12.94
100	4.42	3.51	2.57	0.21	0.48	0.68
150	4.48	3.25	2.57	0.19	0.35	0.38
200	4.55	3.13	2.48	0.20	0.32	0.32
Contrasts[a]						
cover vs no cover	ns	***	***	**	***	***
7.5 vs 15 rate – fescue[b]	ns	ns	ns	***	ns	ns
100 vs 200 rate - barley	ns	ns	ns	ns	ns	ns

B: Barley at maturity[d]

Barley sowing rate (kg ha^{-1})	Plant N uptake (g m^{-2})	Stubble N (g m^{-2})	Grain N concentration (%)	Grain N yield (g m^{-2})
37.5	13.1 (-)	7.1 (-)	2.11 (0.11)	6.3 (0.2)
75	11.5 (0.8)[c]	4.9 (0.2)	2.17 (0.07)	7.6 (0.5)
100	14.6 (1.2)	4.9 (0.5)	2.18 (0.07)	9.2 (0.9)
150	16.2 (2.1)	4.6 (0.5)	2.21 (0.12)	11.7 (1.5)
200	19.3 (0.5)	4.6 (0.5)	2.19 (0.14)	14.2 (0.7)

[a] Significance levels as for Table 3
[b] Excluding 'tall fescue-alone' control
[c] Values in parentheses are standard errors of means
[d] Includes crops with undersown tall fescue

Table 5. Least squares means and standard errors for tall fescue responses at barley maturity over all years.

Barley sowing rate (kg ha^{-1})	Dry matter (g m^{-2})	Tiller numbers (m^{-2})	DM tiller^{-1} (g)
0	324 (38)	977 (147)	0.42 (0.09)
37.5	208 (36)	625 (134)	0.40 (0.08)
75	179 (33)	563 (175)	0.41 (0.04)
100	39 (8)	297 (78)	0.15 (0.01)
150	44 (9)	306 (78)	0.16 (0.01)
200	28 (8)	248 (72)	0.12 (0.01)

There was little difference in final leaf numbers in response to sowing density. These were 9.9, 9.8 and 9.5 for the 100, 150 and 200 kg ha^{-1} sowing rate treatments, respectively. The rate of leaf appearance was linear with thermal time (Fig. 2).

Tissue N percentage did not vary in response to barley sowing rate although at anthesis the N concentration for the 100 kg ha^{-1} treatment was significantly different ($P < 0.05$) from the other sowing rates. However, there was a marked reduction in N concentration over time ranging from 5.08% at

Table 6. Least squares means and standard errors over years for barley yield and yield component responses to barley sowing rate.

Barley sowing rate (kg ha^{-1})	DM yield (t ha^{-1})	Grain yield (t ha^{-1})	HI[a]	TKW[b] (g)	Plant numbers (m^{-2})
37.5	9.2 (1.3)	2.4 (0.1)	0.45 (0.03)	36.1 (0.7)	74 (23)
75	9.1 (0.4)	3.3 (0.2)	0.45 (0.01)	33.7 (1.0)	133 (13)
100	10.2 (0.4)	4.3 (0.3)	0.46 (0.01)	33.7 (0.8)	144 (14)
150	11.5 (0.3)	4.9 (0.2)	0.47 (0.005)	31.2 (0.8)	258 (8)
200	11.9 (0.4)	5.5 (0.2)	0.46 (0.004)	29.6 (0.4)	333 (17)
	Ear number (m^{-2})	**Ears $plant^{-1}$**	**Grains m^{-2}**	**Grains ear^{-1}**	
37.5	476 (84)	6.9 (1.1)	8049 (194)	17.7 (2.4)	
75	619 (42)	4.8 (0.3)	10484 (774)	17.3 (0.9)	
100	700 (44)	5.0 (0.2)	13125 (1180)	19.2 (0.7)	
150	938 (22)	3.7 (0.1)	19511 (732)	21.1 (0.4)	
200	999 (28)	3.1 (0.1)	21997 (1343)	20.4 (0.3)	

[a] HI = harvest index
[b] TKW = thousand kernel weight

17 DAS to 1.41% at 82 DAS (data not shown).

Barley sown at 200 kg ha^{-1} was the best option for maximising DM yield, grain yield and components of yield such as plant number, ear number per unit area, and grains per unit area. As expected, this was offset by fewer ears per plant and reduced grain size. The effect of plant density on grain N concentration was minimal. Grain N concentrations were generally high and reflected the highly fertile sites used for the trial. At this level, the grain was not acceptable for quality malt production but quite suitable as stock feed. Even at the high sowing rate, barley was still able to take up additional N which may otherwise have been available for the tall fescue. Crops for feed grain production would therefore benefit from the higher sowing rates whereas best malting quality grain would be derived from crops sown at or below the recommended (150 kg ha^{-1}) commercial rate. Cultivars selected for high malting quality provide the best option if optimal performance is to be attained from the tall fescue component of the mixture. These cultivars can be sown at a lower sowing rate, and attract a premium provided the grain N quality is acceptable (< 2.0 %).

The effect of barley cover on soil water can be significant, especially in dry seasons. No comparisons were made of water budgets in the fescue monoculture and the companion crop situations. However, work by Chastain and Grabe (1989a) has shown significantly less soil water under the barley cover compared with fescue alone, as well as slight temperature reductions under the barley cover.

Barley Yield

Average grain yields (14% moisture) from 'barley-alone' plots sown at 150 kg ha^{-1} and a 15 cm row spacing were 4.36, 4.32 and 5.15 t ha^{-1} in successive years. There were no consistent effects due to row spacing (15 vs 30 cm rows) in years 1 and 2. However, there was a consistent effect of sowing rate on yield. Averaged over the first two seasons, crops sown at 37.5 kg ha^{-1} yielded 2.78 ($\pm$0.2) t ha^{-1} compared with 3.70 ($\pm$0.4) t ha^{-1} for the 75 kg ha^{-1} sowing treatment and 4.43 t ha^{-1} for crops sown at the commercial (150 kg ha^{-1}) rate. Grain yields were generally higher in year 3, with 5.81, 5.89 and 6.28 t ha^{-1} from sowing rates of 100, 150 and 200 kg ha^{-1}, respectively. In general, tall fescue had no influence on barley grain yield although a single degree of freedom contrast comparing the presence or absence of tall fescue under barley sown at 200 kg ha^{-1} was significant ($P < 0.01$).

SUMMARY

Barley had a strong influence on tall fescue growth by reducing its dry matter production, tillering, and nitrogen uptake. Barley was particularly vigorous in its competitive effect, but there were few differences in tall fescue growth under the barley canopy at barley sowing rates from 100 to 200 kg ha^{-1}. However, at lower barley sowing rates, the barley crops suffered badly in terms of dry matter production and grain yield in spite of improvements in the quality of the grain. The benefits of sowing at lower densities were observed in the improved early establishment and vegeta-

tive growth of tall fescue. Therefore, barley grown in a companion cropping situation can be managed in a similar way to commercial cereal crops grown for either feed or malt grain. A following paper will examine what effect differences in tall fescue vigour during establishment had on subsequent seed production.

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