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GROWTH, YIELD AND QUALITY OF A RANGE OF GRASSES IN A CONTINENTAL CLIMATE

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SUMMARY

The possibility of producing herbage of higher quality than that of tall fescue (*Festuca arundinacea*) in a continental climate with cold winters, hot summers and low precipitation was investigated, with and without irrigation, at Taigu, Shanxi, China. Tall fescue was compared with perennial ryegrass (*Lolium perenne*), meadow fescue (*Festuca pratensis*) and perennial ryegrass × meadow fescue in field swards, managed by cutting, during the year of sowing and in the three subsequent years. Perennial ryegrass yielded well in the year of sowing, but was low yielding subsequently; perennial ryegrass × meadow fescue yielded well in the year of sowing and in the following year. Both of these grasses had high rates of leaf appearance and extension and a high proportion of cell content in the dry matter. Tall fescue yielded well, but was low in proportion of cell content.

INTRODUCTION

Grasses used in areas with a continental climate are typically not those which are of the highest nutritive value, with the result that animal performance is constrained. Tall fescue (*Festuca arundinacea*) tolerates extremes of temperature and a shortage of water and is suitable for some areas with a continental climate (Nelson and Moser, 1994). However, tall fescue is not an ideal grass for animal production, partly because of thick cell walls (Rezvani Moghaddam and Wilman, 1998), a rather low proportion of cell content in the dry matter and rather low digestibility (Wilman *et al.*, 1996).

In order to explore the possibility of producing herbage of higher quality than that of tall fescue in a difficult, continental climate, tall fescue was compared with three other grasses in field swards at Taigu, Shanxi, China, both with and without irrigation. The winters at Taigu are cold and dry; the summers are hot and moderately moist (Wilman *et al.*, 1999). The three other grasses were perennial ryegrass (*Lolium perenne*), meadow fescue (*Festuca pratensis*) and a perennial ryegrass × meadow fescue hybrid, all of which should be of higher quality than tall fescue (Wilman *et al.*, 1996), though not as tolerant of adverse conditions.

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Ground cover and tiller density were reported in the previous paper (Wilman *et al.*, 1999); aspects of growth, yield and quality are reported in the present paper.

MATERIALS AND METHODS

The four grasses studied were: tall fescue cv. Fawn, perennial ryegrass cv. Bastion, meadow fescue cv. Rossa and perennial ryegrass × meadow fescue cv. Prior. Each grass was sown as a pure stand in field plots, each of which measured 2 × 5 m. There were two sites, one irrigated and one not. Within each site there were three blocks, each containing four plots, one for each type of sward. Sward type was allocated at random to the plots within a block. The experiment was carried out on the farm of Shanxi Agricultural University, at Taigu, Shanxi, China. The soil is derived from secondary loess and is very deep, with a high silt content and almost no stones. In the soil near the surface in 1991, pH was 7.5, extractable P was 22 mg L^{-1} and extractable K 116 mg L^{-1}.

The weather at Taigu is very dry during the period November to April. Rainfall is higher but variable in the period May to October. The winter is cold, particularly in the period December to February, and the summer is hot, particularly in the period June to August. Further details are in Wilman *et al.* (1999).

The plots were sown, broadcast by hand, at a rate of 30 kg seed ha^{-1} on 10 July 1989. Ammonium nitrate supplying 90 kg N ha^{-1} and calcium phosphate supplying 60 kg P ha^{-1} were applied to all plots in the seedbed. The plots were cut on 3 October 1989, grazed by sheep at the beginning of December 1989 and cut five times in 1990 in the period May to November, three times in 1991 in the period May to September and five times in 1992 in the period May to October. The average number of days between cuts within a year was 42. Cutting was with a sickle, leaving a stubble height of 4 cm. Dry matter (DM) yield of total herbage was recorded in two quadrats, each 1 m^2, per plot on each date of cutting.

Leaf production was studied during nine periods each of approximately 28 d, in March to December 1990, during eight periods in March to November 1991 and six periods in March to November 1992. At the beginning of each period two young tillers were marked per plot; these were drawn and measured at approximately 14-d intervals to provide records of the rates of leaf appearance and extension. On 20 dates between 4 April 1990 and 27 November 1992 the weight per unit area of fully expanded, green leaf blades of the sown species was determined by recording the area and oven-dry weight of two blades per plot. On 22 dates between 5 April 1990 and 25 October 1992 the emerged leaves and the unemerged leaves were counted on each of two tillers of the sown species per plot. Leaves were counted as unemerged if they were large enough to enclose the shoot apex but not large enough for any part to have emerged into the light. On 15 dates between 5 April 1990 and 31 October 1991 the position of the shoot apex relative to ground level and the number of leaf sheaths protecting the shoot apex were recorded in two vegetative tillers of the sown species per plot.

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On five dates in the period May to November 1990, three dates in the period May to September 1991 and five dates in the period May to October 1992, a sample of green leaf blades of the sown species was taken from each plot, air-dried indoors, milled through a 1-mm screen and a 0.5-g subsample analysed for percentage of cell content in the DM (that is, 100 minus percentage cell wall in DM) by the neutral detergent method of Soest and Wine (1967).

In the analysis of variance of the results, sites (irrigation treatments) had 1 degree of freedom (d.f.), blocks within sites had 4, sward types 3, sites × sward types 3, residual 12 and total 23. Standard errors were calculated from the residual mean square. When results from one site only were analysed, the analysis of variance was as for a randomized block design with 6 d.f. for error.

RESULTS

In the data presented in this paper the main effect of sward type was statistically significant in a majority of cases. The only statistically significant interaction between irrigation treatment and sward type was on one date (out of 13) for percentage cell content.

In the year of sowing the highest-yielding grasses were perennial ryegrass and perennial ryegrass × meadow fescue and the lowest yielding was meadow fescue (Table 1). In the following two years tall fescue was the highest yielding grass and perennial ryegrass the lowest yielding. The yields were much lower in 1991 than in 1990. In 1992 the yields were low on all plots; tall fescue yielded a small amount without irrigation and rather more with irrigation; the other grasses produced a low yield with irrigation and nothing or almost nothing without irrigation. Over the period 1989–92, the highest yielding grass was tall fescue and the lowest yielding was perennial ryegrass; yields over the whole period were 35% higher with irrigation than without.

Table 1. Main effects of sward type and irrigation on the dry matter yield of total herbage (t ha^{-1} a^{-1}) over a four-year period, 1989–92.

	1989	1990	1991	1992	Total
Number of cuts	1	5	3	5	
Sward type:					
Perennial ryegrass	5.83	6.36	2.46	1.54†	15.41
Perennial ryegrass × meadow fescue	5.59	10.04	2.90	1.85†	19.45
Meadow fescue	4.96	9.03	2.89	2.42†	18.09
Tall fescue	5.27	12.15	4.60	3.56†	24.59
s.e. (12 d.f.)	0.113	0.336	0.135	0.607†	0.617
Mean	5.41	9.39	3.21	2.34†	19.39
Site:					
Non-irrigated	5.17	8.82	2.13	0.40	16.52
Irrigated	5.66	9.97	4.28	2.34	22.25

†With irrigation only (6 d.f.).

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Table 2. Main effects of sward type and irrigation on rates of leaf appearance and extension over a three-year period, 1990–92.

	Number of leaves appearing (per tiller per week)			Leaf extension (cm per tiller per week)		
	1990	1991	1992	1990	1991	1992
Number of periods	9	8	6	9	8	6
Sward type:						
Perennial ryegrass	0.495	0.420	0.465†	8.53	6.10	8.91†
Perennial ryegrass × meadow fescue	0.421	0.458	0.493†	8.46	7.21	10.98†
Meadow fescue	0.453	0.477	0.450†	6.92	6.08	8.36†
Tall fescue	0.386	0.335	0.330†	6.32	5.37	5.79†
s.e. (12 d.f.)	0.0208	0.0158	0.0305†	0.468	0.378	0.775†
Mean	0.439	0.423	0.435†	7.56	6.19	8.51†
Site:						
Non-irrigated	0.442	0.434	—	7.47	6.06	—
Irrigated	0.436	0.411	0.435	7.65	6.32	8.51

†With irrigation only (6 d.f.).

Table 3. Main effects of sward type and irrigation on oven-dry weight per unit area of fully expanded, green leaf blades and number of emerged leaves per tiller over a three-year period, 1990–92.

	Weight per unit area of leaf blade (mg cm^{-2})			Number of emerged leaves per tiller		
	1990	1991	1992	1990	1991	1992
Number of dates	6	6	8	8	7	7
Sward type:						
Perennial ryegrass	4.42	5.02	5.17†	3.98	4.02	4.19†
Perennial ryegrass × meadow fescue	4.00	4.70	5.18†	3.87	4.03	4.07†
Meadow fescue	3.78	4.30	4.25†	3.92	3.77	4.43†
Tall fescue	4.48	5.48	4.89†	3.43	3.02	4.50†
s.e. (12 d.f.)	0.086	0.148	0.367†	0.099	0.094	0.091†
Mean	4.17	4.88	4.87†	3.80	3.71	4.30†
Site:						
Non-irrigated	4.23	5.15	—	3.73	3.70	—
Irrigated	4.11	4.60	4.87	3.88	3.72	4.30

†With irrigation only (6 d.f.).

The rates of leaf appearance and extension were consistently lower in tall fescue than in the other grasses (Table 2). The weight per unit area of leaf blade was greater in perennial ryegrass and tall fescue than in meadow fescue (Table 3). The number of emerged leaves per tiller was lowest in tall fescue in 1990 and 1991, but not in 1992 (Table 3). The number of unemerged leaves per tiller was similar in each of the four grasses (Table 4). In 1991 the shoot apices of tall fescue were lower relative to ground level than those of the other grasses (Table 4). There were fewer sheaths protecting the shoot apex in tall fescue than in the other three grasses

Table 4. Main effects of sward type and irrigation on number of unemerged leaves per tiller, position of shoot apex relative to ground level and number of sheaths protecting the apex.

	Number of unemerged leaves per tiller			Position of shoot apex relative to ground level (mm)†		Number of sheaths protecting the apex	
	1990	1991	1992	1990	1991	1990	1991
Number of dates	8	7	7	8	7	8	7
Sward type:							
Perennial ryegrass	1.37	1.49	2.03‡	+1.83	+0.22	5.32	5.53
Perennial ryegrass × meadow fescue	1.45	1.47	2.07‡	+1.65	+1.01	5.37	5.50
Meadow fescue	1.43	1.56	2.00‡	+2.73	−0.11	5.32	5.32
Tall fescue	1.39	1.47	2.05‡	+1.75	−2.31	4.80	4.47
s.e. (12 d.f.)	0.045	0.042	0.114‡	0.273	0.447	0.095	0.115
Mean	1.41	1.50	2.04‡	+1.99	−0.30	5.20	5.21
Site:							
Non-irrigated	1.40	1.57	—	+1.88	−0.36	5.13	5.28
Irrigated	1.42	1.42	2.04	+2.11	−0.24	5.27	5.13

† + = above ground − = below ground, ‡ With irrigation only (6 d.f.).

(Table 4). There appeared to be no overall difference between the non-irrigated and the irrigated sites in respect of rates of leaf appearance and extension, number of emerged leaves per tiller, position of shoot apex and number of sheaths protecting the apex (Table 2, 3 and 4). In the second harvest year (1991) irrigation appeared to reduce weight per unit area of leaf blade and number of unemerged leaves per tiller (Table 3 and 4).

Tall fescue and meadow fescue had a higher average DM content than perennial ryegrass and perennial ryegrass had a higher average DM content than perennial ryegrass × meadow fescue (Table 5). In 1990 the proportion of cell content in leaf blade DM was greater in perennial ryegrass and perennial ryegrass × meadow fescue than in tall fescue and meadow fescue (Table 5). In 1991 the proportion of cell content was greater in perennial ryegrass than in meadow fescue and tall fescue and greater in perennial ryegrass × meadow fescue than in meadow fescue. In 1992 the proportion of cell content was greater in perennial ryegrass than in tall fescue and meadow fescue, and greater in perennial ryegrass × meadow fescue and meadow fescue than in tall fescue. Both DM content and the proportion of cell content in leaf blade DM appeared to be rather higher on average where water was not applied. The proportion of cell content was generally lowest in the summer (Fig. 1); the highest values were recorded in November 1990.

DISCUSSION

The herbage quality advantage of perennial ryegrass over tall fescue is illustrated by the percentage of cell content in leaf blade DM which averaged 57% in

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Table 5. Main effects of sward type and irrigation on percentage dry matter (DM) in total herbage and percentage cell content in leaf blade dry matter.

	Percentage DM	Percentage cell content in leaf blade DM		
	1989–91	1990	1991	1992
Number of dates	9	5	3	5
Sward type:				
Perennial ryegrass	22.68	58.1	56.0	56.3†
Perennial ryegrass × meadow fescue	20.84	57.1	54.1	55.2†
Meadow fescue	24.15	53.8	51.4	53.8†
Tall fescue	24.12	53.3	51.8	49.1†
s.e. (12 d.f.)	0.209	0.74	0.81	0.56†
Mean	22.95	55.6	53.3	53.6†
Site				
Non-irrigated	24.04	56.2	55.0	—
Irrigated	21.86	54.9	51.7	53.6

†With irrigation only (6 d.f.).

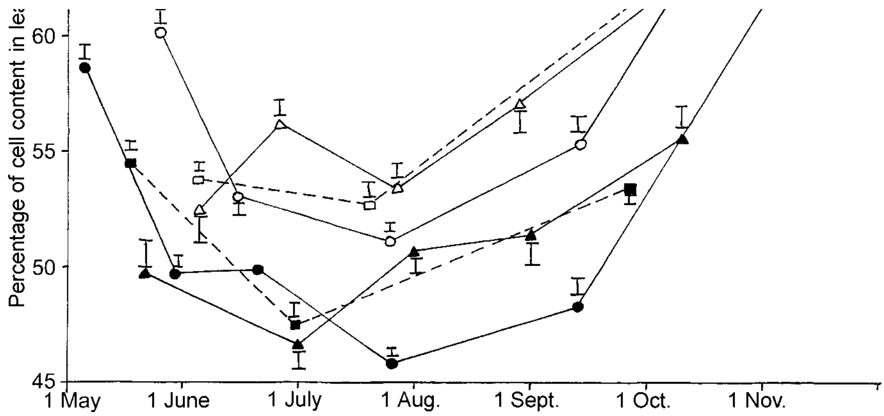

Fig. 1. Percentage cell content in leaf blade dry matter (DM) at different times of year in perennial ryegrass (open symbols) and tall fescue (closed symbols) in 1990 (○—○, ●—●), 1991 (□– – –□, ■– – –■) and 1992 (△—△, ▲—▲). Vertical bars indicate s.e.

perennial ryegrass compared with only 52% in tall fescue. These values were lower than those recorded in Experiment 1 of Wilman *et al.* (1996) at Aberystwyth (where the harvested herbage of perennial ryegrass contained an average of 61% cell content in the DM compared with 55% in tall fescue), probably mainly because of higher temperatures at Taigu than at Aberystwyth at most of the times when the crops were sampled (Soest, 1994). Similarly the lower values in July and August than in October and November in the present experiment (Fig. 1) were probably due mainly to the higher temperatures in the former than in the latter months. However, the difference in favour of perennial ryegrass was large and consistent in both environments and at all times of sampling.

At both Taigu and Aberystwyth the percentage of cell content in perennial ryegrass × meadow fescue was only a little lower than that in perennial ryegrass, whereas that in meadow fescue was similar to, or only slightly above, that in tall fescue. According to this evidence and that of Kunelius (1990), ryegrass × fescue hybrids can be expected to have a significant quality advantage over fescues. There may be environments in which this advantage can be exploited, if varieties can be produced which are sufficiently persistent and high yielding; such environments would be rather too harsh for perennial ryegrass, but not so harsh that it is necessary to use tall fescue. The ryegrass × fescue hybrid cv. Prior, used in the present experiment, yielded well in the year after sowing, but was little better than perennial ryegrass subsequently. It should be possible to produce ryegrass × fescue hybrids equal in quality to Prior, but higher yielding and suited to continental climates.

The relatively high yield of perennial ryegrass in the year of sowing in the present experiment suggests that this species can establish well and make good use of the summer climate in this environment. Its high rates of leaf appearance and extension and the large number of emerged leaves per tiller compared with tall fescue would contribute to relatively rapid establishment and relatively high yield in the year of sowing. On the other hand, perennial ryegrass may have been allocating a lower proportion of assimilates to developing its root system during the establishment period (Garwood and Sinclair, 1979; Wilman *et al.*, 1998), which may have made it more vulnerable to winter damage than tall fescue. The position of the shoot apex relative to ground level and the number of leaf sheaths protecting the apex may be among the other factors which affect the extent of winter damage. The shoot apex of perennial ryegrass seems typically to be rather higher, relative to ground level, than that of tall fescue (Table 4 and Wilman *et al.*, 1994), which may tend to leave the apex more exposed to frost and cold winds; on the other hand, ryegrass shoot apices appear to have more sheaths protecting them than those of tall fescue. It should be possible to produce varieties of perennial ryegrass which will survive cold, continental winters better than cv. Bastion, without losing high quality and vigour of establishment and growth.

The perennial ryegrass × meadow fescue hybrid outyielded perennial ryegrass decisively in the year after sowing, hinting at the potential for incorporating fescue genes in ryegrass to increase winter survival and subsequent yield in continental climates, without losing quality or vigour of growth. The rates of leaf appearance and extension were at least as high in the hybrid as in Bastion.

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