Performance of setaria in the northern North Island

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Abstract

Setaria sphacelata is a perennial C_4 grass that has high potential summer yield, but its persistence and cool-season production are poor. An experiment investigated whether a winter oats cover crop could negate these poor traits. While oversowing oats into established setaria increased total winter-spring herbage production, the use of a cover crop reduced setaria persistence despite minimum soil temperatures being 1.5°C higher. Starch and soluble sugar levels in three different leaf and stem fractions of setaria were low and showed little seasonal variation. *S. sphacelata* and *S. neglecta* plants that had survived previous evaluations were transplanted into a field nursery and screened for a further 3 years. From this nursery, blocks of four phenotypically different lines were then established and their performance (herbage production and quality) was assessed for 2 years. Mean annual yields of the more productive blocks were 12.5 t /ha, 60% of this occurring during January-March. Herbage quality was assessed as being low-medium, leaf *in vitro* digestibilities and crude protein being 70% and 12% respectively. Within this "persistent" population, soluble sugars in the basal fractions of the plant appear important in assisting cool-season persistence. The place of a perennial C_4 grass such as setaria in farm systems was investigated using the computer model Stockpol. A small specialist block of setaria may have merit for feeding breeding stock where there is a need to miriimise the risk of drought in northern zones of New Zealand.

Keywords: carbohydrates, cover crop, forage quality, persistence, *Setaria* spp.

Introduction

Low pasture growth from January to April regularly limits animal production in New Zealand's pastoral systems. The species sown in pastures are generally of temperate origin and a combination of low soil moisture and high temperatures during late summer-early autumn restricts growth. Annual summer crops can be sown to cover this deficit, but the cost of establishment can often negate the benefits.

In warmer areas of New Zealand, C_4 pathway grasses such as paspalum *(Paspalum dilatatum* Poir) and kikuyu *(Pennisetum clandestinum)* contribute significantly to warm-season pasture production (Lambert 1967); however feed quality of these species is often poor. Setaria (*Setaria sphacelata)* is another perennial C_4 grass, which can produce in excess of 20 t DM/ha annually (Taylor *et* al. 1976; Sithamparanathan 1979). However, poor persistence, low feed quality, low cool-season production and specific management requirements have meant that there has been little development of this species in New Zealand.

A long-term series of experiments was conducted at AgResearch Whatawhata Research Centre in the North Island of New Zealand (latitude 37°S) to investigate aspects of setaria persistence and production. The experimental region is classified as warm-temperate with a mean annual air temperature of 13°C, 42 ground frosts below -1 °C, 16 ground frosts below -3°C and rainfall of 1600 mm.

This paper reports on results from two experiments designed to test the ability of a winter cover crop and plant screening to improve setaria persistence.

Methods

Experiment 1 - Oats cover crop

The objective of this experiment was to assess the impact of a winter oats cover crop on cool-season herbage production and setaria persistence. In addition, the experiment provided an opportunity to monitor levels of non-structural carbohydrates throughout the year and to determine whether carbohydrate reserves are important in cool-season persistence.

A block of *S. sphacelata* (cv. Narok) was sown in early November, 1979 and divided into 8 plots of 0.011 ha each. The site was north-west facing with an 8" slope. Two treatments (with or without oats) were randomly allocated within 4 block replicates. On the appropriate plots oats were broadcast at 160 kg/ha in late March 1980 and trampled with sheep to ensure ground contact. After 22 days, oat seedling densities averaged 308/m². Urea was applied at 50 kg N/ha on 24 April, 12 June and 20 November 1980. Plots were grazed with cattle on 28 May, 7 October and 12 December 1980. Net herbage accumulation was determined by differences. in post and pre-grazing herbage mass which was estimated by cuts to ground level. A high post-grazing residual was left after the May grazing (≈3.0 t DM/ha) to enhance winter survival of setaria plants. Setaria tiller densities were determined in November 1980.

Factors that may have determined persistence were measured by the following methods. Temperature probes were placed in the O-5 mm soil depth zone and, between 10 July and 20 July, temperatures were measured in both treatments adjacent to setaria crowns. Bare ground and shaded air temperatures (I 00 mm above ground) were also measured. On 7 occasions throughout 1980, setaria plants were sampled from both treatments for the determination of non-structural carbohydrate (NSC) levels. Plants were broken into 3 fractions, viz:

1. leaf
2. leaf sheath (excluding the basal 30 mm of sheath)
3. crown (lower 30 mm of sheath plus basal stem)

Ground plant tissue (200 mg) were extracted to AOAC (1975) recommendations using 80% ethanol and total sugars were determined by the method of Bailey (1958). The residue was boiled in water and starch was determined as glucose by addition of amyloglucosidase and then glucose oxidase (AOAC 1975).

Nursery plantings

In November 1980, setaria plants that survived the cover crop experiment were sampled and transplanted into a field nursery that was adjacent to the experiment site, as were surviving plants of S. *neglecta* (various C.P.I. accessions) that had been planted in 1979. Climate records showed these years (1981-1983) as being near the long-term average for frost numbers (Table 1). Between 1980-1983, this nursery area was mob grazed with sheep and cattle.

Experiment 2 - Herbage production and quality of persistent lines

This experiment sought to quantify the production and herbage quality of a mixed *Setaria* spp. population made from plants that had survived 3-5 years of field screening at Whatawhata. These results would then provide some basis for assessing the likely role of setaria as a forage source within a farm systems context.

In December 1983 plants within the nursery were classified into 4 phenotypic groupings, viz: fine leaf width, medium leaf width, coarse leaf width with erect habit, and coarse leaf width with prostrate habit. Tillers were transplanted into 4 adjacent blocks on the basis of these classes. In autumn 1984, the morphological features of these 4 classes were visually scored (Table 2).

Subterranean clover (*Trifolium subterraneum* cv Tallarook) and white clover (*Trifolium repens* cv Grasslands Pitau) were broadcast sown between rows at the time of transplanting. The site was north facing with a slope of 20”. Urea was applied at 50 kg N/ha in November 1984. After a 12-month establishment phase, herbage yield was measured by cutting sample areas at a height of 100 mm from the base of the crown. Blocks were then grazed with sheep and cattle to 100 mm. When required, blocks were mown after grazing to remove reproductive stem material. These yield cuts continued for 2 years (June 1984–June 1986).

Forty tillers were sampled at dawn from each block at 7 harvest dates during the second production year. Tillers were broken into 3 fractions, viz:

1. leaf (leaf lamina plus sheath above 30 mm from crown base).
2. crown sheath (basal 30 mm of leaf sheath).
3. stem (underground stem plus the lower 100 mm of reproductive stem).

These fractions were analysed for NSC as described for experiment 1, for total nitrogen (Gehrke *et* al. 1972) and *in* vitro digestibility.

Table 1 Number of ground and screen frosts

	Ground frosts below -1°C	Screen frosts below 0°C
1979	19	7
1980	37	9
1981	44	6
1982	62	21
1983	45	14
1984	48	12
1985	39	8
1986	44	14
Mean 1952-1980	39.2	10.9

Table 2 Morphological features (mean of individual plant scores) of setaria blocks.

Block/Phenotype	Leaf width	Erectness	Heading
Fine leaf	1.21	4.04	3.10
Medium leaf	3.56	3.68	1.87
Coarse leaf, erect	4.00	4.79	1.14
Coarse leaf, prostrate	4.2	2.8	2.4
Scoring Criteria	1 = Fine leaved 5 = Coarse leaved	1 = Prostrate form 5 = Erect form	0 = No seed-heads 5 = Many seed-heads

Results and discussion

Experiment 1 -Winter oats cover crop

Net herbage accumulation andpersistence

Total net herbage accumulation was 30% greater where the oats cover crop was used (Table 3), the greatest increase occurring during the June-September period. The presence of a cover crop did, however, reduce setaria growth, particularly in mid-late spring as new season growth began. This lower setaria production reflected poor survival under a cover crop regime, with setaria tiller densities of 15/m^2 and 52/m^2 on 6 November, for with and without oats treatments respectively.

Table 3 Net herbage accumulation for experiment 1 (kg DM/ha).

	-- No cover crop --		---Covercrop---		
	Setaria	Other sp.	Setaria	Oats	Other sp.
9 Nov-14 Jan	1700	560	1630	0	500
16 Jan-21 Mar	3200	870	3350	0	1130
26 Mar-28 May	1370	90	870	1010	0
30 May-7 Oct	-1010	610	-1630	5690	0
7 Oct-12 Dec	2250	510	850	-1450	1100
Species total	7510	2640	5070	5250	2730
Treatment total	10150			13050	
SED			420		

Temperature

Differences between treatments in ground temperatures were greatest on 17-18 July (Figure 1). Minimum temperatures adjacent to setaria crowns were only 1.5°C higher where the cover crop was used. Further, daily maxima were lower in the cover crop treatment. While the sowing of oats provided some small measure of insulation, the benefits did not outweigh the competitive impact of the cover crop on setaria density and growth.

Starch and soluble sugar levels

Starch levels in all three fractions were similar and remained at a constant, relatively low level throughout the season (Figure 2). The November sampling was an exception which cannot be explained. Paspalum, a C_4 grass that survives in this experimental environment, has starch levels within its rhizomes that increase from 1.3% of herbage dry weight in summer to 10% in autumn (Thorn et *al.* 1989). This build-up of reserves is assumed to enhance its ability to survive over winter. No similar build-up was displayed in any of the three setaria fractions.

Soluble sugars (Figure 2) were least in the leaf lamina fraction during the winter-spring period when the leaves were chlorotic. Sugar levels in the basal crown fractions were higher, but showed no seasonal pattern of accumulation or usage. There were no significant differences in soluble sugars between treatments. It can be concluded that setaria plants had to rely on current photosynthates to survive through winter-spring. Given the apparent importance of retaining choroplast integrity during cold temperatures, a nursery was established to screen for plants that would survive climatic conditions at the experimental site.

Figure 1 Crown temperatures 17-18 July for setaria with oats (-----), setaria only (----) and 100 mm air temperature (———).

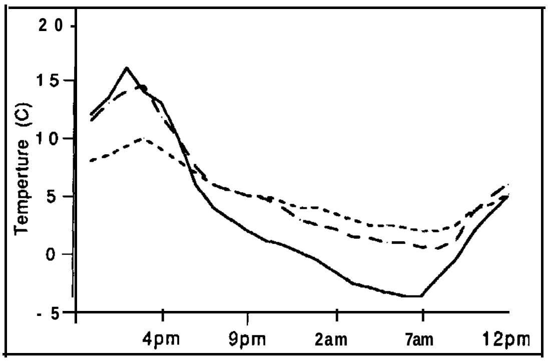
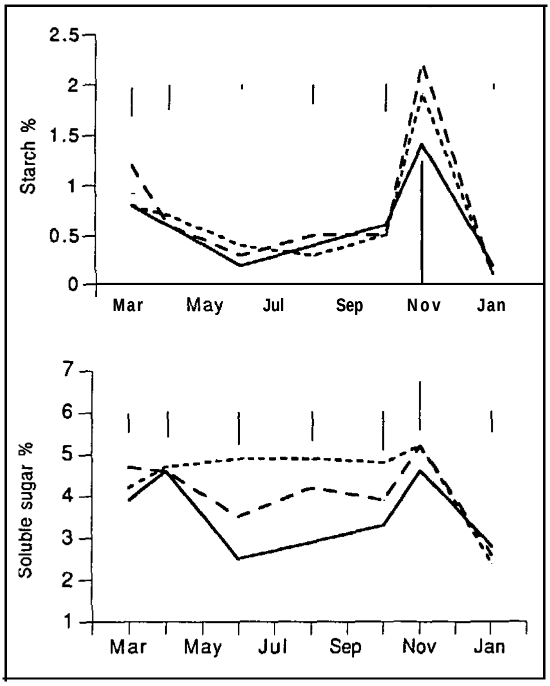


Figure 2 Starch levels and sugar levels (% of dry weight) for leaf ———), leaf sheath (----) and crown (-----) (bars show SED).



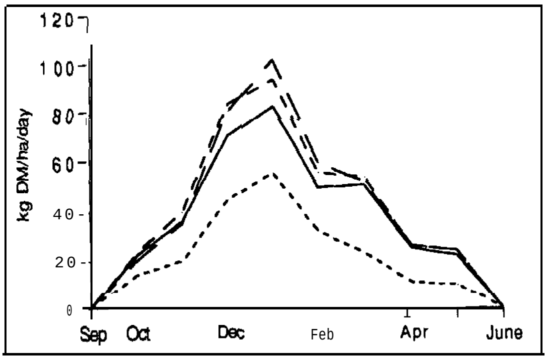
Experiment 2 -Production and quality of persistent lines

Herbage production

Total herbage production was least for the fine-leaf phenotype in both years (mean 6.8 t DM/ha). The other three lines had similar annual yield performances which across the two years averaged 12.5 t DM/ha. These production levels were well below the 25 t DM/ha yields in small-plot evaluations within this environment recorded by Sithamparanathan (1979). While the difference between experiments may highlight the dangers of extrapolating from small plots, it must be acknowledged that yields may have been greater in our experiment if more N had been applied. Although clovers were sown into the setaria blocks, their survival and production were negligible, apparently due to the vigorous, tall growth of setaria during summer-autumn.

Over the same two years, total annual production of improved ryegrass-white clover pastures grown on soils of similar slope and fertility averaged 12.7 t DM/ha (Gillingham et al. 1990). Whereas pasture production during January-March was 15% of the annual total, setaria achieved 60% of its annual production during the same period (Figure 3).

Figure 3 Interpolated growth patterns (mean of 2 years) for fine leaf (-----), medium leaf (––––) coarse leaf/erect (- -) and coarse leaf/prostrate (———).

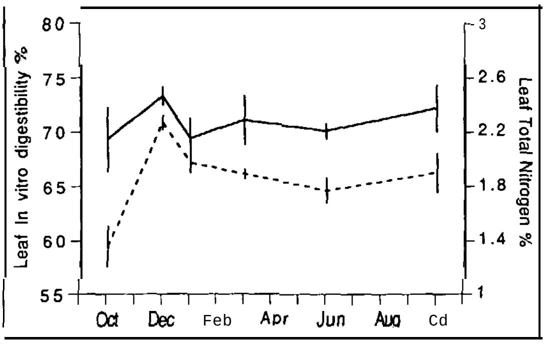


Herbage quality

While all three fractions were analysed for *in vitro* digestibilities and total herbage N, only the results from the leaf fraction are relevant to herbage quality. This fraction included leaf lamina and all but the bottom 3 cm of leaf sheath. Leaf digestibility remained constant throughout the year (Figure 4). Digestibility levels of 70% would be similar to that of controlled leafy pasture of temperate species during summer (Waghom & Barry 1987). While this might suggest that setaria leaf will provide an above-maintenance diet, it must be stressed that dried herbage samples were ground rather than minced and may therefore overstate actual quality (Waghom & Caradus 1994).

Total N in the leaf fraction was generally consistent at around 1.8–2.0% of dry weight. The low value recorded in the October 1984 sampling was not repeated in the same month one year later. This level of total N would equate to approximately 12% crude protein, a level that is very close to minimum requirements for ruminant growth (Waghorn & Barry 1987).

Figure 4 *In vitro* digestibility (———) and total nitrogen (-----) levels of setaria leaf component, mean of 4 phenotypic groups (bars show SED).



Soluble sugars and starch levels

Starch levels in all three fractions were consistently low throughout the year (Figure 5). These results reinforce those of experiment 1 and work by Davies & Forde (1991), and indicates that starch is of little importance to the carbon economy of setaria.

In contrast to the results of experiment 1, soluble sugars displayed a marked seasonal pattern and during winter-spring high levels were recorded in basal stem and sheath fractions (Figure 5). Levels of 10-15% of dry weight were higher than those reported for Narok stems by Davies & Forde (1991). These high levels were measured in a mixed population of *S. sphacelata* and *S. neglecta* plants that had demonstrated persistence at Whatawhata. Current soluble sugar status in basal fractions of setaria therefore appear to be important to its cool-season survival.

Application of setaria in farm systems

Perennial setaria species can be considered as a low-medium quality forage source that could augment pastures in summer-dry, warmer regions of New Zealand. They could minimise risk in drought-prone areas.

The possible role of setaria was assessed in a Northland farm system using the computer model

Figure 5 Starch levels and sugar levels (% of dry weight) for leaf (-), crown sheath (-----) and stem (----) (bars show SED).

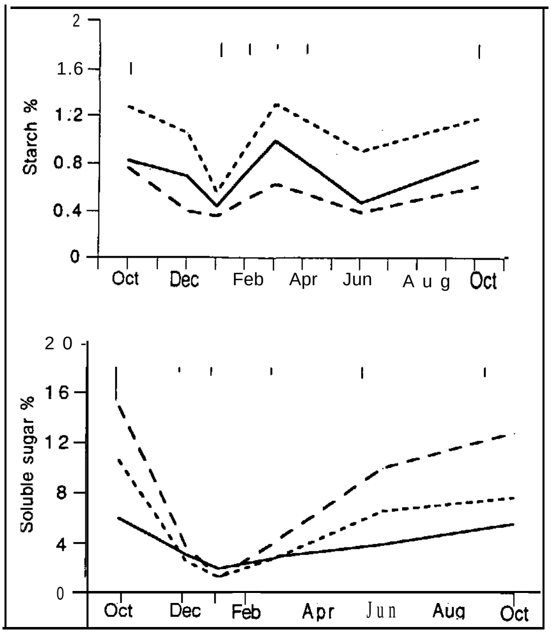
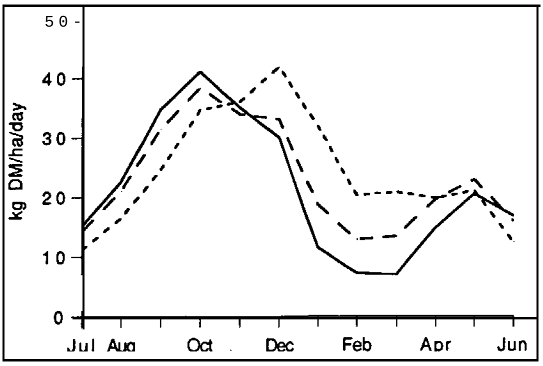


Figure 6 Simulated farm pasture supply patterns for no setaria (———), 10% setaria (----) and 30% setaria (-----).



Stockpol (Marshall *et* al. 1991). The simulated model farm had a sheep:cattle ratio of 40:60, the cattle being Friesian bulls bought in at 3 months and sold at 20 months. Setaria herbage growth rates were interpolated on a monthly basis from the yield cuts of experiment 2 (Figure 3) and forage quality was judged as medium. The mean of 3 years' (1989-92) pasture growth rates on a Northland farm (Webby & Sheath 1991) were also used in the analysis. Three scenarios were tested, viz. no setaria, 10% of farm area in setaria and 30% in setaria.

The introduction of 10% of farm area in setaria reduced total pasture supply slightly during winter and spring, but nearly doubled supply during January-March (Figure 6). The 30% scenario reduced winter and spring supply significantly, but nearly tripled summer supply. Using the described stock policy, stocking rates could be increased by 22% and 25% for the 10% and 30% setaria scenarios respectively. Alternatively, the addition of such a perennial summer-growing species would sustain breeding stock liveweights during and following difficult dry periods and thereby reduce competition for forage with younger, growing livestock. Ideally this would be breeding cows, as experience has shown that sheep grazing alone at Whatawhata has not adequately controlled reproductive stem growth of setaria.

If setaria is to have a role, it will be on the basis of being a small, specialist block on the farm. It is unlikely to be compatible with temperate grasses, but investigation into successful legume comparisons would benefit forage quality. Since the end of experiment 2, the setaria blocks have received a further 9 years of sheep and cattle grazing as per normal farm practice. Surviving plants are an important resource and have recently been sampled for further study and possible development in Northland.

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