Evaluation of sorghum, sudan-grass and pearl millet cultivars in Manawatu

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Abstract

Sorghum, sudan-grass and pearl millet are versatile summer forages able to be grazed or conserved as silage. However, there is little recently published information on the performance these crops in New Zealand. A trial was carried out at Massey University, Palmerston North, to compare forage yields and crop morphology of four sorghum *x* sudan-grass hybrids (Pac 8421, Pac 8423, Pacific BMR and Bettagraze), two sudan-grass (Superdan 2 and Sprint) and one pearl millet (Nutrifeed) cultivars sown on the 8 and 21 December 2009. At final harvest, 57 and 58 days after sowing for the first and second sowing dates respectively, dry matter yields decreased (P<0.005) with delayed sowing from 12,792 kg ha^{-1} to 11,356 kg ha^{-1}. There were cultivar differences (P<0.0001) at both sowing dates. Mean yields (across sowing dates) ranged from 9,823 (Nutrifeed) to 13,953 kg DM ha^{-1} (Pac 8423). There was a significant interaction (P<0.0001) between sowing date and cultivar for yield at the second harvest; cultivar differences for the first sowing date were larger than for the second, which suffered more from cool autumn temperatures. There was a strong, positive, linear relationship between plant height at harvest and DM yield ($R^2 = 0.69$). Mean leaf:stem ratio, for the first sowing (1.9), was significantly (P<0.001) higher than in the second sowing (1.8) and was influenced by cultivar.

Additional keywords: Sorghum, sudan-grass, pearl millet, maize, sowing date, yield, plant height, leaf: stem ratio

Introduction

Sorghum (*Sorghum bicolour* (L.) Moench), sudan-grass (*Sorghum sudanense* (Piper) Stapf.) and pearl millet (*Pennisetum glaucum* (L.) R. Br.) are warm-zone cereals grown as forage for livestock in regions where high temperature and low rainfall, during late summer and early autumn, result in feed deficits on pastoral farms. Sorghum can be classified into 3 groups; forage sorghum, sudan-grass and sorghum *x* sudan-grass hybrids (Douglas, 1980). Forage sorghums are mainly ensiled or made into hay while sudan-grass and sorghum *x* sudan grass hybrids are primarily grazed *in situ*. The base temperature for sorghum ranges from 8-12°C (Hammer *et al*., 1989) and for pearl millet, 10-12°C (Ong and Monteith, 1984). Soil temperatures, at 10cm depth, of at least 16-18°C are required for good establishment of these crops (Gerlach and Cottier, 1974). The optimum temperature for growth of sorghum is 25-30°C (Ketterings *et al*., 2007).

New Zealand has undergone considerable

changes in precipitation pattern over the past three decades meaning that drier summers and autumns are now more prevalent in the North Island (Ummenhofer *et al*., 2007). This reduces pasture production, resulting in reduced milk yields in dairy cows and growth rates in beef cattle (Cox, 1968). Forage sorghum, sudan-grass and sorghum *x* sudan-grass hybrids are often utilised for supplementary feed in these situations, particularly where crops are required for grazing *in situ* rather than silage. The main summer cereal crop in New Zealand, maize, is generally preferred because it is capable of producing higher yields of high quality silage, but it is not suitable for grazing (Douglas, 1980).

Attributes of these warm zone cereals include heat and drought tolerance, high yield potential, good water use efficiency, good re-growth potential after cutting or grazing and few pest and disease problems. Consequently, livestock farmers in cooler areas, such as the southern North Island, are interested in growing these crops even though they require warmer temperatures for germination and growth than other summer cereal forages e.g. maize (*Zea mays* L.) (Douglas, 1980).

Some research was carried out on these crops during the 1970's (Cottier, 1973; Gerlach and Cottier, 1974) in New Zealand, but there has been little recent research on their performance. This trial was undertaken to evaluate the performance of a range of currently available cultivars and cultivars being assessed for release in New Zealand.

Materials and Methods

The trial work was conducted on the Pasture and Crop Research Unit, Massey University, Palmerston North (40°22'56.29 S, 175°36'26.20 E). The soil type is a Manawatu sandy loam, a recent soil from alluvium, proximate to the Manawatu River. Previously the paddock had been in ryegrass-white clover pasture (4 years). Before sowing, soil nutrient analysis was conducted to the depth of 15cm to determine soil nutrient status (Table 1).

Table 1: Soil nutrient analysis of soil on the Pasture and Crop Research Unit

Nutrient	mg kg^{-1} of soil
Nitrogen	76.81
Phosphorous	36
Potassium	86.02
Calcium	1380
Magnesium	146.41
Sodium	27.6

This revealed adequate levels of phosphate and potassium, consequently only nitrogen (N) fertiliser (100 kg N ha^{-1}) was applied after crop emergence. Glyphosate herbicide was sprayed at 3 kg ha^{-1} to kill existing vegetation plants prior to cultivation. Hand weeding and hoeing were used to control weeds that emerged during the growing period.

Four sorghum *x* sudan-grass hybrids (Pac 8421, Pac 8423, and Pacific BMR, all brown midrib (BMR) hybrids, and Bettagraze), two sudan-grass (Sprint and Superdan 2) and one pearl millet (Nutrifeed) cultivar were evaluated. One maize hybrid (P39G12) was included in the trial for comparative purposes.

Treatments were arranged in a completely randomised block design with 4 replicates. The trial was sown on 8 December and again on 21 December 2009 (re randomised) at the same site after soil temperature had reached 16 to 18°C. Maize was only sown in the early trial. All plots apart from maize were sown with a cone seeder (15 cm row spacing) and were 10 m long and 1.5 m wide. Maize plots consisted of 4 rows spaced at 75 cm. Sowing rates (20 and 15 kg ha^{-1}) were used to target plant populations of 90 to 110 and 90 to 120 plants m^{-2} for sorghum and pearl millet respectively. Maize was sown by hand at 110,000 seeds ha^{-1}.

Meteorological data was obtained from the AgResearch Grasslands weather station located 300 m from the trial site. Plant height (PH), tiller density, dry matter yield (DM), and growth rate were determined. Plant height was measured weekly as the height between the horizontal curve of the tallest leaf and the soil surface. The first cuttings of both sowings and second cutting of the first sowing were done at approximately 100 cm plant height, in accordance with recommended management for each cultivar (Cottier, 1973; Pacific Seeds, 2009). However, the second cutting of the second sowing was taken at 50 cm because of frosting. After the first harvest, plots were immediately trimmed to 15 cm using a sickle-bar cutter to allow re-growth. Four 0.15 m^2 quadrants $plot^{-1}$ were sampled for yield determination. The two outer rows of each plot were not sampled. The first and second cuts of the first and second sowings were done on 2 February and 22 March and 16 February and 26 March 2010 respectively for all cultivars. Maize was harvested on 20 April 2010 at approximately 30 to 35% whole crop dry matter (DM). After weighing, ten tillers were randomly sampled from harvested material from each plot to determine the % DM, and dissected into leaf and stem components to allow calculation of the yield of each component and the leaf:stem ratio. Three maize plants were collected for calculation of % DM. All samples were dried in a forced air oven at 70°C for 72 hours or until no further weight loss recorded (maize).

The Proc GLM procedure of SAS was used to analyse treatments effects using a combined analysis of sowing dates. Least significant differences were used to separate means at P=0.05. Proc CORR was used to explore the association between yield and other agronomic characteristics (plant height and tiller density). sowing date and cultivars were treated as random effects.

Results

The 2009 spring in Palmerston North was cold and wet, meaning that soil temperatures did not reach the minimum required for germination of these warm-zone crops until early December (Table 2). Temperatures were below the long term mean (1928-1980) in November and December 2009 and in March 2010, however, above average temperatures were experienced in February 2010. Air and soil temperatures were higher in the later sown crop during establishment and from emergence up until the first cut but cooler temperatures in March 2010 resulted in the mean temperature after the first cut in the second sowing being lower than the first sowing (Table 3).

Table 2: Mean air temperatures (°C) for the 2009-2010 season compared with the long term mean (1928-1980 (NZMS, 1983)), recorded at AgResearch Grasslands (40°23'S, 175°37'E), Palmerston North.

	Month				
	November	December	January	February	March
2009-2010 mean	13.0	15.4	17.3	18.7	15.9
Long term mean	14.2	16.1	17.3	17.6	16.4

Table 3: Summary of mean air and soil temperatures (°C) for each crop production phase at each sowing date. Temperatures recorded at AgResearch Grasslands, Palmerston North.

	Sowing date			
Growing period (2009-2010)	8 December		21 December	
	Air	Soil	Air	Soil
Sowing to emergence	15.0	15.5	17.1	17.6
Emergence to first cut	17.1	17.7	17.8	18.1
First to second cut	17.4	17.8	16.6	16.9
Mean	16.5	17.0	17.2	17.5

There were significant yield differences among cultivars for the first cut and total yield (Table 4). The highest yielding group of cultivars included Pac 8423 (13,953 kg DM ha^{-1}), Bettagraze (12,704 kg DM ha^{-1}) and Sprint (12,426 kg DM ha^{-1}). At the second harvest there was little effect of cultivar from the second sowing date, but there was a large cultivar effect at the first sowing date (Pac 8421 and Pac 8423 were much higher yielding). Leaf to stem ratio's ranged from 1.8 to 2.0 and 1.5 to 1.7 for the first and second cut respectively. There was no influence of cultivar on leaf to stem ratio. Tiller density was strongly influenced by cultivar; Sprint and Superdan 2 had higher tiller densities than all other cultivars at both harvest.

Sowing date had a significant effect on yield at both harvests and on total yield; total yield was highest for the 8 December sowing (12,792 kg DM ha^{-1}) compared with 21 December (11,356 kg DM ha^{-1}). However, the effect of sowing date varied with harvest period. For the first cut yields were higher with later sowing whereas for the second cut yields were higher with earlier sowing. The relative difference was highest for the second cut where yields for the early sowing were more than twice those of the later sowing. This is reflected in growth rates for each sowing date over each harvest period. Mean growth rates were highest at the second cut (129.6 kg ha^{-1} day^{-1}) for the early sowing but for the later sowing date growth declined (77.8 kg ha^{-1} day^{-1}) greatly over the second harvest period. Leaf to stem ratio was not influenced by sowing date but there was a small sowing date effect on tiller density for the first cut; earlier sowing producing more tillers than later sowing.

Interactions between cultivar and sowing date were observed for yield at the second cut and the leaf to stem ratio for the first cut (Table 4). The interaction between cultivar and sowing date for yield at the second cut is shown in Figure 1. Pac 8423 and Bettagraze had higher second cut yields than all other cultivars when sown early but were similar to the other cultivars with later sowing. The interaction between cultivar and sowing date for the leaf to stem ratio arose because in Nutrifeed the leaf to stem ratio for the first cut increased with later sowing, whereas in all other cultivars the ratio declined, though in Pac 8423 and Pac 8421 the decline was minor (Figure 2).

Table 4: Combined analysis of yield (kg DM ha^{-1}), leaf to stem (L:S) ratio and tiller density (tillers m^{-2}) for the first and second harvest, and total dry matter (TDM).

Cultivar	Yield			L:S ratio		Tillers	
	Cut 1	Cut 2	TDM	Cut 1	Cut 2	Cut1	Cut 2
Bettagraze	7213	5491	12704	1.8	1.6	240	340
Nutrifeed	5848	3975	9823	1.8	1.6	332	308
Pac 8421	7325	3469	10794	2.0	1.7	249	348
Pac 8423	8206	5747	13953	1.9	1.6	233	338
Pacific BMR	6125	3970	10095	1.9	1.6	192	277
Sprint	7994	4432	12426	1.8	1.5	378	520
Superdan 2	7365	3849	11214	2.0	1.6	376	518
Significance	0.03	NS	0.007	NS	NS	0.0001	0.002
$LSD_{(0.05)}$	1280	-	1674	-	-	29	86
December 8	6997	5959	12792	1.9	1.6	297	381
December 21	8837	2879	11356	1.8	1.6	254	376
Significance	0.02	<0.0001	0.005	0.0001	NS	0.03	NS
Interaction	NS[1]	0.02	NS	0.001	NS	NS	NS

[1]NS=Not significant at P=0.05 probability level.

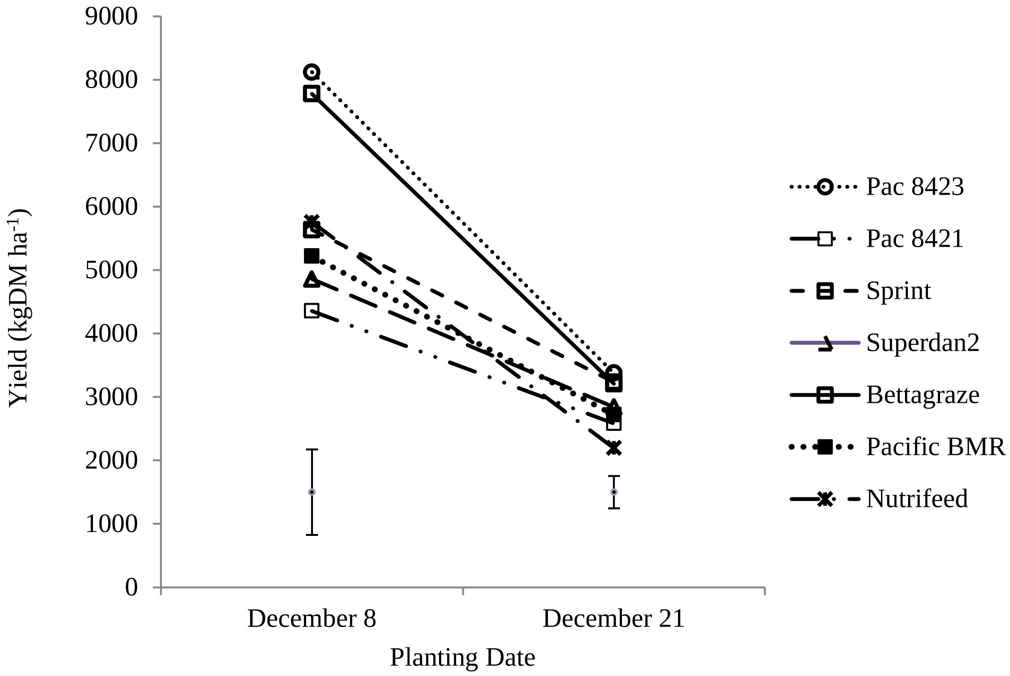

Figure 1: The interaction between sowing date and cultivar on yield at the second harvest.

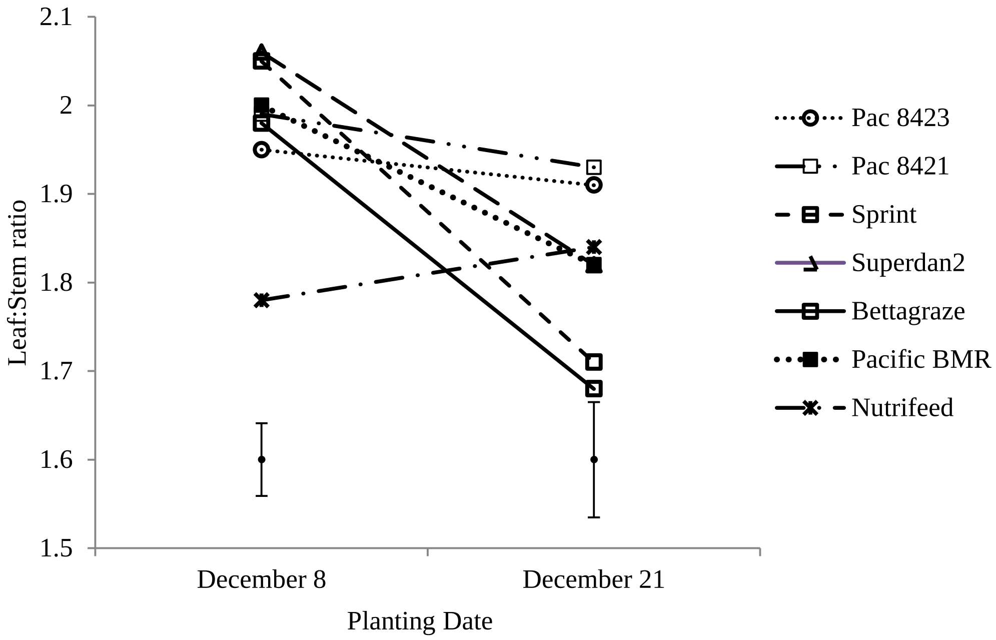

Figure 2: The interaction between sowing date and cultivar on leaf to stem ratio at the first harvest.

Plant height was measured at the time of each yield assessment. The mean height at the first cut was 135.1, 130.1, 129.9, 118.9, 113.8 and 98.8 and 87.7 cm for Pac 8423, Sprint, Bettagraze, Superdan 2, Pac 8421, Pacific BMR and Nutrifeed, respectively. The association between height, tiller density and yield was initially explored with correlation analysis. There was no correlation between yield and tiller density but yield showed a high significant linear relationship with plant height (Figure 3).

Date of 50% ear emergence was monitored in all plots; ear emergence only occurred in the early sown plots and only in Bettagraze, Pac 8421, Pac 8423 and Sprint which reached 50% ear emergence 73, 89, 78 and 81 days after sowing, respectively. The onset of cool temperatures in March (Table 2) and the damaging effect of frost (grass minimum temperatures of -0.8 and -3.2°C on 13 and 18 March, respectively) effectively halted development.

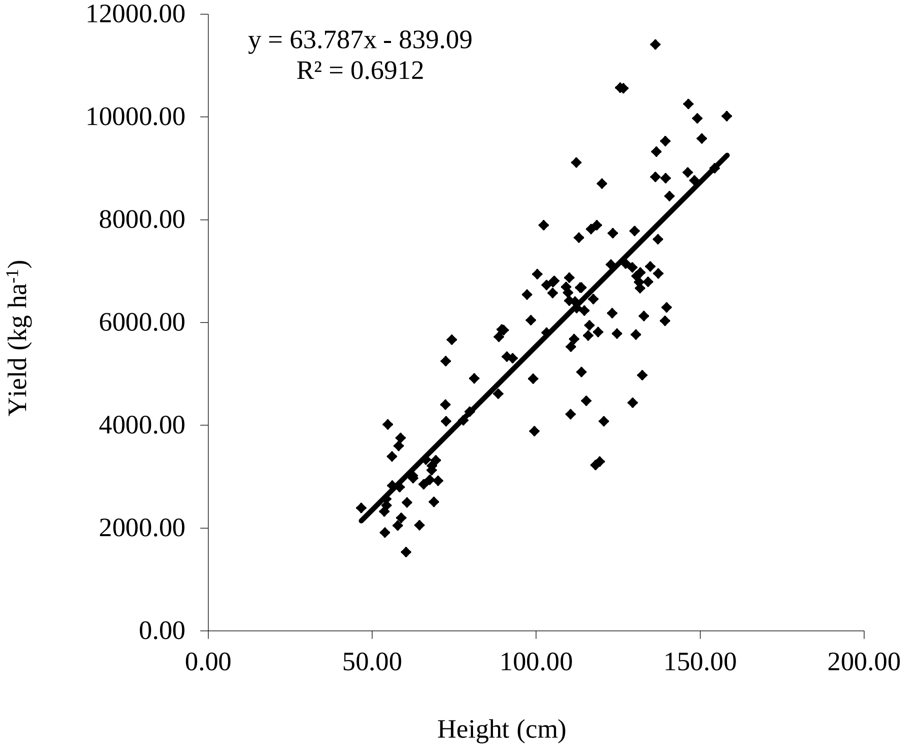

Figure 3: The regression between yield and plant height for different cultivars at both sowing dates and harvests.

Discussion

Yields achieved by the better performing cultivars in both the early and later sowings in this study are generally higher than yields previously reported in New Zealand. This can be attributed to cultivar improvement. For example Gerlach and Cottier (1974) reported yields between about 9,400 and 9,700 kg DM ha^{-1} for sudan-grass and sorghum-sudan-grass hybrids, respectively after 77 days. Cottier (1973) reported yields of 6610, 8520 and 8010 kg DM ha^{-1} for Japanese millet (*Echinochola crus-galli* (L.) P. Beauv.), sorghum *x* sudan-grass and sudan-grass, respectively. In this study yields in the later sowing were initially better than for the earlier sowing but regrowth following the first harvest was poor, a result of declining autumn temperatures (Table 2). Optimum temperature for these crops is above 25°C (Sullivan, 1961) whereas the mean temperature in March 2010 was 15.9°C.

It is probable that yields could have been higher if sowing was earlier than 8 December (Causley, 1990). In this study sowing date was delayed by low soil temperatures but soil temperatures in the Manawatu generally reach the minimum required for germination of these crops in mid-November (NZMS, 1983). While there is an increased risk of frost with earlier sowing, frosted crops can recover and go on to produce high yields. However, this is dependent on growth stage (Causley, 1990). Causley (1990) reported total yields for a sorghum-sudan-grass hybrid ranging between 21,300 kg ha^{-1} for an early November sowing to 11,800 kg ha^{-1} for a late December sowing.

The performance of Pac 8423 and Pac 8421, which both carry the brown midrib gene (BMR), was better than that of Pacific BMR, an established cultivar which also carries the brown midrib gene. The brown midrib gene improves the digestibility of forage by decreasing lignin content in the dry matter. Miller and Stroup (2004) found that the BMR trait was associated with low vigour and low yield, however in this study the two experimental cultivars, particularly Pac 8423 performed well.

Nutrifeed, a pearl millet cultivar, produced the lowest yields in both sowing dates. Anderson and Guyer (1986) reported similar results. Nutrifeed tiller density declined after the first harvest, in contrast to all other cultivars. Millet has been found to generally produce less regrowth following cutting or grazing than sorghum (Douglas, 1980). In this study this may have been exacerbated by Nutrifeed being sensitive to the cooler conditions (Rachie and Majmudar, 1980), resulting in reducing regrowth due to the lower temperatures experienced after the first cut in the second sowing (Table 3). Tiller density in the sudan-grass cultivars was greater than in the sorghum *x* sudan-grass cultivars, a reflection of the greater tillering ability of sudan-grass (Anderson and Guyer, 1986). Tiller density was greater after the first harvest at both sowing dates, probably because the environmental conditions, particularly temperature, enhanced tiller production (Piggot and Farrell, 1984). Also, cutting to 15 cm will have greatly increased the light reaching suppressed tillers below 15 cm.

In previous comparisons of maize with sorghum in New Zealand, most studies have found that the maize produced higher yields, the difference being less in northern areas of the country (Douglas, 1980). In this study maize was included in the early sowing for comparative purposes, producing a yield of 17,437 kg DM ha^{-1}, higher than any of the sorghums. However, this yield was accumulated over a longer growth period. Final harvest for the sorghums from the first sowing occurred on 22 March whereas the maize plots were harvested on 20 April. The 8 December sowing date is late for maize, even for early maturing hybrids (Wilson *et al*., 1994). Mean growth rates for the best sorghum cultivar (Pac 8423) and maize (P39G12) were similar; 131.1 kg DM ha^{-1} day^{-1} and 146.2 kg DM ha^{-1} day^{-1} for P39G12 and Pac8423 respectively.

The mean leaf to stem ratio for the first cut of all cultivars was higher than that for the second cut (Table 4) indicating that forage quality was probably higher for the first cut (Elseed *et al*., 2007). This may be because tiller density increased after the first cut, resulting in increased competition for light which induced greater stem elongation (Caravetta *et al*., 1990). In this study there was a significant, but relatively weak (r = -0.34), negative correlation between tiller density and the leaf to stem ratio.

The relationship between height and yield in this study was quite strong (R^2 = 0.69). A strong positive correlation between plant height and total biomass yield in sorghum has been previously reported (Maiti and Soto, 1990; Brito *et al*., 2000). The association between height and yield suggests that height might be used to estimate yield (Piggot, 1989) which would assist farmers with feed budgeting.

Conclusion

Sowing date had a significant effect on the forage yields of sorghum, sudan-grass and pearl millet cultivars used in this study, Delaying sowing reduced yields overall possibly because cool autumn temperatures advanced senescence and growth. Initially however, later sown plants grew better than early sown because they experienced higher temperatures after emergence which enhanced growth. There were significant cultivar differences, the highest yielding group included Bettagraze, Sprint and Pac 8423. Plant height was positively correlated to yield.

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