Optimising barley biomass production through phenology and plant architecture in mixed farming systems

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Key findings

- At Giles Corner in 2024, grain yield was significantly higher in elite spring grain varieties compared to winter types with Neo CL (5.58 t/ha) and Titan AX (5.44 t/ha) being top performers.
- The yield of simulated grazed plots compared to un-grazed (control) achieved similar grain yields in majority of treatments.
- Improved harvest index in grazed plots helped maintain high grain yields compared to lower harvest index achieved in the un-grazed (control).
- The variety Beast was a top performer for early season DM production and total seasonal forage value compared to other varieties tested.
- The winter type variety Newton had three simulated grazes in the Up to Z (Zadocks) 30 treatment removing a cumulative total of 3.13 t/ha DM, prior to additionally yielding 3.39 t/ha of grain.

Introduction

Barley is a versatile species for mixed farming systems because it offers opportunities for fast feed production for livestock as well as reliable grain production across varied seasons. Previous work has demonstrated the benefits of wheat, and to a less extent barley, in providing dual purpose (graze and grain) crops that maximise gross margins in the medium-high rainfall zones. Other recent work with wheat has shown the value of sowing slower developing winter wheats early. The release of new winter barley phenologies, as well as different canopy architecture types, may provide more opportunities to optimise barley biomass for forage, grain, or opportunistic grain and graze scenarios in different environments. The aim of this SA Discovery Farms and SAGIT co-funded project is to identify opportunities to exploit new barley phenologies and architecture types to further improve mixed farming production across variable growing seasons.

Methodology

A field trial was established at Giles Corner on a red clay loam over rock soil, which was dry sown on May 14 with germination occurring after season breaking rains on June 1. Rainfall for the growing season totalled 232 mm (April-October), which was in the lowest 10% of years for Giles Corner (Decile 1). There was limited heat stress during the growing season, but there were several frost events, with significant ones including: -3.3°C September 13, -3°C September 18, -1.4°C September 26 (measured at 1.2 m by a TinyTag within a Stevenson screen). Weeds, pests and diseases were managed using local grower practice and as to not limit grain yield. Starting soil nitrogen was approximately 125 units on a 2023 bean stubble. At sowing, 100 kg/ha DAP was added and topped up with 100 L/ha UAN across the site on July 30. There were 10 barley varieties that varied for both phenology and plant architecture, with a summary of each in Table 1. Varieties were sown to target 150 plants/m^2 with sowing rate adjusted for seed size. Four different grazing treatments were used to demonstrate different use cases of barley in mixed farming systems. A summary of each treatment is presented in Table 2, where a mower was used to simulate grazing for each grazing treatment.

Table 1: Barley varieties used in the trial with relative plant type, maturity and release year.

Variety	Plant Type	Maturity Group	Release year
Beast ⦶	Tall	Quick spring	2020
Neo ⦶ CL	Semi-prostrate	Mid spring	2023
Kraken ⦶	Semi-prostrate	Mid spring	2021
Maximus ⦶ CL	Erect	Quick-mid spring	2020
Newton ⦶	Prostrate	Slow winter	2023
Titan AX ⦶	Tall	Mid-slow spring	2022
RGT Planet ⦶	Semi-prostrate	Mid spring	2017
Cyclops ⦶	Erect	Quick-mid spring	2022
SEC047	Tall	Very quick spring	Not released
AGTB1007	Semi-prostrate	Winter	Not released

Table 2: Four grazing treatments with the farming system scenario, activities performed and projected outcomes of each. Z30 = Zadoks growth stage 30 (start of stem elongation, Zadoks, 1974).

Treatment	Scenario	Grazing Activity	Outcome
Untreated control (UTC)	Grain	None, managed as a grain crop	Un-grazed grain yield benchmark
Up to Z30	Rotational grazing to Z30 and grain	Multiple grazes before Z30 (springs x2, winters x3 mows), before being left for grain	Value of longer phenological vegetative phase duration of winters and final grain yield
Z30	Graze and grain	Single graze at Z30 (mown once), before being left for grain	Total vegetative biomass production value and final grain yield
Forage	Continuous grazing	Repeated grazing at regular time intervals during the growing season (July 23, August 9, September 3)	Total seasonal biomass/forage production value for each variety (re-growth potential)

The main measurements taken and discussed within this report are growth stage, dry matter (DM) removed from each grazing, harvest index (HI) and grain yield. Quadrat hand cuts were conducted on plots immediately before being mowed, representing the amount of biomass removed per m^2, which was dried at 60°C for DM. Further analysis is still to come on feed/hay quality, tiller counts, grain quality and a financial breakdown of gross margins.

The trial was a split plot design with grazing treatment being the main plot and variety the sub plot with four replicates. Plot size was 5 m x 1.37 m with 6 rows at 22.86 cm spacings, and plot centres 1.8 m. Data was analysed spatially using a linear mixed model (REML) through statistical package GenStat 23rd Edition at the 5% significance level and by multiple comparisons through a Bonferroni test.

Results and Discussion

Varietal differences in grain yield in response to grazing treatments

Grain yield varied considerably across treatments, with there being a significant interaction of grazing by variety ($p<0.001$). Displayed in Table 3, grain yields achieved were reasonable considering the Decile 1 rainfall, with most treatments falling between 3 to 6 t/ha. For the un-grazed grain plots (UTC), all the elite commercial spring phenology varieties performed well, with Neo CL being the standout out at 5.58 t/ha grain yield. Kraken, a spring forage variety was significantly lower yielding, which was to be expected with it being bred mainly for forage production. The very quick developing breeding line SECO47 was also considerably low, which was likely in combination with a severe frost event on September 13 (-3.3°C). Visual observations two weeks post the frost event identified floret sterility on heads and stunted/pinched grains. The winter phenology types, Newton and AGTB1007 were significantly lower yielding than Neo CL in the UTC, likely related to the late seasonal break an establishment occurring in June. However, AGTB1007 was competitive with other elite spring grain varieties, with no significant difference in grain yield to RGT Planet, Cyclops and Beast, indicating that it may have a more flexible sowing window than other winter types.

Table 3: Grain yield of every variety for grain (UTC), as well as grain and graze (Z30 and Up to Z30) treatments. There was a significant grazing x variety interaction, so different letters represent significant differences between treatments.
** SEC047 UTC experienced a significant frost event at flowering, which likely reduced yields, interpret with caution. na = data not available*

Grain Yield (t/ha)	**Grain and Graze Treatment**		
Variety	**UTC**	**Z30**	**Up to Z30**
Beast ⓓ	4.99^{hi}	4.89^{hi}	5.01^{hi}
Cyclops ⓓ	5.33^{hij}	5.00^{hi}	4.92^{hi}
Kraken ⓓ	3.22^{abc}	3.80^{cde}	4.00^{def}
Maximus ⓓ CL	4.94^{hi}	4.92^{hi}	4.67^{fgh}
Neo ⓓ CL	5.58^{ij}	5.77^{j}	5.51^{ij}
RGT Planet ⓓ	5.15^{hij}	5.18^{hij}	4.95^{hi}
Titan AX ⓓ	5.44^{ij}	5.37^{hij}	5.33^{hij}
SEC047	*3.06^{ab}	3.78^{cde}	na
AGTB1007	4.72^{gh}	3.69^{b-e}	4.16^{efg}
Newton ⓓ	4.01^{d-g}	2.82^{a}	3.39^{a-d}
P-value (grazing x variety)	**<0.001**		

The influence of grazing on grain yield was minor for all spring types, with all producing no significant reduction in grain yield compared to the UTC. Again, Neo CL was the standout across grazing treatments, even achieving a small non-significant increase in grain yield in response to a single simulated graze at Z30. Newton and AGTB1007 had significant yield reductions from the Z30 treatment compared to the UTC. However, in contrast both varieties did not have a significant reduction in grain yield for the Up to Z30 grazing treatment compared to the UTC. Both varieties received three simulated grazes for this treatment due to them reaching Z30 much later than the spring types. This extended vegetative phase allowed for more time for potential grazing, resulting in more biomass removal before getting locked up for grain. This longer phase and higher biomass grazed off likely resulted in the reduction in grain yield in a dry finish to the season, which will be discussed further below.

Potential for significant grazing prior to Z30 before being left for grain

The addition of winter and spring phenology types in the trial allowed for direct comparisons of the influence of relative vegetative phase duration (time from germination to start of stem elongation) on the potential DM available for grazing without lowering grain yields. The two grain and graze treatments (Z30 and Up to Z30) produced significantly different DM values between varieties for each treatment (Table 4). The Z30 treatment (single simulated graze at approximately Z30) ranged in DM totals of 0.7 t/ha for SEC047, to Newton producing 2.6 t/ha. This is likely linked to the duration of the vegetative phase for each variety, where SEC047 reached the start of stem elongation (and was grazed) on July 23, while Newton reached Z30 on September 3, effectively giving it five weeks of biomass production. For the Up to Z30 treatment (multiple grazes to Z30), the winter types of AGTB1007 and Newton had significantly more DM from repeat grazing during the vegetative phase compared to the spring types (Table 4). Newton also had significantly more DM than AGTB1007. The opposite occurred for grain yield for these treatments, where AGTB1007 significantly out-yielded Newton.

Table 4: Vegetative dry matter (DM) totals removed through simulated grazing for each variety, and the relative timings for each grazing event. The Z30 treatment involved a single simulated graze at the approximate start of stem elongation. The Up to Z30 treatment had multiple simulated grazes at specified graze timings until the start of stem elongation, with the individual totals added together. There was a significant variety interaction within each treatment, so different letters represent significant differences between varieties. na = data not available

Vegetative dry matter removal	**Up to Z30**		**Z30**	
Variety	**DM (t/ha)**	**Graze timings**	**DM (t/ha)**	**Graze timing**
SEC 047	na	na	0.70^{a}	23 July
Cyclops Ⓓ	1.03^{a}	July 23, August 9	1.02^{a}	August 9
Maximus Ⓓ CL	1.04^{a}	July 23, August 9	1.09^{ab}	August 9
RGT Planet Ⓓ	1.14^{a}	July 23, August 9	1.47^{abc}	August 9
Titan AX Ⓓ	1.15^{a}	July 23, August 9	1.21^{abc}	August 9
Kraken Ⓓ	1.34^{a}	July 23, August 9	1.51^{abc}	August 9
Neo Ⓓ CL	1.39^{a}	July 23, August 9	1.40^{abc}	August 9
Beast Ⓓ	1.43^{a}	July 23, August 9	1.96^{cd}	August 9
AGTB1007	2.15^{b}	July 23, August 9, August 22	1.89^{bcd}	August 22
Newton Ⓓ	3.13^{c}	July 23, August 9, September 3	2.56^{d}	September 3
P-value (variety)	***<0.001***		***<0.001***	

The removal of plant biomass prior to Z30 through simulated grazing had no statistically significant reduction in final grain yield across grain and graze treatments compared to the UTC. However, the grazing prior to Z30 did reduce the final dry matter left at crop maturity. Evident in Figure 1, the two grain and graze treatments generally had a lower final dry matter, with some un-grazed varieties producing over 14 t/ha of DM by harvest time. This is important as final DM is positively correlated with grain yield (Figure 1), known as harvest index (HI). However, the grain and graze treatments were able to maintain high grain yields by significantly improving their HI ratio, with some treatments producing a HI of over 0.5. This demonstrates a strong efficiency of converting DM into grain yield at the end of the season for the grazed treated plots. The correlation for the Z30 (r^2=0.85) and Up to Z30

(r^2=0.77) is even stronger than the UTC (r^2=0.66), which may also indicate that they are all responding similarly in their DM recovery post grazing.

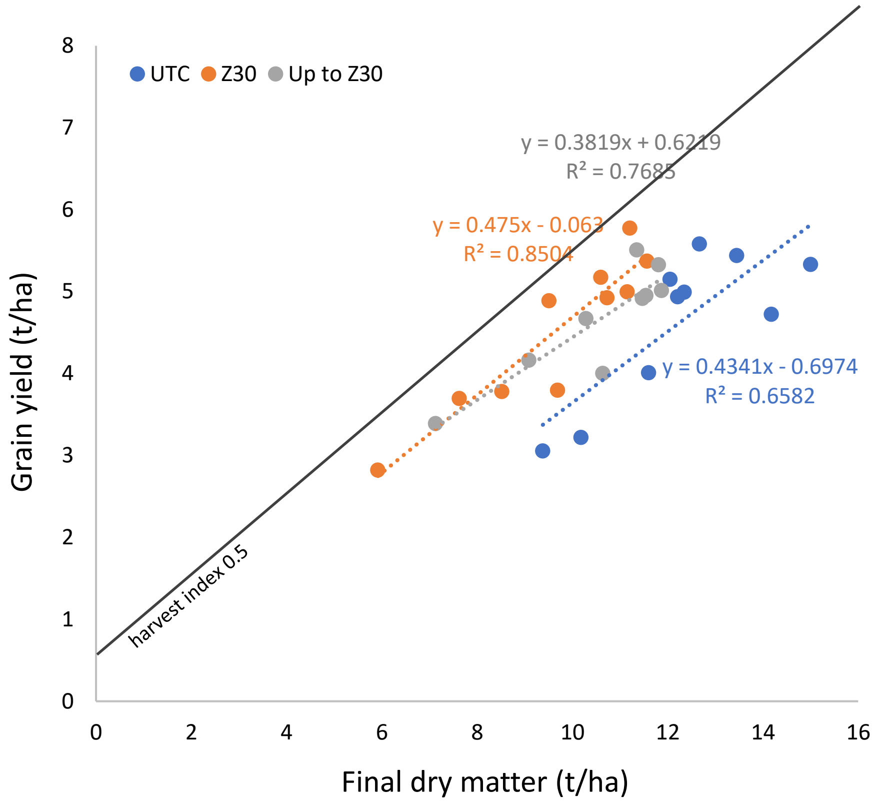

Figure 1: Relationship between grain yield and final dry matter across all barley varieties and individual grazing treatments at Giles Corner in 2024, with the dotted line representing the linear correlation for each grazing treatment. The orange dots are the Z30, grey Up to Z30 treatments, while the blue are the UTC plots. The solid black line is a harvest index ratio of 0.5 that represents a high efficiency of converting biomass into grain yield.

Variety differences in early vigour and total seasonal DM production

The first graze timing on July 23 identified small differences in early DM production between varieties. The top variety, Beast, had 0.77 t/ha of DM was significantly higher than the lowest varieties Maximus CL (0.58 t/ha DM) and Cyclops (0.59 t/ha DM). All other varieties fitted in between and were not significantly different to each other. Even though the differences are small at this time point, any increase in DM would be important for early feed available for livestock, to help address the frequent autumn feed gap in mixed farming systems. Beast performed strongly again following the first simulated graze, also being at the top for the second simulated graze too, with his trend evident (Figure 2). Maximus CL was again significantly lower for DM production post the first graze, with Cyclops performing slightly better, but both still being near the lowest indicating that 'erect' types may not be suitable for early season DM production. Additionally, SEC047 being a very quick developing variety did not produce significantly more DM than other slower developing varieties, suggesting that development speed may not be important for fast early season DM in dry conditions.

The final simulated graze on the September 3 created more variation across varieties due to much more re-growth likely from subsequent rainfall and warmer temperatures. In contrast to previous grazes, Cyclops produced the most DM at 5.01 t/ha compared to Newton being the lowest at 3.6 t/ha DM. For total forage production several varieties grouped together, which included Beast, Kraken, Titan AX, SEC047 and Cyclops, all totalling over 6 t/ha DM cumulative (Figure 2). Maximus remained low for the whole season totalling 4.9 t/ha DM as well Newton dropping off by the last simulated graze at 4.93 t/ha DM. Further seasons data will help in solidifying trends between varieties, as well as potential influences of weed populations with repeat grazing, as there was limited weed pressure in the 2024 trial. However, Beast does initially look to be a strong performer in DM production at Giles Corner, which is consistent with the same trial results from Minnipa in 2024 as well.

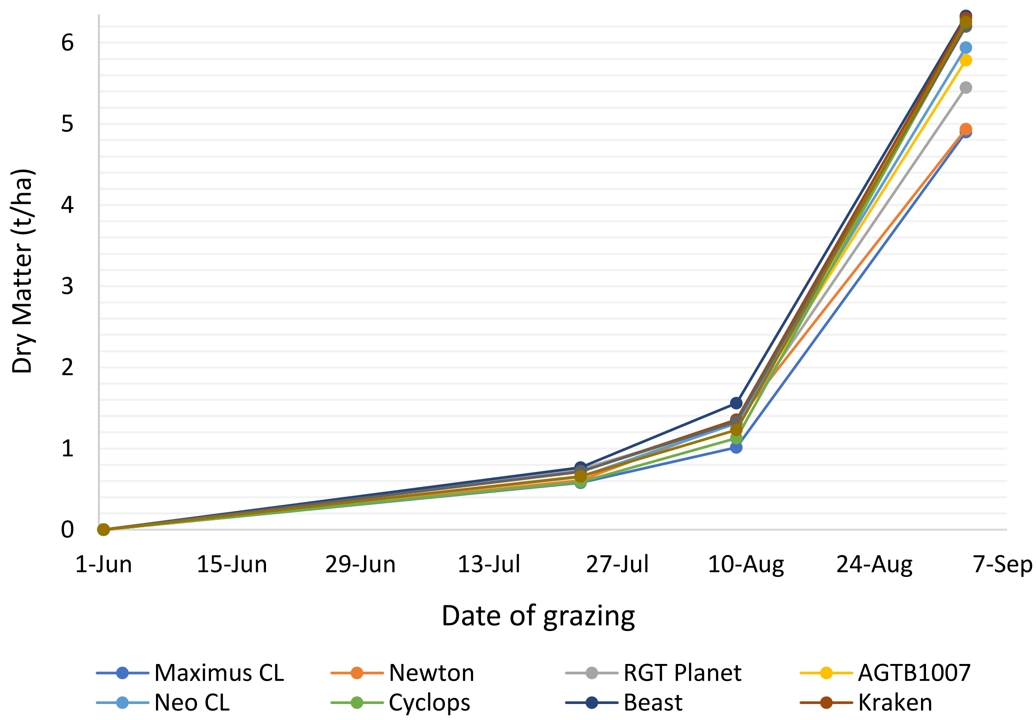

Figure 2: The total cumulative DM produced from the forage treatment, where the same plots were grazed three times during the season (July 23, August 9, September 3).

Conclusions

The impact of grazing on final grain yields at Giles Corner in 2024 was small, with majority of varieties having no significant reduction in grain yield compared to UTC. This is particularly significant during a growing season with Decile 1 rainfall and suggests some varieties tested could have provided a grazing source for livestock in the dry conditions and still recovered the same grain yield as if ungrazed. The grain and graze treatments were able to maintain high yields mainly due to an improved HI ratio across varieties. However, further data to come on grain quality will determine if there was any trade-off in reduced grain quality. The only significant reduction in grain yield following grazing was the two winter types, Newton and AGTB1007. However, these two varieties produced the most vegetative biomass prior to being locked up for grain. This highlights the use-case of the extended vegetative phase of winter phenology types compared to the quicker springs in mixed farming systems. For early season DM production, Beast was the strongest performer, being at the top after each grazing for DM removal.

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