Oaten hay variety response to nitrogen and early seeding; a three-year summary

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Key findings

- Hay yields were consistently improved from early May sowing due to crops maximising access to available soil water in challenging seasons at Hart.
- Interactions between sowing date and variety were inconsistent for hay quality, however sowing earlier did reduce some measures of hay quality.
- Low rates of nitrogen (N) fertiliser (30 - 60 kg N/ha depending on the season) provided the most benefit for hay yields across these trials. Responses in higher rainfall years are expected to favour greater N inputs.
- Hay yield responses for varieties were similar, with seasonal conditions favouring mid-maturing varieties.
- Varieties did not respond differently to applied N however, caution should be taken in interpreting N response from the SA trial series alone, due to consecutive dry seasons limiting soil N mineralisation for the crop.

Introduction

The National Hay Agronomy (NHA) project was a four-year investment, funded by AgriFutures Australia, with trials conducted across South Australia, Western Australia, New South Wales and Victoria from 2019 – 2021. These trials investigated the agronomic management of oats through variety selection, nutrition, and time of sowing strategies and their influence on hay yield and quality. This article will summarise the key results from the 2019 to 2021 trials at the Hart field site, focusing on nine oaten hay varieties, two sowing dates and three applied N rates.

Methodology

Each trial from 2019 to 2021 investigated two times of sowing (TOS); early and late May, with three N rates; 30, 60 and 90 kg N/ha and nine oat varieties. The varieties grown at Hart in 2019 were Brusher, Carrolup, Durack, Forester, Koorabup, Mulgara, Williams, Wintaroo and Yallara. In 2020 and 2021 Vasse replaced Forester, due to this variety having a very long season maturity, leading to poor performance at Hart and more broadly across the national program. Trials were established as replicated split-split plot designs and were managed to ensure a weed, insect and disease-free canopy with pesticide application as necessary. A summary of plot size, seeding dates, seeding fertiliser and starting soil N at 0-60 cm is provided in Table 1.

Nitrogen treatments were applied as split applications with two thirds at seeding and one third at early tillering. This aimed to achieve good early vigour, plant establishment and thin stems. Plant establishment counts were conducted in June for each TOS with seed rates targeting 320 plants/m^2. Seeding densities were calculated based on grain weight and germination to ensure the target seeding rate was reached for each variety in each year.

Table 1. Summary of agronomic details for trials conducted in 2019 to 2021.

2019			
Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) + Impact @ 60 kg/ha
Seeding date	May 3 and June 5		
Location	Hart, SA	**Starting soil N (0-60cm)**	26 kg N/ha
2020			
Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) + Impact @ 60 kg/ha
Seeding date	May 6 and May 25		
Location	Hart, SA	**Starting soil N** (0-60cm)	53 kg N/ha
2021			
Plot size	1.75 m x 10.0 m	**Fertiliser**	Seeding: DAP (18:20) + Impact @ 70 kg/ha
Seeding date	May 3 (effective May 10) and June 1	**Starting soil N** (0-60cm)	88.5 kg N/ha
Location	Hart, SA		

Measurements

Plant height (cm) and lodging assessments (scale = 1 – 9, 9 no lodging) were conducted prior to hay cutting. Oaten hay development was monitored by assessing Zadoks crop growth stage (GS) from booting (GS 43-49) until top florets were watery ripe (GS71). Once the middle florets were at watery ripe, hay cuts were taken 15 cm from the ground in each plot (4 x 1 m row). Samples were dried in an oven at 60°C for at least 48 hours or until dry and weighed to calculate hay yield (t/ha). Samples were ground to < 1 mm and hay quality characteristics including Acid Detergent Fibre (% ADF), Neutral Detergent Fibre (% NDF), Crude Protein (% CP), Water-Soluble Carbohydrates (% WSC), digestibility (% IVD) and colour measured by Minolta *a* (data not shown) were measured using the National Oat Breeding NIR calibration. Stem thickness was measured by digital calipers of the squashed internode at the base of the cut stem and leaf greenness of dried plant samples was measured using a SPAD-502 Plus chlorophyll meter.

Yield and quality data was analysed using GenStat V19, and statistical comparisons between treatments were made with Least Significant Difference (LSD) of p=0.05. In the tables, best performing varieties or treatments are highlighted in orange. These are calculated as all treatments within LSD of the best performing treatment.

Hay quality descriptors

Acid Detergent Fibre (ADF %) estimates the least-digestible fraction of hay (cellulose and lignin) and for top quality export hay should be less than 32%. Neutral Detergent Fibre (NDF %) estimates the structural carbohydrates of the hay and is negatively correlated with animal intake so as NDF increases the amount of hay an animal will consume decreases. Ideally NDF will be less than 55-57% for top quality export hay. Digestibility (IVD %) estimates the percentage of hay that can be readily broken down in the rumen and high-quality hay will have a value of at least 58%. Crude Protein (CP %) consists of both true protein and non-protein N in hay and is an important parameter for developing rations. For export quality oaten hay, CP % should be in the 4-10% range. Water Soluble Carbohydrates (WSC %) are aligned with the palatability and sweetness of the hay as they are sugars that can be rapidly fermented in the rumen. High quality export oaten hay will have WSC greater than 18%. The indicative values provided for hay quality are a guide as outlined in the Producing Quality Oat Hay, AEXCO (2016), but each exporter has their own quality targets depending on their end customers and markets.

Climate during growing season

Due to dry seasonal conditions at Hart in 2019 and 2021, establishment of the early sown plots occurred on marginal soil moisture. In 2019 there was sufficient soil moisture and subsequent rainfall after sowing for both TOS 1 and TOS 2 to germinate. In 2021, TOS 1 oat varieties were sown dry ahead of a rain event on May 10 however only 9 mm fell over the three days and germination was uneven. Therefore, supplementary irrigation of 10 mm in-furrow was applied on May 17 by dripper irrigation. In 2020, higher than average summer and April rainfall meant stored soil moisture was sufficient for germination.

The 2019 season at Hart was characterised by a very dry summer, average May and June rainfall which allowed plant establishment, followed by a spring drought. The site only received 161 mm of growing season rainfall (GSR) from May to October, and 188 mm annual rainfall. This resulted in a decile one year, and very low hay yields for the season. Hart's average GSR is 300 mm with an annual rainfall of 400 mm.

In 2020, Hart experienced a wet season, receiving a decile 7 GSR of 335 mm and a decile 9 annual total of 502 mm. This was comparatively better than 2019, however, rainfall in 2020 was not evenly distributed throughout the year. Higher than average rainfall during summer and April meant stored soil moisture was available to the crop at seeding. Below average rainfall was received in May, and this continued throughout winter with a June/July combined rainfall of 38 mm. The trial presented symptoms of water and N stress with slow biomass accumulation during this dry winter period. Warm conditions also caused rapid progression through plant growth stages, resulting in varieties reaching watery ripe on the same date. Although spring rainfall was above average with 209 mm falling from August to the end of October, it was too late to be beneficial to hay production but did assist grain fill (data not shown).

Leading into the 2021 season, the Mid-North region, including Hart, was dry, resulting in limited soil moisture prior to seeding with a late season break of 19 mm occurring on May 25. Rainfall over the winter months was average to above average before a dry start to spring and then very wet November. Overall, GSR rainfall for 2021 was at a decile 3 (231 mm), with a decile 5 year for annual rainfall of 401 mm. The variation in rainfall distribution across the three years for GSR and annual rainfall should be taken into consideration when interpreting the findings of this research.

Results and Discussion

Varieties

Across three seasons at Hart, hay yields were influenced by variety selection (Tables 2 – 4). In the 2019 and 2021 seasons, an interaction between variety and TOS was observed for hay yield (Tables 5 and 7). In 2021, average hay yields for varieties ranged from 3.4 – 4.8 t/ha (Table 4). Yallara and Wintaroo were high yielding, achieving average hay yields across the two sowing dates of above 4.5 t/ha. These two varieties have consistently yielded well across three seasons. In 2020, in addition to Yallara and Wintaroo, Brusher and Carrolup, both mid-maturing varieties and Durack, a quick variety, were also high yielding at Hart (Table 3).

Varieties with a quick to mid-maturity consistently yielded well in trials at Hart due to their suitability to shorter, drier and warmer environments. In contrast, Forester in 2019 and Vasse in 2020 and 2021 have performed poorly across the trial program due to their slower development speed. Forester struggled to flower in 2019 with TOS 2 becoming necrotic in the boot, whilst Vasse struggled to get full panicle emergence and flowered in the boot in 2020 and 2021. This indicates neither of these varieties are suited to the shorter growing season at Hart.

Table 2. Effects of variety, sowing date and nitrogen for a range of hay yield and quality traits at Hart in 2019. The best performing varieties for key traits are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Hay yield (t/ha)	Stem diameter (mm)	ADF (%)	NDF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+5	35	3.1	3.5	23.0	45.1	9.1	73.5	3.4	29.2
Carrolup	18-Sep	31	2.9	3.2	23.6	42.8	10.0	73.7	3.8	30.8
Durack	-6	32	3.0	3.5	24.5	46.0	9.1	71.2	4.1	28.6
Koorabup	+3	30	3.0	3.4	24.1	46.0	9.0	72.2	3.7	28.7
Mulgara	+2	39	3.3	3.8	24.6	45.3	8.9	72.8	3.8	26.5
Forester	+43	25	1.5	3.3	22.4	40.9	8.8	79.4	2.3	34.8
Williams	+3	29	3.2	3.5	23.7	45.6	10.0	72.4	3.6	26.5
Wintaroo	+7	37	3.2	4.0	24.6	47.6	8.2	71.6	3.9	25.7
Yallara	+2	37	3.2	3.7	22.7	42.1	8.5	73.6	3.4	33.4
Average	**+0**	**33**	**2.9**	**3.5**	**23.7**	**44.6**	**9.1**	**73.4**	**3.6**	**29.7**
Significance (V)	-	***	***	***	***	***	***	***	***	***
LSD (p≤0.05)	-	*3*	*0.1*	*0.2*	*0.7*	*1.3*	*0.4*	*1.0*	*0.2*	*2.1*
TOS1 - 3 May	+0	37	3.5	4.0	23.6	43.3	8.0	73.5	3.6	33.0
TOS2 - 5 June	+0	29	2.3	3.1	23.8	45.9	10.2	73.2	3.5	26.5
Significance (TOS)	-	***	**	***	*n.s.*	**	***	*n.s.*	*n.s.*	***
LSD (p≤0.05)	-	*2*	*0.4*	*0.2*	-	*1.1*	*0.6*	-	-	*0.7*
30 kg N/ha	+0	33	2.5	3.4	24.2	45.3	7.9	72.5	3.6	31.0
60 kg N/ha	+0	33	3.0	3.6	23.4	44.2	9.1	73.5	3.5	30.2
90 kg N/ha	+0	32	3.1	3.6	23.4	44.3	10.2	74.1	3.6	28.0
Significance (N)	-	*n.s.*	***	***	***	***	***	***	**	***
LSD (p≤0.05)	-	-	*0.1*	*0.1*	*0.2*	*0.5*	*0.2*	*0.5*	*0.1*	*0.9*
Significance (N x V)	-	*n.s.*	***	*n.s.*	*n.s.*	*n.s.*	**	*n.s.*	*n.s.*	*n.s.*

Significance: n.s. not significant; * p≤0.05, ** p≤0.01, *** p≤0.001ADF: acid detergent fibre, NDF: neutral detergent fibre, CP: crude protein, IVD: in vitro digestibility, WSC: water soluble carbohydrates

Table 3. Effects of variety, sowing date and nitrogen for a range of hay yield and quality traits at Hart in 2020. The best performing varieties for key traits are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Hay yield (t/ha)	Stem diameter (mm)	ADF (%)	NDF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+0	66	3.5	4.3	27.6	48.7	10.1	68.9	3.9	25.9
Carrolup	18-Sep	56	3.4	4.0	27.6	47.6	10.3	68.7	3.8	25.9
Durack	-7	57	3.1	4.4	28.4	50.9	11.1	65.9	4.3	21.4
Koorabup	+0	55	3.0	4.2	28.4	50.1	10.5	67.3	4.1	23.5
Mulgara	+0	60	3.0	4.4	28.3	49.3	10.7	68.5	4.0	23.9
Vasse	+5	46	2.3	3.7	30.0	53.8	11.9	68.5	4.4	15.3
Williams	+0	49	2.9	4.5	28.1	50.2	11.7	67.7	4.2	21.2
Wintaroo	+0	60	3.2	4.3	27.5	48.9	10.4	68.9	3.9	24.1
Yallara	+0	55	3.2	4.2	27.0	47.4	10.4	69.0	3.7	25.9
Average	**+0**	**56**	**3.1**	**4.2**	**28.1**	**49.7**	**10.8**	**68.2**	**4.0**	**23.0**
Significance (V)	-	***	***	*n.s.*	***	***	***	***	***	***
LSD (p≤0.05)	-	*3*	*0.4*	-	*0.8*	*1.2*	*0.5*	*1.2*	*0.2*	*1.1*
TOS1 - 6 May	+0	63	3.5	4.4	28.4	49.8	10.1	67.1	4.2	24.3
TOS2 - 25 May	+0	49	2.7	4.1	27.8	49.5	11.5	69.2	3.9	21.7
Significance (TOS)	-	*	*n.s.*	*n.s.*	*	*n.s.*	*	**	**	*
LSD (p≤0.05)	-	*10*	-	-	*0.3*	-	*1.2*	*1.2*	*0.1*	*2.0*
30 kg N/ha	+0	56	3.1	4.2	28.2	49.6	10.0	67.9	4.0	24.8
60 kg N/ha	+0	56	3.1	4.2	28.1	49.7	10.9	68.1	4.0	22.7
90 kg N/ha	+0	56	3.1	4.2	28.0	49.6	11.6	68.5	4.0	21.5
Significance (N)	-	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	***	*n.s.*	*n.s.*	***
LSD (p≤0.05)	-	-	-	-	-	-	*0.3*	-	-	*0.6*
Significance (N x V)	-	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*

Significance: n.s. not significant; * p≤0.05, ** p≤0.01, *** p≤0.001

ADF: acid detergent fibre, NDF: neutral detergent fibre, CP: crude protein, IVD: in vitro digestibility, WSC: water soluble carbohydrates

Variation in cutting dates across 2019 and 2020 was narrow, with varieties progressing quickly to watery ripe due to water stress. The mild spring conditions in 2021 resulted in cutting dates across a 6-week period for varieties and sowing dates (Figure 1). Yallara, sown early on May 3, was the highest yielding variety (6.0 t/ha).

Table 4. Effects of variety, sowing date and nitrogen for a range of hay yield and quality traits at Hart in 2020. The best performing varieties for key traits are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Lodging (9-0)	Hay yield (t/ha)	Stem diameter (mm)	ADF (%)	NDF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+0	63	8.4	4.2	5.0	26.4	48.8	10.6	69.7	4.4	21.1
Carrolup	23-Sep	58	8.6	4.1	5.0	27.5	48.4	11.0	67.3	4.6	19.3
Durack	-6	58	9.0	4.2	4.8	27.3	48.3	9.8	66.9	4.8	22.6
Koorabup	-3	56	9.0	3.9	5.1	27.4	47.2	12.0	68.9	4.0	18.8
Mulgara	+0	63	8.7	4.2	5.2	26.5	46.3	10.9	70.6	4.0	21.9
Vasse	+16	47	8.1	3.4	4.9	25.2	45.4	10.7	74.4	3.6	23.8
Williams	+6	52	8.5	4.2	5.2	27.2	49.3	11.4	67.7	4.2	17.6
Wintaroo	+7	61	8.7	4.5	5.3	26.6	46.5	9.9	70.4	4.0	22.4
Yallara	-2	63	8.9	4.8	5.1	25.9	46.4	9.5	69.0	4.6	24.9
Average	**+0**	**58**	**8.7**	**4.2**	**5.1**	**26.7**	**47.4**	**10.6**	**69.4**	**4.2**	**21.4**
Significance (V)	-	***	**	***	*n.s.*	***	***	***	***	***	***
LSD (p≤0.05)	-	*4*	*0.4*	*0.4*	-	*0.7*	*1.3*	*0.7*	*1.2*	*0.3*	*1.2*
TOS1 - 3 May	+0	66	8.8	5.0	5.9	27.6	48.4	10.0	67.4	4.7	21.0
TOS2 - 1 June	+0	50	8.6	3.3	4.2	25.7	46.4	11.3	71.5	3.8	21.8
Significance (TOS)	-	***	*n.s.*	**	**	*	*	*	**	**	*n.s.*
LSD (p≤0.05)	-	*5*	-	*0.9*	*0.6*	*1.5*	*1.8*	*1.0*	*2.3*	*0.4*	-
30 kg N/ha	+0	59	8.8	4.2	5.1	26.8	47.8	9.6	68.7	4.5	22.6
60 kg N/ha	+0	57	8.6	4.2	5.0	26.6	47.2	10.7	69.7	4.2	21.4
90 kg N/ha	+0	56	8.6	4.1	5.1	26.6	47.1	11.6	69.9	4.0	20.2
Significance (N)	-	***	***	*n.s.*	*n.s.*	*n.s.*	*	***	***	***	***
LSD (p≤0.05)	-	*1*	*0.1*	-	-	-	*0.6*	*0.3*	*0.6*	*0.1*	*0.7*
Significance (N x V)	-	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*

Significance: n.s. not significant; * p≤0.05, ** p≤0.01, *** p≤0.001
ADF: acid detergent fibre, NDF: neutral detergent fibre, CP: crude protein, IVD: in vitro digestibility, WSC: water soluble carbohydrates

Variety selection influenced hay quality, although across all three seasons quality traits were high (Table 2 – 4). Stem diameter and greenness (SPAD; data not shown), were an exception with differences observed in 2019 only.

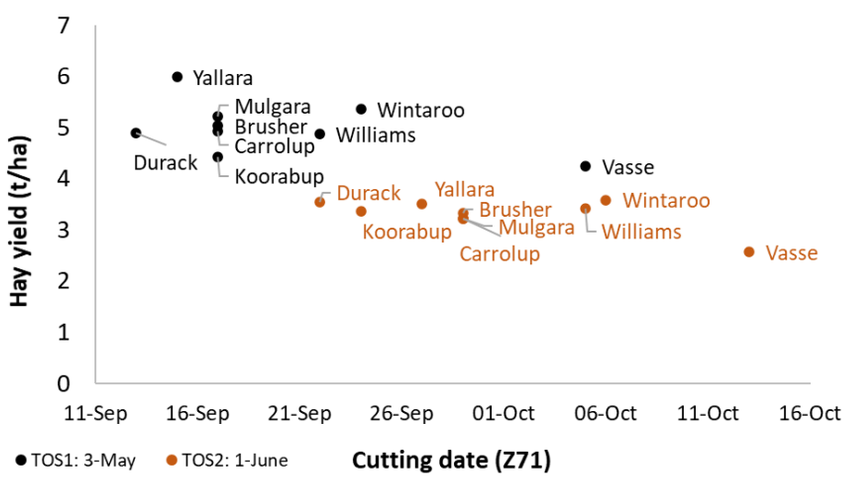

Figure 1. Hay yield by cutting date for early May and early June planting at Hart in 2021.

Time of sowing

Sowing date across three years of trials consistently influenced hay yield and quality. Hay yields were maximised from early May sowing (Tables 2 – 4) in two out of three seasons at Hart. In 2020, hay yields were increased due to early sowing (data not shown). Earlier sowing in all three years resulted in taller plants with a positive relationship between hay yield and plant height across the varieties. It should be noted that there was no lodging in 2019 and 2020, with minimal lodging in 2021. The positive relationship between hay yield and plant height may not be maintained for all varieties in seasons where there is significant lodging.

Hay quality was very good at Hart meeting export quality due to dry seasonal conditions and lower hay yields. Earlier sowing, however, did reduce hay quality across most of the measured traits in all three seasons (Tables 2 – 4). Stem diameter was thin (<6 mm) but thicker from earlier sowing in all three years. Digestibility (IVD%) and CP (%) were lower from earlier sowing in all three years. Fibre fraction ADF (%) was higher from earlier sowing in 2020 and 2021 but NDF (%) was inconsistently influenced by sowing date across the three seasons. Lignin (%) was higher from earlier sowing in 2020 and 2021 however WSC (%) was higher for earlier sowing in 2019 and 2020 but not affected by sowing date in 2021.

Variety x time of sowing

Varieties responded differently to sowing date for hay yield in two out of three years and some hay quality traits across all three years (Tables 5 – 7). However, due to the inconsistencies between years, no clear conclusions can be made from the SA trial series alone on the interaction that variety and sowing date have on hay quality.

Caution should be taken regarding this observation due to the short height of Vasse from later sowing resulting in some stem diameter measurements taken above the top node rather than the internode. Only small and insignificant differences occurred in 2021 with all varieties having thinner stems from later sowing (Table 7).

Table 5. Interaction between variety and sowing date for hay yield and quality traits at Hart in 2019. The best performing variety x sowing date combinations are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Hay yield (t/ha)	ADF (%)	NDF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+2	38	3.8	22.1	42.7	7.8	74.6	3.0	34.6
Carrolup	11-Sep	37	3.3	23.7	42.3	9.0	72.7	3.9	32.1
Durack	-6	38	3.7	25.2	45.5	8.2	69.6	4.3	30.8
Koorabup	+2	34	3.6	24.3	45.6	8.1	73.0	3.8	30.1
Mulgara	+0	44	3.9	24.3	43.3	8.0	73.6	3.8	34.5
Forester	+44	27	1.9	21.6	38.7	7.3	79.5	2.2	39.8
Williams	+2	32	3.3	23.8	45.1	8.6	72.4	3.7	28.5
Wintaroo	+7	43	3.9	24.1	45.2	7.0	72.8	3.8	31.0
Yallara	+0	41	3.8	23.0	41.4	7.8	73.7	3.6	35.6
TOS1		**37**	**3.5**	**23.6**	**43.3**	**8.0**	**73.5**	**3.6**	**33.0**
Brusher	+7	32	2.4	23.9	47.5	10.4	72.3	3.8	23.8
Carrolup	26-Sep	25	2.6	23.4	43.4	11.0	74.8	3.7	29.6
Durack	-6	26	2.4	23.9	46.5	10.0	72.8	4.0	26.3
Koorabup	+4	27	2.4	23.9	46.5	9.9	71.4	3.6	27.4
Mulgara	+4	35	2.6	24.9	47.4	9.8	72.1	3.8	25.2
Forester	+42	23	1.1	23.2	43.1	10.3	79.4	2.4	29.8
Williams	+4	26	2.0	23.5	46.1	11.4	72.4	3.5	24.4
Wintaroo	+7	32	2.5	25.0	50.0	9.5	70.3	3.9	20.3
Yallara	+4	33	2.6	22.5	42.7	9.2	73.5	3.2	31.2
TOS2		**29**	**2.3**	**23.8**	**45.9**	**10.2**	**73.2**	**3.5**	**26.5**
Significance (TOS X V)	-	*	***	***	**	**	***	***	***
LSD (p≤0.05)	-	*4*	*0.43*	*0.9*	*1.9*	*0.7*	*1.7*	*0.2*	*2.8*
LSD (p≤0.05) - same TOS	-	*4*	*0.20*	*0.9*	*1.8*	*0.5*	*1.4*	*0.2*	*2.9*

Table 6. Interaction between variety and sowing date for significant hay quality traits at Hart in 2020. The best performing variety x sowing date combinations are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Stem diameter (mm)	ADF (%)	CP (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+0	74	4.3	28.4	9.0	67.2	4.1	27.3
Carrolup	16-Sep	63	4.1	27.9	9.7	67.8	3.9	27.1
Durack	-9	60	4.4	28.3	10.4	65.2	4.2	23.7
Koorabup	+0	62	4.2	28.9	10.0	66.1	4.2	24.1
Mulgara	+0	70	4.5	29.0	9.7	66.7	4.3	25.3
Vasse	+6	48	4.5	29.0	11.3	68.7	4.5	18.3
Williams	+0	57	4.6	28.8	11.2	66.2	4.5	21.5
Wintaroo	+0	70	4.6	28.1	9.6	67.5	4.1	25.0
Yallara	+0	60	4.1	27.0	10.2	68.6	3.7	26.2
TOS1		**63**	**4.4**	**28.4**	**10.1**	**67.1**	**4.2**	**24.3**
Brusher	+0	58	4.3	26.9	11.3	70.7	3.7	24.5
Carrolup	21-Sep	49	3.9	27.3	11.0	69.7	3.8	24.7
Durack	-4	54	4.4	28.5	11.9	66.7	4.4	19.2
Koorabup	+0	47	4.2	28.0	11.0	68.4	4.0	23.0
Mulgara	+0	50	4.3	27.7	11.8	70.3	3.8	22.4
Vasse	+3	45	2.9	30.9	12.5	68.2	4.4	12.3
Williams	+0	41	4.5	27.4	12.3	69.2	3.9	20.9
Wintaroo	+0	51	4.1	27.0	11.1	70.3	3.7	23.2
Yallara	+0	50	4.2	26.9	10.6	69.5	3.6	25.5
TOS2		**49**	**4.1**	**27.8**	**11.5**	**69.2**	**3.9**	**21.7**
Significance (TOS X V)	-	***	***	**	*	*	*	***
LSD (p≤0.05)	-	*4*	*0.2*	*0.5*	*1.2*	*1.8*	*0.3*	*1.0*
LSD (p≤0.05) - same TOS	-	*2*	*0.1*	*0.5*	*0.7*	*1.7*	*0.3*	*0.8*

Table 7. Interaction between variety and sowing date for significant hay yield and quality traits at Hart in 2021.The best performing variety x sowing date combinations are highlighted in orange.

	Z71 relative to Carrolup (days)	Plant height (cm)	Lodging (9-0)	Hay yield (t/ha)	Stem diameter (mm)	ADF (%)	NDF (%)	IVD (%)	Lignin (%)	WSC (%)
Brusher	+0	72	9.0	5.0	6.0	28.2	50.9	66.0	5.1	20.1
Carrolup	17-Sep	65	9.0	4.9	5.9	28.7	50.4	64.2	5.0	17.1
Durack	-4	71	9.0	4.9	5.7	27.6	48.3	65.8	5.3	25.0
Koorabup	+0	63	9.0	4.4	5.8	29.1	50.3	65.7	4.5	15.5
Mulgara	+0	70	9.0	5.2	6.2	28.1	47.7	67.8	4.6	20.2
Vasse	+18	53	7.2	4.3	5.3	25.9	46.2	72.2	3.9	23.4
Williams	+5	58	9.0	4.9	6.2	27.4	47.8	68.1	4.3	19.6
Wintaroo	+7	68	8.6	5.4	5.9	26.9	46.0	70.0	4.1	23.2
Yallara	-2	71	9.0	6.0	6.1	26.9	47.9	66.4	5.2	24.7
TOS1		**66**	**8.8**	**5.0**	**5.9**	**27.6**	**48.4**	**67.4**	**4.7**	**21.0**
Brusher	+0	53	7.9	3.3	4.0	24.7	46.7	73.4	3.6	22.2
Carrolup	29-Sep	50	8.2	3.2	4.1	26.3	46.4	70.3	4.1	21.5
Durack	-7	46	9.0	3.5	3.9	27.0	48.3	68.0	4.3	20.1
Koorabup	-5	49	9.0	3.4	4.4	25.8	44.1	72.2	3.5	22.0
Mulgara	+0	55	8.3	3.2	4.1	24.8	44.8	73.5	3.5	23.5
Vasse	+14	41	9.0	2.6	4.4	24.6	44.5	76.6	3.2	24.2
Williams	+6	46	8.1	3.4	4.2	27.0	50.8	67.3	4.1	15.7
Wintaroo	+7	53	8.9	3.6	4.7	26.3	47.0	70.7	3.9	21.6
Yallara	-2	54	8.8	3.5	4.2	24.9	45.0	71.5	4.0	25.1
TOS2		**50**	**8.6**	**3.3**	**4.2**	**25.7**	**46.4**	**71.5**	**3.8**	**21.8**
Significance (TOS X V)	-	*	***	*	*	***	***	***	***	***
LSD (p≤0.05)	-	*6*	*0.6*	*0.9*	*0.7*	*1.6*	*2.2*	*2.5*	*0.2*	*2.1*
LSD (p≤0.05) - same TOS	-	*5*	*0.6*	*0.5*	*0.6*	*1.0*	*1.8*	*1.8*	*0.2*	*1.7*

In 2019 Durack had lower ADF % from delayed sowing compared to earlier sowing whilst Brusher and Forester had lower ADF from earlier sowing. In 2020 most varieties had lower ADF from delayed sowing except Vasse which was lower in the earlier sowing. Durack and Yallara maintained the same ADF across both sowing dates. In 2021, most varieties had lower ADF from later sowing except Durack, Vasse, Williams and Wintaroo which did not respond to sowing date.

In 2019 all varieties had increased CP% from later sowing (likely due to the lower overall hay yields) although some varieties (Brusher, Forester and Williams) had slightly larger increases in response to delayed sowing. Likewise in 2020, all varieties except Koorabup, Vasse, Williams and Yallara increased CP% from later sowing.

In 2019 NDF % increased from delayed sowing for Brusher, Mulgara, Forester and Wintaroo whilst in 2021 all varieties decreased NDF % from delayed sowing except for Williams where it increased and Durack and Wintaroo where there was no response to sowing date.

In 2019 digestibility (IVD%) was higher from earlier sowing for Brusher and Wintaroo whilst it was lower for Durack and Carrolup and did not respond for all other varieties. In 2020, Durack, Vasse and Yallara maintained digestibility across sowing dates whilst all other varieties had higher digestibility from later sowing. In 2021, Williams and Wintaroo maintained digestibility across sowing dates whilst all other varieties had higher digestibility from later sowing.

In 2019 the lignin content of most varieties did not respond to sowing date or was slightly lower from delayed sowing except for Brusher whilst in both 2020 and 2021 all varieties had either the same or lower lignin contents from delayed sowing.

In 2019, WSC decreased with delayed sowing in all varieties except Carrolup and Koorabup which maintained WSC across the two sowing dates. In 2020, the same trend occurred except the varieties Williams and Yallara maintained WSC across the two sowing dates. In 2021 the varieties responded differently with Brusher, Carrolup, Koorabup and Mulgara having higher WSC from delayed sowing. Williams and Durack had lower WSC from delayed sowing and Vasse, Wintaroo and Yallara maintained WSC across the two sowing dates.

Nitrogen management

Responses to N were not consistently experienced across all three years except for an increase in CP % and a decrease in WSC %. In 2020, no other responses to N occurred (Table 2). In 2019 and 2021, leaf greenness (SPAD, data not shown) and digestibility (IVD %) increased with applied N whilst NDF % decreased. Other responses to an increase in applied N were only experienced in one out of the three years (Tables 1-3). This result was expected due to the low in-season rainfall experienced across the trial series in SA. Applications of high rates of N will not be available to the crop without sufficient in-season rainfall to aid N mineralisation. It should also be noted that the soil starting N increased year on year.

There were minimal N x variety interactions across the three seasons with only hay yield and crude protein in 2019 having significant differences. In both these cases, the interaction was driven by the lack of response of Forester to applied N and caution should be taken with this variety due to its unsuitability at the Hart field site as already discussed. As varieties responded the same to applied N, we would suggest future work does not need to focus on the interaction of variety and N rate.

Conclusion

The 2019 to 2021 seasons at Hart were not typical seasons with either below average rainfall or rainfall occurring too late to be beneficial to a hay crop. As a result, caution should be taken in making statewide assumptions from these three trials. Due to the dry growing seasons, there was minimal lodging and in all three years there was a benefit from earlier sowing to maximise biomass accumulation and subsequent hay yields. Hay quality across all three years was good and early to mid-maturity varieties performed well. As a result of these environmental conditions, varieties did not respond differently to applied N but in the best year (2021), Yallara was a clear best performer for hay yield whilst maintaining quality when sown early.

Acknowledgments

The authors would like to acknowledge AgriFutures Australia and thank them for their continued support towards the National Hay Agronomy program (PRJ 011029).

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