The effect of nitrogen fertilisers on Phalaris aquatica L. pastures at low temperatures in south eastern NSW

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Abstract
An experiment was conducted to determine the nitrogen (N) response of phalaris pastures under cold temperatures in south eastern NSW. Four N treatments (0, 30, 60 and 90 kgN/ha) were applied at four different times from mid-May to mid-July. The application of N increased leaf extension rate, final leaf length but not average leaf width of the emerging leaf. Tiller numbers almost doubled when the highest rate of N was applied compared to 0N (1291 vs 2458 tillers/m^2). Nitrogen application increased dry matter (DM) accumulation at both the four and eight week harvest. Cold temperatures did not reduce the N response in phalaris pastures.

Keywords
Nitrogen use efficiency, growth, grass, forage

Introduction
Historically, pastures in south-eastern Australia have relied on the legume component to fix atmospheric nitrogen (N) and supply it to the grass species in the pasture (Rawnsley et al., 2019). With a greater number of intensively managed pastures, legume N fixation has been unable to meet the N supply requirements of the pasture (Eckard and Franks, 1998). N availability in winter is low, due to cool temperatures limiting nitrogen release from the soil by mineralisation of organic matter (Angus, 2001). Low N availability has prompted research and extension into the use of strategic applications of urea to boost pasture production in the last 20-30 years (Eckard and Franks, 1998). The N response of pastures is well studied in high input grazing systems, such as perennial ryegrass dairy pastures in Tasmania (Eckard and Franks, 1998), and south Western Australia (Bolland and Guthridge, 2007). There has been very little research conducted on how phalaris pastures respond to N. The primary documented example is from Simpson (1965) where they explored the effect of N on dry matter yield when applied in July. This current experiment sought to determine the response of N on phalaris pastures under cold temperature conditions in south east NSW.

Methods
A field site was established on a property at Tumut, NSW (-35.304265 S, 148.243852 E) which was situated 282m above sea level with an 811mm average annual rainfall (Bureau of Meteorolgy , 2020). The soil was a loam/loamy clay soil with low soil N and high Colwell P (Table 1).

Table 1. Initial soil test results from the Tumut field site at 0-10 and 10-20cm.

	0-10cm	**10-20cm**		**0-10cm**	**10-20cm**
Ammonium Nitrogen (mg/kg)	3	2	Sulfur (mg/kg)	8.4	5.3
Nitrate Nitrogen (mg/kg)	11	5	Organic Carbon (%)	2.93	1.94
Phosphorus Colwell (mg/kg)	73	51	Conductivity (dS/m)	0.054	0.046
Potassium Colwell (mg/kg)	97	77	pH $_{(CaCl2)}$	5.5	5.6
PBI	88.7	94.4	pH $_{(H2O)}$	6.4	6.4

Phalaris (cv. Confederate) was the most dominant species, with other pasture species sporadically present included *Trifolium subterraneum*, *Lolium rigidum*, and *Bromus spp*. The field site had been grazed by cattle 7 days prior to the commencement of the experiment. The site was mown to a uniform height of 5cm four days prior to the first application of nitrogen. Superphosphate was applied at 180 kg/ha as a basal application prior to commencement. A randomised complete block design with four times of application throughout the year, four nitrogen treatments with four replicates. Individual plots measured 4 x 6m wide. Application dates were 15 May, 4 June, 25 June and 16 July and at each time of application 0, 30, 60 or 90 kg N/ha was applied as urea (46% N). The urea was applied by hand and watered with 5mm of water.

At the commencement of each nitrogen application, two emerging leaves (approx. 20-40mm long) were identified in each plot, and their lengths were measured using digital Vernier callipers. Every three days the length of the leaves were recorded, until the subsequent leaf tip was visible. The fully extended leaf length and width were recorded. The mobile application Canopeo (Version 1.1.7; Oklahoma State University, 2015) was used to measure the green canopy cover of each plot. A tiller count was conducted on all plots on the 17/9/20. Biomass cuts were taken at 4 and 8 week intervals for each time of nitrogen application at ground level in two 50 x 50cm quadrats (0.25m^2) per plot. Pasture samples were dried at 80˚C for 48 hours. A temperature logger recorded soil (10cm deep) and air temperature (1.3 m). The lowest air temperature was -5.9˚C compared to the lowest soil temperature of 4.8˚C. Growing degree days (GDD) were calculated on 0˚C a base temperature. During the experiment 246 mm of rain was recorded.

All data were analysed using GenStat 20th edition (version 20, VSN International Ltd, Hemel Hempstead, UK). Data were assessed for normality and analysed by analysis of variance (ANOVA) and differences determined using LSD calculated at the 0.05 level.

Results

Leaf extension rate in phalaris increased as N rate increased when measured in days or GDD. The timing of the application also affected leaf extension rate but there was no interaction between N rate and treatment timing. The mid July application had a faster leaf extension than any other treatment time. Utilising GDD appears to have removed some of the variation between treatments (i.e. smaller P value) but the daily calculation was still strongly significant. The increase in leaf extension rate with treatments resulted in longer leaves under increased N application. Leaf width of the emerging leaf was not different between N or application treatments and averaged 6.3 ± 0.9 mm. Tiller counts taken at the end of the experiment indicated that N increased tiller numbers linearly with 90N having almost double the number of tillers compared to 0N treatment (Table 2) but there was no difference between treatment timings.

Table 2. Leaf extension rates (mm/day and mm/GDD), final leaf length (mm) and tiller numbers (tillers/m^2) for nitrogen treatments; 0N, 30N, 60N and 90N and treatment times; T1, T2, T3, and T4.

			Nitrogen			
	0N	30N	60N	90N	**LSD**	**P value**
mm/day	2.55	3.70	4.06	4.73	**0.567**	**0.004**
mm/GDD	0.30	0.43	0.47	0.54	**0.064**	**<0.001**
Leaf length (mm)	92.8	101.0	102.8	113.1	**11.9**	**0.014**
Tiller number (tillers/m^2)	1291	1760	2147	2458	**113.4**	**<0.001**
			Treatment Timing			
	T1	T2	T3	T4	**LSD**	**P value**
	Mid May	Early June	Late June	Mid July		
mm/day	4.20	3.44	3.31	4.09	**0.567**	**0.004**
mm/GDD	0.43	0.37	0.40	0.53	**0.064**	**<0.001**
Leaf length (mm)	94.6	95.6	98.8	120.6	**11.9**	**<0.001**

At the four week DM harvest there was an interaction between N rate and treatment time for DM accumulation (Fig 1). Increasing N rate always increased DM yet the difference between N rate treatments varied. At the eight week DM harvest, DM increased linearly with N rate with each N treatment rate increased from the previous N rate (Table 3). The addition of 90 kg/ha of N resulted in an increase of 1300 kgDM/ha after eight weeks. There was no interaction or main effect of application timing for the eight week DM harvest.

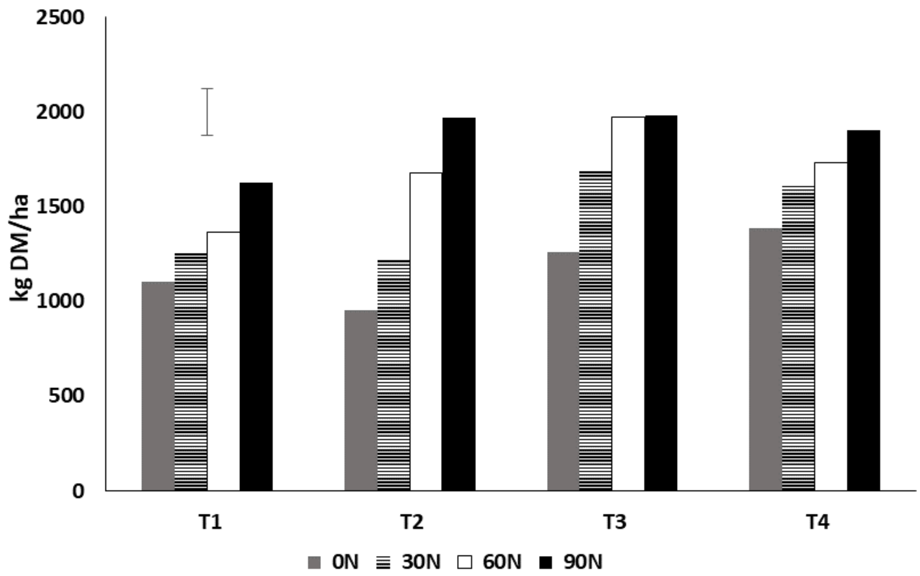

Figure 1. Dry matter (kg DM/ha) at four weeks after T1 (mid-May), T2 (early June), T3 (Late June) and T4 (mid-July) with four N treatments (0, 30, 60 and 90kg N/ha). LSD = 243kg DM/ha.

It was clear from observing urine patches within the plots that the N response of the phalaris pasture was not saturated. The urine patches at the end of the experiment had accumulated on average 7362 kg DM/ha far exceeding any other treatment. The N use efficiency (NUE) calculated as the increase in DM divided by the rate of N indicated that there was no difference in rate of N applied. NUE did change with treatment timing with T1 being lower than T3 but not different to T2 and T4 (Table 3).

Table 3. Dry matter (DM) at eight weeks for nitrogen treatments; 0N, 30N, 60N and 90N. Nitrogen use efficiency (NUE) for treatment times T1 (mid-May), T2 (early June), T3 (Late June) and T4 (mid-July).

			Nitrogen			
	0N	30N	60N	90N	**LSD**	**P value**
DM yield (kgDM/ha)	1542	1885	2445	2800	188.2	<0.001
			Treatment Timing			
	T1	T2	T3	T4	**LSD**	**P value**
NUE (kgDM/ha.kgN)	Mid May 10.8	Early June 13.0	Late June 16.1	Mid July 14.0	**3.50**	**0.04**

Discussion

At this site all N treatments were responsive. This is likely due to the fact that clover content of the pasture was extremely low, that is it was not measureable. The low clover content would be due to the dense phalaris stand and the lax grazing management conducted allowing phalaris to outcompete any clover species. Urine patches were still easily observed in the 90N treatment. The application of N increased leaf extension rate resulting in longer leaves which combined with greater tiller numbers increased light interception through greater canopy cover. Interestingly leaf width was unchanged due to N but this could be due to measurements used. It is likely that N application may effect later leaves as compared to the measured leaf in this experiment which had already appeared and therefore the width had already been determined. The treatment timing treatments from May to July in this experiment were developed to determine if there were any differences in response to N under cold temperatures. When leaf measurements were coverted to GDD commonly T4 was different indicating that perhaps plant development was playing a role in these differences. While there were some treatment timing effects in DM accumulation all treatment timings demonstrated a response to N application. The calculated GDD between timing treatments ranged from T2 with 513 GDD to T4 with 550 GDD. This averages at a daily difference of 0.7 °C. The eight week periods following N application received on average 31 frost and the lowest air temperature recorded was -5.9˚C.

The minimum soil temperature was 4.8˚C which exceeded the base temperature for phalaris (Moot et al. 2000). Therefore the timing treatments achieved only small differences in temperature but winter soil temperatures in south eastern NSW are high enough for plant growth to occur. It is suggested that cold temperatures in south eastern grazing lands of NSW are not too cold to prevent a response to N application. Therefore in many environments in autumn and winter on phalaris pastures it is expected that there will be a response to N application.

Only two treatment timings were different in NUE whereas all other treatment combinations were similar. All plots were mown prior to the application of T1 to 5 cm which severly reduced leaf area. Initial Canopeo estimates ranged from 14 % at T1 to 69% at T3. A regression of average initial Canopeo percentage for each treatment timing by NUE was positive and significant ($p = 0.03$, $y = 0.0856x + 9.875$, $R^2 = 0.93$). It is likely that the leaf area mediates NUE.

Table 4. The cost of extra dry matter produced (c/kg DM) for a range of NUE values. A base price of $750 was used, with $825 and $900 reflecting a 10% and 20% increase on the base price.

	Urea price ($/t)		
N response (kg DM/ha.kg N)	$750	$825	$900
10	16.3	17.9	19.6
12.5	13.0	14.3	15.7
15	10.9	12.0	13.0

At $750/t, the cost of an additional kilogram of DM ranged from 10.9 to 16.3c/kg DM (Table 4). This is similar to the N response and cost for perennial ryegrass (Eckard and Franks 1998). The application of N can produce extra dry matter at a price which is less than importing alternatives, such as hay.

Conclusion

The application of N to phalaris pastures increased leaf extension rate resulting in longer leaves which when combined with greater tiller numbers increased canopy cover. At no time did cold temperatures prevent a positive response occurring to N application. In south eastern Australia it is likely that low temperatures will not inhibit N response in phalaris pastures.

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