N and P responses for oaten hay

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Abstract
Oaten hay has found an important place in cropping rotations with around 550,000 t produced for export. This crop is grown as a cash crop as well as a rotational crop to manage herbicide resistant ryegrass. Despite this importance, there is little information on the nutrient demands and removals of oaten hay and to address this, the Dahlen long term fertilizer experiment at Horsham in Victoria, was sown to oaten hay in 2012. The experiment was established in 1996 with five rates of nitrogen (0, 20, 40, 80, 160 kg as urea) and four rates of phosphorus (0, 9, 18, 36 kg as triple super) applied annually over the past 16 years.

The site mean yield was around 6 t/ha of dry matter and samples from each plot were tested for quality through Feedtest® (digestibility, crude protein, neutral detergent fibre and the estimated metabolizable energy) as well as the mineral nutrient content. The effect of added P was clear in this experiment, with the first 9 kg of P giving a 77% increase in dry matter. Increasing P from 9 to 18 kg gave an additional 24% in dry matter. However, the higher hay yield was of a lower quality, with lower crude protein, higher fibre content and a lower ME.

Like phosphorus, applied nitrogen had a significant effect on the quality of fodder produced, and extra N increased crude protein content from 8.4% (nil N) to 13.1% (80N). Balancing N and P meant that the yield gains due to the added P also maintained quality by maintaining N supply.

Key Words
Fertilizer, Long term experiments, fodder quality, digestibility, nutrient density.

Introduction
Current cropping systems have largely developed into no-tillage or minimum tillage systems, with weeds managed either culturally through a range of weed management strategies (crop topping, competitive crops, early sowing, seed destruction) and/or using pre-sowing and/or in-crop herbicides. Managing herbicide resistance is a challenging problem, particularly as many populations of annual ryegrass (*Lolium rigidum* L. display resistance to several herbicide modes of action (Owen et al. 2007). Incorporating forage or hay crops into rotations allows an alternative management strategy to be deployed, where herbicide resistant weeds such as annual ryegrass can be removed from the paddock before the seed is shed. As a consequence, many growers have been producing hay from cereals such as oats (*Avena sativa* L.) which is exported principally to Japan, Korea and Taiwan and this trade was over 500,000 t in 2005-6, but the trade has declined with the drought in eastern Australia since then (Zwer and Faulkner 2006).

Despite the size of the industry, there is little information about comparative nutrient requirements of oaten hay, and the effect of N and P nutrition on hay quality. The Victorian DPI (2007) indicates that fodder value should be based on the cost per unit of metabolizable energy (ME, MJ/kg) rather than the cost per tonne of feed, although protein content is also important. For example, a 450 kg cow with a calf up to four months old will need to eat 85 MJ per day, and can eat around 10 kg of dry matter (2.2% of body weight). This means she will require a minimum ME of 8.4 MJ/kg feed and 10% protein. Similarly, a 300 kg steer growing at one kg/ha per day will need 76 MJ/day, and can eat only 7.6 kg DM per day, so that the ME content of the hay should be at least 10 MJ/kg and 13% protein (Victorian DPI 2007).

This paper reports on the response to N and P of the yield and fodder quality for oaten hay. The magnitude of the nutrients exported is also reported.

Methods

The Dahlen long term nutrition experiment, 10 km west of Horsham, was established in 1996 to investigate the interaction of different rates of N and P within a modern cropping system. Since establishment, the site has been in a canola, wheat, barley, pulse rotation. The soil at the site is a vertisol. The fertilizer treatments imposed are five rates of nitrogen (0, 20, 40, 80, 160 kg as urea) and four rates of phosphorus (0, 9, 18, 36 kg as triple super) applied annually over the past 16 years. No N is applied during the pulse phase of the rotation. Prior to 2011, there were two series of N treatments, either all N at sowing or split 50:50 between sowing and stem elongation, but this split was not applied in the current experiment and all N was applied at sowing. Fertilizer treatments are combined in a 2*5*4 factorial design (prior split N; N rate: P rate) with three replications,

The site has been direct drilled and no stubbles have been removed, and the site was burnt only once in 2000. In 2011, to reduce annual ryegrass burdens in the paddock, the site was sown with oats (cv Mulgara) using the existing fertilizer treatments. Mulgara is a mid-season oat variety specifically bred for hay production (SARDI 2012). The oats were sown in mid-May and the standing crop cut on 20 September 2011 when the heads were still in the flag leaf. One square meter of sample was taken and dried at 45^{o}C initially, when subsamples for quality and nutrient analysis were taken, and then dried at 70^{o}C to constant weight. This hay cutting time was a little earlier than normal, as many growers would wait until ear emergence. However, delaying cutting usually increases biomass produced, but the quality declines.

Soil samples (0-10 cm) were collected from the whole site (120 plots) and analysed for Colwell P, mineral N, potentially mineralisable N, total soil N, C and P as well as other analytes which will not be reported here. In addition, the 0N0P, 0N18P, 80N0P, 80N18P, 160N0P and 160N:18P treatments were sampled for mineral N to 150 cm. Fodder samples were analysed for crude protein, digestibility, neutral detergent fibre, and estimated metabolizable energy analysed by the Feedtest® laboratory using Near Infra Red Spectroscopy (Feedtest 2012). Nutrient composition of the fodder samples was assessed using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). Samples were digested with 11 ml of nitric acid (HNO_3)/perchloric acid ($HClO_4$) mixture (10:1 v/v), boiled down to approximately 1 ml of $HClO_4$ and made to 25 ml final volume using de-ionised water. This final solution was then analysed for nutrients on ICP-OES (ARL 3580 B, Appl. Res Lab. SA, Ecublens, Switzerland) and results are reported on a dry weight basis. Only fodder P content is reported here from the ICP-OES analyses. Yield, quality and nutrient contents are expressed at nil moisture content.

These data were analysed using a factorial analysis of variance with four rates of P and five rates of N combined.

Results

The mean Colwell P values for each P rate treatment at sowing in 2011 were 17, 41, 72 and 125 mg/kg for the 0, 9, 18 and 36 P treatments respectively. The soil mineral N contents in the top 60 cm at sowing were all relatively low, although there were large to very large N reserves beyond 60 cm (Table 1). This “bulge” of mineral N is probably a consequence of two wet summers at the site. The starting soil organic C level in 1996 was 1.14% (±0.18). Plots at the site which had received high rates of N had significantly higher soil organic C levels where adequate P was also supplied.

Table1. The soil chemical analyses at sowing, 2011, for six treatments at Dahlen long term fertilizer experiment.

		Top 10 cm					Mineral N kg/ha	
N	P	Mineral NO_3 mg N/kg	Total Soil N %	Total Soil C %	Total Soil P %	Pot. Min. N (kg/ha)	0-60 cm	0-150 cm
0	0	12.5	0.098	1.08	0.020	30	24	52
0	18	15.7	0.113	1.23	0.032	61	25	64
80	0	13.2	0.108	1.10	0.022	40	33	334
80	18	25.2	0.133	1.37	0.028	74	40	110
160	0	13.0	0.122	1.10	0.022	30	30	683
160	18	20.0	0.127	1.33	0.033	50	40	348
LSD (p=0.05)		4.8	0.022	0.15	0.007	36	12	134

The site mean yield was around 6 t/ha of dry matter, and fodder yield was significantly affected by the rate of applied P (*p*=0.000) (Figure 1) but there was no significant effect of N on dry matter yield. The P effect is expected based on the Colwell soil P test values, and the nil response of the crop to added N suggests that the crop was able to tap into the subsoil N reserves, which were considerable especially where there was prior N applied. Within the N treatments, there were no differences in the amount of potentially mineralisable N so that around 80 kg N/ha was an adequate N supply for this crop.

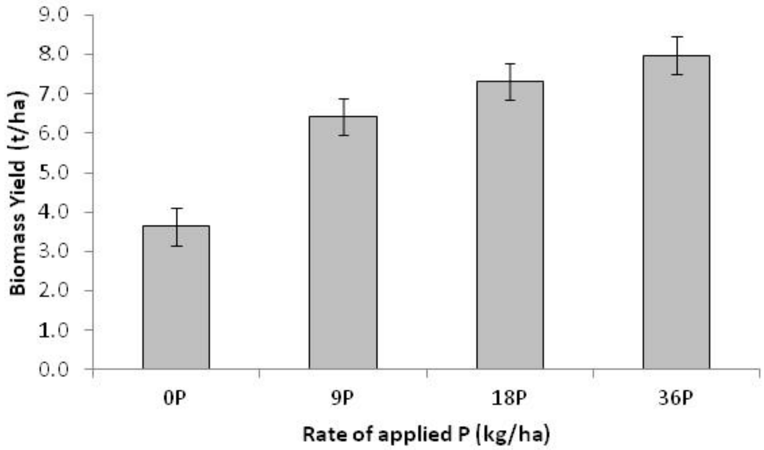

Figure 1. The effect of applied P on yield of oaten hay in 2011 at the Dahlen long term fertilizer experiment. The vertical bar is the standard error of the means.

Even though fodder yield was not increased with added N, the crude protein content did increase significantly by almost 50% (Table 2). As a result, N off-take figures, which are the product of the N content and the yield, for the 0, 80 and 160 kg N application rates also rose significantly to be 75, 121 and 132 kg N/ha respectively. So, N supply and demand was in balance for the low N treatments, but an additional 30-40 kg N/ha has been removed over the estimated N supply for the high N treatments.

Table 2. The effect of applied N and P on oaten hay crude protein content. P value for the N effect, P effect and the N*P effect are 0.000, 0.000 and 0.035. The interaction LSD (*p*=0.05) is 0.56.

CP%	0P	9P	18P	36P	Mean
0N	10.1	8.1	8.1	7.2	8.4
20N	11.7	9	8.9	9.1	9.7
40N	13.5	11.2	10.4	8.9	11.0
80N	15.8	14.5	11.2	11	13.1
160N	15.1	13.1	12.3	13.1	13.4
Mean	13.2	11.2	10.2	9.9	

Table 3. The effect of applied N and P on oaten hay metabolizable energy content (MJ/kg). P value for the N effect, P effect and the N*P effect are 0.000, 0.000 and 0.016. The interaction LSD (*p*=0.05) is 0.19.

ME MJ/kg	0P	9P	18P	36P	Mean
0N	12.1	11.4	11.0	11.1	11.4
20N	11.8	10.7	10.7	10.6	11.0
40N	11.8	10.9	10.1	10.1	10.7
80N	11.9	11.0	10.2	9.9	10.8
160N	11.6	10.2	9.9	10.3	10.5
Mean	11.8	10.8	10.4	10.4	

The ME content of the oaten hay declined with both added N and added P, with some of the higher fertilizer rates resulted in hay quality with ME less than 10 MJ/kg but still above the AFIA quality standard of 9.5 MJ/kg for A grade cereal hay (Feedtest 2012). This grading system has a protein factor as well, with grade 1 more than 10%, grade 2 between 8 and 10% and grade 3 from 4 to 7%. The nil P treatments would all be graded as A1 quality, the low N treatments with >9 kg P/ha graded as A2. Any treatment with more than 40 kg N was A1 quality. In addition to raising quality, the added N increased the yield of both ME/ha and protein/ha.

The mean P content of the hay was 0.16% and this was slightly but significantly increased where P was added from 0.16% to 0.18% for the nil and 36 kg P treatment respectively. N did not significantly affect P content. The combined effect of the slightly higher P content and the biomass increase resulted in total P off-take increasing from 5.2 kg P/ha at the nil P rate, to 9.4, 12.9 and 17.4 kg P/ha for the 9, 18 and 36 kg P/ha applied. Based on these data, the 9 kg application rate approximately balances the P off-take b the crop, while higher rates are likely to further increase the soil P test values.

Conclusion

The results reported here indicate that oaten hay is quite responsive to P, but under the conditions of the experiment, it seemed that the N demand of the crop was largely met by N present pre-sowing plus in-crop mineralisation. The use of both N increased hay crude protein content, while added P reduced it. Added fertilizers decreased the ME content of the hay but generally increased yield. These data emphasise the importance of balancing N and P in terms producing oaten hay that has a balance of both yield and quality.

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