The effect of phosphate fertiliser on oaten hay and grain production in Western Australia

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Abstract
Production of oats for hay and grain export markets is increasing in Western Australia and growers are seeking information on P management of their oat crops. The results of this study suggested that growers should apply a minimum of 10 kg/ha P with oaten hay or grain irrespective of soil P levels. The current research showed 40kg/ha was the optimum rate of P for yield and quality of both oaten hay and grain. Oat varieties differ in their P requirements for hay production and grain. For hay production Carrolup has higher requirement for P whilst for grain Wandering requires more P than Carrolup. Soil analysis is a necessary tool for predicting oat response to P fertilisation. Better response to applied P is expected where soils are deficient in their inherent P level.

Key Words
Oaten hay, oat varieties, hay yield, hay quality, grain yield, grain quality, P

Introduction
Western Australian oats has a reputation as the best in the world with its bright colour, plump grain and low levels of admixture. Oats is an integral part of cropping system of Western Australia particularly due to their rotational benefits in controlling weeds by cutting for hay. The WA export hay industry has matured dramatically in previous few years and forged a strong reputation for exporting premium quality hay. Limited research on P fertiliser management for oaten hay and grain production has been conducted in Western Australia despite the growing prominence of both in current agricultural production systems. Phosphorus fertilisation is essential for oaten hay and grain production and is one of the most common nutrient inputs for this crop. Phosphorous (P) is involved in many essential metabolic roles within the plant, and deficiencies result in slow growth, suppressed yields, inferior quality and subsequently lost income. In WA cropping systems P is recognised as a limiting factor due to its inherent deficiency of plant available form and cost of fertiliser. The objective of this study was to addresses the P requirement of some of the prominent oat varieties grown in WA to assist in reducing fertiliser cost and improving yields and quality of both oaten hay and grain.

Methods
Field experiments with five rates of P (0, 10, 20, 40 and 80 kg/ha) were conducted at four locations - Katanning, Meckering, Narrogin and Yerecoin (Table 1). These sites with low fertility represent wide range of soils prevailing in Wheatbelt of Western Australia; and are located in medium to high rainfall zones of the state.
Four commonly grown varieties (Malik 2008) - Carrolup, Dalyup, Hotham and Wandering – with a targeted density of 240 plants/m^2 were sown at 3 cm depth in 20 m long plots over 8 rows (18 cm row spacing) in a split plot randomised design with P as main plots and varieties as sub plot treatment using 3 replications spread over 3 banks. For all treatments (except the control) 10kg P/ha was applied with seed as triple superphosphate (20.5% P) and the remaining dose was topdressed in front of the seeder. In all plots a basal dose of 50 kg K/ha as muriate of potash (49.5% K) was topdressed at seeding in the separate fertiliser box. Required amount of urea to 80kg N/ha as urea was topdressed by hand 6 weeks after seeding in all
From each plot, hay was hand cut at the watery ripe stage (Z71) as per the protocols used by the National Oat Breeding Program. The samples were oven dried for several days and weighed to determine hay yield. The samples were then milled and analysed for quality parameters -dry matter (DM), acid detergent fibre (ADF), neutral detergent fibre (NDF), crude protein (CP), in vitro digestibility (IVD), estimated metabolisable energy (estME) and water soluble carbohydrates (WSC) on a NIRS6500 machine using calibrations developed by the National Oat Breeding Program. Grain samples were measured for average grain weight, hectolitre weight, screenings, grain brightness, grain protein, oil and groat contents.

Table 1. Chemical properties of soils used in experiments.

Analyses	Katanning	Meckering	Narrogin	Yerecoin
pH ($CaCl_2$)	5.0	4.8	5.0	4.6
Clay (%)	8.0	3.0	6.0	4.5
Organic carbon (%)	1.62	0.57	1.42	0.84
N (NH_4) (µg/g)	22.0	4.0	10.0	3.0
N (NO_3) (µg/g)	33.0	5.0	14.0	11.0
Total N (%)	0.10	0.05	0.10	0.07
P (HCO_3) (µg/g)	23.0	11.0	22.0	17.0
Total P (µg/g)	200.0	77.0	130.0	95.0
K (HCO_3) (µg/g)	16.0	17.0	40.0	35.0

Results

Effect of P on hay yield and quality

Hay yield

Phosphorus application significantly influenced hay yield (Figure 1). On average across the four sites hay yield increased with every unit of P applied up to a maximum of 40kg/ha. After 40 kg/ha of applied P hay yield slightly increased with increasing fertiliser and then slightly decreased with additional units. Thus the economic optimum level of applied P to maximise hay yield was found to be 40kg /ha.

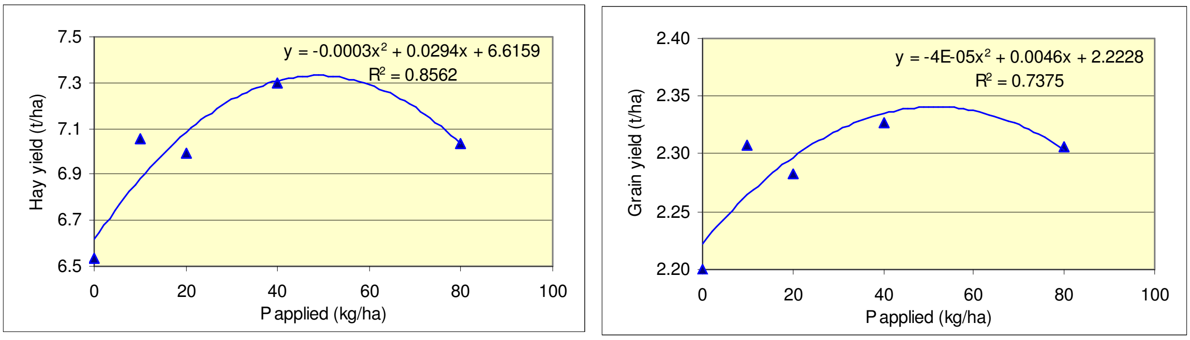

Figure 1. Effect of applied P on hay and grain yield. Data are averaged over four locations (LSD < 0.001 = 0.3 and 0.4 for hay and grain, respectively).

Varieties also showed differences in their P requirement for hay production. The milling variety Carrolup when cut for hay has a higher requirement for P than Hotham and non-milling varieties Wandering and Dalyup (Figure 2). At Katanning hay yields of Carrolup increased from 6.3 t/ha to 10.1 t/ha (a 60 per cent increase), Wandering 6.9 t/ha to 9.4 t/ha (a 36 per cent increase), Hotham 6.3 t/ha to 9.2 t/ha (a 46 per cent increase) and Dalyup 5.4 t/ha to 8.7t/ha (a 61 per cent increase) when 40 kg P/ha was applied.

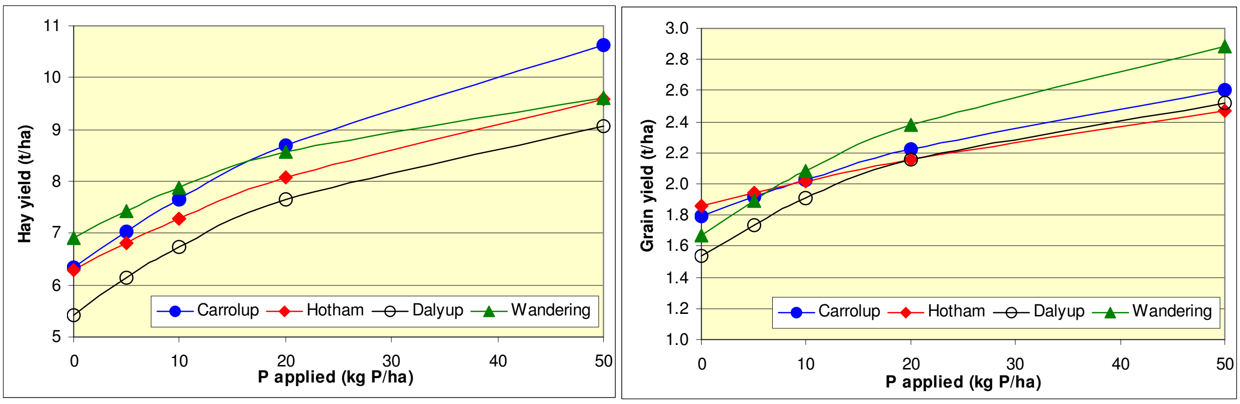

Figure 2. Comparative response of Carrolup, Hotham, Dalyup and Wandering oat varieties to applied P for hay and grain production at Katanning

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Hay quality

Phosphorus application generally has no significant effect on hay quality, however higher P application tend to increase ADF and NDF contents and a reduction in CP, IVD, estME and WSC, all characteristics of a decrease in hay quality (Table 2). The response of hay quality to increasing amounts of applied P was however site specific. At the Yerecoin and Meckering sites where initial available soil P was less than 20 mg/kg soil, drop in hay quality was more sensitive due to application of higher amount of P. Whereas at the sites where soil available P was more that 20 mg/kg such as at Katanning and Narrogin, there was no substantial effect of applied P on the hay quality.

Table 2. Effect of applied P on oaten hay quality (average of four varieties) grown on four locations.

Site	**Available P (mg/kg soil)**	**P applied (kg/ha)**					
		0	10	20	40	80	Average
				CP (%)			
Yerecoin	17	5.8	6.0	5.4	5.6	5.3	5.6
Katanning	23	4.9	4.9	4.9	4.7	5.0	4.9
Narrogin	22	6.1	5.5	5.7	6.0	5.6	5.8
Meckering	11	5.8	5.9	6.4	6.4	6.3	6.2
Average		5.7	5.6	5.6	5.7	5.5	
LSD (<0.05): Site = 0.5; P = NS; Site x P = 0.7							
				ADF (%)			
Yerecoin	17	34.2	35.4	34.9	35.4	36.3	35.2
Katanning	23	35.1	34.9	35.3	34.7	34.6	34.9
Narrogin	22	32.2	32.4	31.9	32.0	32.1	32.1
Meckering	11	31.3	31.6	32.3	31.9	33.2	32.1
Average		33.2	33.6	33.6	33.5	34.0	
LSD (<0.05): Site = 1.2; P = NS; Site x P = NS							
				NDF (%)			
Yerecoin	17	54.1	55.6	54.5	55.6	56.5	55.2
Katanning	23	58.1	57.7	59.1	58.0	57.1	58.0
Narrogin	22	54.2	54.0	53.1	53.0	53.5	53.6
Meckering	11	51.4	51.3	52.9	52.3	54.4	52.4
Average		54.4	54.6	54.9	54.7	55.4	
LSD (<0.05): Site = 1.7; P = NS; Site x P = 2.2							
				IVD (%)			
Yerecoin	17	61.6	60.9	60.5	60.3	59.6	60.6
Katanning	23	59.1	58.8	58.4	59.2	59.3	59.0
Narrogin	22	63.3	63.7	64.3	65.4	64.8	64.3
Meckering	11	64.1	63.1	62.8	63.6	61.9	63.1
Average		62.0	61.6	61.5	62.1	61.4	
LSD (<0.05): Site = 1.2; P = NS; Site x P = 1.6							
				estME (MJ/kg DM)			
Yerecoin	17	8.8	8.7	8.6	8.6	8.5	8.7
Katanning	23	8.4	8.4	8.3	8.5	8.5	8.4
Narrogin	22	9.1	9.2	9.3	9.4	9.3	9.3
Meckering	11	9.2	9.1	9.0	9.2	8.9	9.1
Average		8.9	8.8	8.8	8.9	8.8	
LSD (<0.05): Site = 0.2; P = NS; Site x P = 0.3							
				WSC (%)			
Yerecoin	17	24.4	21.7	23.5	22.6	21.5	22.7
Katanning	23	19.8	19.9	18.4	18.8	19.3	19.2
Narrogin	22	23.0	25.2	25.5	25.8	25.9	25.1
Meckering	11	27.0	26.3	24.6	24.2	22.0	24.8
Average		23.5	23.3	23.0	22.9	22.2	
LSD (<0.05): Site = 1.9; P = NS; Site x P = 2.7							

From the studies it is evident that in the soils where initial available P (Colwell P) is less than 20 mg/kg soil, adding fertiliser P upto 40 kg/ha is optimum to maintain profitable hay yield and appreciable quality. Applying P beyond this level will not benefit hay yield or quality.

Effect of P on grain yield and quality

Grain yield

Application of P significantly influenced grain yield. The response function was quadratic (Figure 1) in nature as seen with hay yield response. This means that oat grain yield increased only upto 40 kg/ha applied P after which there was no yield improvement and it started declining at higher levels of applied P. On an average there was 6 per cent yield advantage by applying 40 kg/ha P over control where no P was applied.

For grain production the varieties differ in their P requirement and their behaviour for grain synthesis was opposite to that of hay production (Figure 2). For example dwarf variety Wandering was found to have higher P requirement for grain production than Hotham and non dwarf Carrolup. The data in Figure 2 suggests that grain yield of Wandering increased from 1.6 t/ha with no P applied to 2.8 t/ha when 40 kg P/ha was applied (a 66 per cent increase); whereas the corresponding increase in grain yield of Carrolup was only 40 per cent from 1.8 t/ha with no P applied to nearly 2.5 t/ha for the same amount of applied P. For Hotham and Dalyup the corresponding yield increases were 28 percent (1.8 to 2.3 t/ha) and 59 percent (1.5 to 2.4 t/ha), respectively when 40 kg P/ha was applied over control.

Grain quality

Application of P significantly influenced grain quality. Results indicated that even a small application of 10 kg/ha P was significant to improve grain hectolitre weight, protein and groat contents and reduced the screening levels (Table 3) and quality improvement due to these parameters continued with increasing amount of applied P. However average grain weight remained unchanged irrespective of amount of P applied.

Table 3. Effect of applied P on grain quality of oat (data are averaged over four locations).

	P applied (kg/ha)					
	0	10	20	40	80	*LSD (<0.05)*
Hectolitre weight (kg/hl)	51.6	52.1	52.3	52.7	53.0	0.3
Average grain weight (mg)	29.9	30.6	28.8	30.9	31.8	NS
Screening (<2.0 mm)	6.3	5.7	5.8	4.9	4.5	0.9
Protein (%)	10.7	11.0	11.1	11.1	11.2	0.2
Oil (%)	6.6	6.6	6.7	6.5	6.5	0.1
Groat (%)	73.2	74.3	74.6	74.9	75.8	0.4

Conclusion

Phosphorus supply early in the season is critical for formation of hay and grain yields. It is suggested that P be applied prior to crop establishment since an adequate supply of P is critical for rapid stand development. The studies indicate that 40 kg P/ha is required to maximise hay yield and grain yield of oats. However, response to P will largely depend on the inherent soil levels and P retention index. Soil testing is thus required before a decision on P application can be made. It will save a lot of unnecessary, costly inputs if the sufficient amount of P is already available in the soil. The application of higher rates of P may not be economical in soils with P levels greater than 20 ppm.

References

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