Phosphorus Requirements of Newly Released Lupin Varieties

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ABSTRACT

Rahman and Gladstones in 1974 reported that *L. luteus* had a high tolerance to P deficiency when compared with *L. angustifolius and L. albus*. Bolland (1997) reported the opposite in his findings with *L. albus* more tolerant than *L. angustifolius* to P deficiency which in turn was more tolerant than *L. luteus.* A series of pot trials was conducted with modern lupin genotypes, including *L.mutabilis* to determine the response to P application. This series of trials indicated these species tolerate P deficiency in the following order *L. albus* > *L. luteus* > *L. angustifolius*. *L. mutabilis* showed very little response to P application because of a very high P content in its seed. Mandelup is a vigorous producer of dry matter and the highest yielder of *L. angustifolius* genotypes released at present but it requires more P to produce the same dry matter biomass compared to the other lupin species.

These trials also showed that if *L. mutabilis* is to be effectively grown on WA soils more needs to be understand about its requirement for P nutrition.

INTRODUCTION

Lupins are uniquely well suited to the deep sandy soils of the Western Australian (WA) wheat belt (White, 1990). Over one million hectares of narrow leafed lupins was sown in WA in 1999 (French *et al.* 2008). Production of lupins however, has now declined to less than 400,000 ha in 2008, partly due to problems with weed control, disease and lower prices for lupin grain. In response new varieties with improved disease and herbicide tolerance have been released, and new species that produce valuable, high quality grain are being developed. How these new cultivars respond to P fertiliser, the most expensive and important input into lupin production is not known.

Rahman and Gladstones in 1974 reported that of the then cultivated species, *L. luteus* had a high tolerance to P deficiency when compared with *L. angustifolius and L. albus*. Bolland (1997) reported the opposite with *L. albus* being more tolerant than *L. angustifolius* to P deficiency which in turn was more tolerant than *L. luteus.* Varieties examined by these researchers however, are now obsolete, and they did not include *L. mutabilis*, a new high quality variety with substantial potential in WA. This paper examines the relative requirements of the latest lupin varieties to there response to phosphorus fertiliser application.

KEYWORDS

phosphate, *Lupinus* species, dry matter yield, P concentration

MATERIALS AND METHODS

Soil was collected from uncleared land at five locations representing important lupin growing areas in the south west agricultural area of WA (Table 1). The response of four lupin genotypes (Table 2) to P fertiliser (seven rates: 0, 0.01, 0.02, 0.03, 0.04, 0.09, 0.18 µg phosphate/g soil) was examined on each soil type in pot experiments conducted consecutively over a 12 month period (excluding the hot summer months). The treatments were replicated 3 times and were placed in a complete randomised block design.

Pots contained 4,000g of air dried soil and were sealed at the bottom to prevent drainage. Full basal nutrients (except N and P) were applied in solution to the soil surface of each pot. Phosphate was applied as a suspension of Potassium Dihydrogen Orthophosphate (KH_2 PO_4 technical grade) also to the soil surface. After the nutrients and KH_2 PO_4 had dried they were mixed throughout the soil by shaking.

Ten seeds per pot were sown and inoculated with Group G, peat-based rhizobium inoculum. The water content of pots was maintained at field capacity by regularly watering to weight. About 10 days after germination the pots were thinned to 4 plants/pot for all soils except Chittering (3) and were harvested between 46 and 57 days after seeding (DAS). Shoots were cut at soil level and placed in paper bags and dried at 50-60°C for 3 days.

After drying, shoots were weighed to determine dry matter production (yield) then ground and analysed for P content (McQuaker *et al.* 1979). Relative yields were determined by dividing the dry matter of shoots at each P rate, by the maximum dry matter of shoots obtained by each genotype.

Plant roots were washed out from the Chittering, WHRS and Valentine soils to check nodule development and to see if proteoid (sometimes called cluster) roots were present.

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Table 1. Soil characteristic for the individual soils.

Soil property	LOCATION				
	Chittering	Merredin	Mullewa	Valentine	WHRS
Texture	1.5	1.5	1.5	1.5	1.5
Gravel %	70-75				
Colour	Light brown	Grey pink	Brown	Light brown	Grey
Phosphorous mg/kg	1	3	2	-1	2
Potassium mg/kg	35	71	74	41	22
P R I	17.6	8.83	3.3	1.6	4
Total P mg/kg	71	56	44	21	28
Organic carbon %	1.4	0.35	0.28	0.89	0.48
pH ($CaCl_2$)	5.0	4.7	5.3	6.1	4.8

Table 2. Seed P content prior to the commencement of the trial. The same seed source was used for all soils.

Species	Cultivar	P concentration (%)
L.angustifolius	Mandelup	0.30
L.albus	Andromeda	0.39
L.luteus	Wodjil	0.48
L.mutabilis	P 26961	0.80

Table 3. P content (g/plant) of four lupin genotypes in response to phosphate application.

Soil	Lupin genotypes					LSD
	P rate	Mandelup	Wodjil	Andromeda	P26961	
Chittering	0	0.024	0.045	0.047	0.109	
	0.01	0.025	0.063	0.071	0.103	
	0.02	0.030	0.054	0.062	0.129	
	0.03	0.030	0.083	0.089	0.127	0.029
	0.04	0.054	0.099	0.101	0.143	
	0.09	0.119	0.150	0.124	0.155	
	0.18	0.195	0.216	0.196	0.196	
Mullewa	0	0.031	0.087	0.085	0.122	
	0.01	0.084	0.141	0.117	0.175	
	0.02	0.143	0.189	0.157	0.210	
	0.03	0.210	0.255	0.200	0.222	0.073
	0.04	0.227	0.352	0.258	0.228	
	0.09	0.404	0.403	0.386	0.397	
	0.18	0.515	0.734	0.653	0.599	
Valentine	0	0.031	0.044	0.050	0.118	
	0.01	0.046	0.073	0.060	0.118	
	0.02	0.072	0.101	0.072	0.152	
	0.03	0.122	0.144	0.097	0.184	0.059
	0.04	0.145	0.171	0.143	0.211	
	0.09	0.237	0.313	0.204	0.328	
	0.18	0.372	0.474	0.327	0.474	
WHRS	0	0.029	0.046	0.059	0.108	
	0.01	0.057	0.094	0.084	0.144	
	0.02	0.124	0.163	0.121	0.182	
	0.03	0.148	0.206	0.159	0.191	0.068
	0.04	0.171	0.228	0.191	0.260	
	0.09	0.245	0.394	0.305	0.352	
	0.18	0.323	0.681	0.439	0.522	

RESULTS AND DISCUSSION

PLANT DEVELOPMENT AND SYMPTOMS

Generally, the rate of plant development was faster for all plant genotypes, except P26961 when P was applied (data not shown). With an increased rate of P application, plants of Mandelup, Wodjil and Andromeda were taller, produced more leaves and flowered earlier.

Discolouration and necrosis appeared on the older leaves of plants grown on all soil receiving less than 0.02 µg phosphate/g soil except for P26961 where symptoms only occurred on the Chittering soil. These symptoms were similar to those of P deficiency as described by Snowball and Robson (1986). Where more than 0.02 µg phosphate/g soil was applied symptoms of P deficiency did not occur on any plant. At the highest rate of P (0.18 µg phosphate/g soil), most plants appeared to be healthy but Mandelup and Andromeda grown on WHRS soils showed symptoms similar to P toxicity (resemble appearance of water stress; the extremities of the leaflet becoming a very pale green, dehydrated and brittle (Snowball and Robson, 1986)).

A further set of symptoms occurred on P26961 that did not change with the rate of P application. The lower leaves of this genotype grown at all rates of P on all soils were a pale yellow colour and this progressed to upper leaves as the plant grew. The plant did not shed these leaves.

Where roots were observed on the Chittering, Valentine and WHRS soils only Andromeda (*L. albus*) formed proteoid roots. There was no noticeable difference in number of proteoid with the change in rate of P. All plants grown on these two soils also appeared to be well nodulated.

The delayed development of plants at the low rates of P application, and the strong symptoms of P deficiency indicates that all soils had very low levels of P in their natural state. Adding P removed P deficiency as a major factor restricting growth of plants on these soils. However, the general yellowing of P26961 indicated that another deficiency possibly N, was restricting growth of these plants. Nodules appeared on the roots of the plants but we don't know if they were functioning well. P26961 has been observed in field trials with pale green or yellowing older lower leaves. (Smith & Clements unpublished 2007). Adding nitrogen or potassium fertiliser to these plants has improved their colour and growth. If the growth of P26961 was restricted by N or K nutrition in the pot trials described here it is unlikely we would have observed the full response to P in this genotype. Further investigation into the effect of N and K on *L. mutabilis* would be warranted if this species is to be grown in WA.

It is unlikely that plants of other species were N deficient because lupin nodules are usually well functioning by 42 days after inoculation (Gault *et al.* 1986).

DRY MATTER PRODUCTION

Plants grown without additional P produced between 20–60% of the maximum dry weight of shoots except for P26961 which produced between 65–100% of the maximum dry weight of shoots (Fig. 1–5). Difference between genotypes was generally consistent across all soil types. The order of the relative yields were Mandelup < Wodjil < Andromeda < P26961. Adding P increased yields of all genotypes on all soils except for P26961 grown on the Chittering and Valentine soils.

Maximum dry weight of shoots was produced with the addition of 0.18 µg phosphate/g soil for Mandelup on the Chittering, Merredin and Valentine soils, at 0.09 µg rate for Mullewa and at 0.04 µg for WHRS.

Wodjil reached its maximum dry weight of shoots with the addition of 0.18 µg phosphate/g soil on the Chittering and Mullewa soils and with the addition of 0.09 µg on the Valentine and WHRS soils. For the Merredin soil maximum growth of Wodjil occurred with the addition of 0.04 µg.

Andromeda reach its maximum dry shoot weight between 0.03–0.04 µg on the Mullewa, Valentine and WHRS soils and was at the 0.18 µg rate for Chittering and Merredin soil.

P26961 produced maximum dry shoot weight with only 0.01 to 0.04 µg phosphate/g soil applied except for Mullewa and Valentine which was reached at 0.09 µg phosphate/g soil.

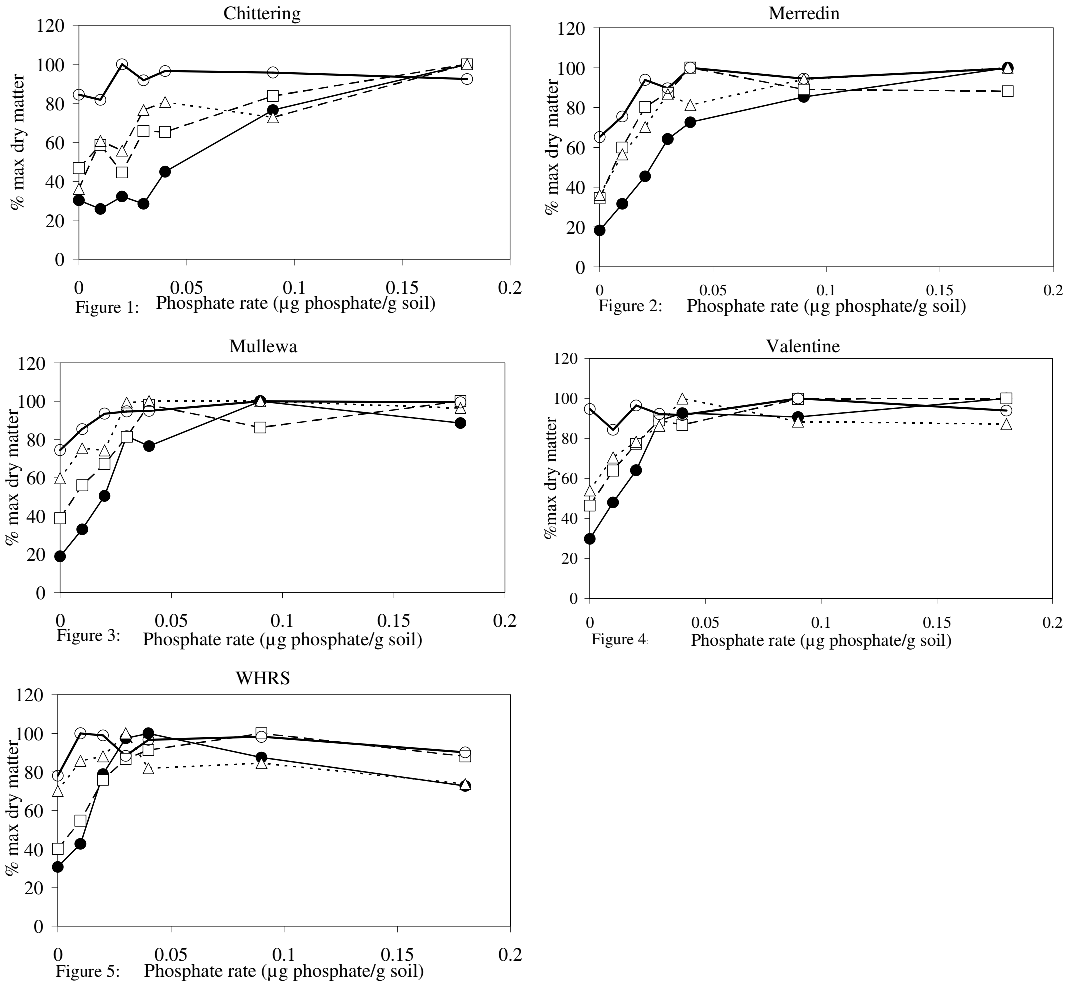
The dry weight of shoots of all genotypes was reduced by 10–27% at the highest rate of P (0.18 µg phosphate/g soil) applied to the WHRS soil. The dry weight of P26961 was reduced the least while that of Mandelup was reduced the most.

Uptake of P by plants showed a similar response to P application as the dry weight (Table 3). Without P applied to the soil the P content of P26961 was three to five times higher than the P content of Mandelup shoots. Adding P increased the P content of all plants so that at the highest rate of P application, P content in shoots were generally similar for all genotypes.

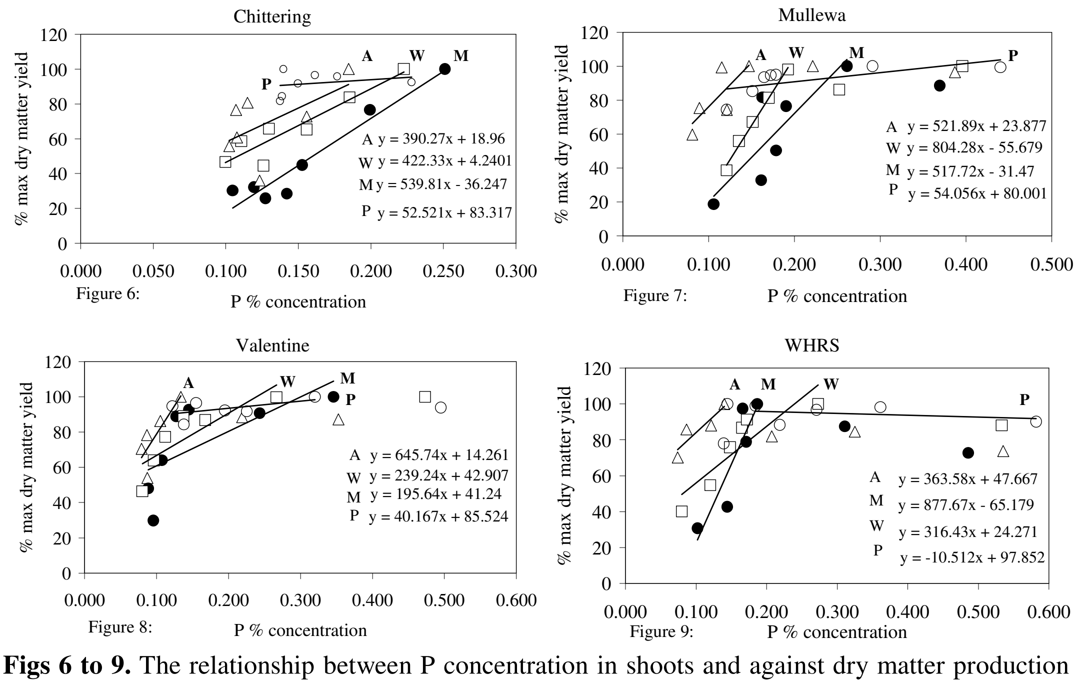
The relative ability of plants to grow and take up P at low rates of P application as seen in these trials agrees with that observed by Bolland (1997). *L. mutabilis* however, which was not examined by Bolland *et al.* (1989) showed a much greater ability to produce shoots on P deficient soil than the other three genotypes. This is likely due to the high P content of its seed (Table 2). High P content in lupin seed (Table 2) has previously been shown to an increase dry matter of shoots at the low rates of P applied on phosphate deficient soil (Bolland *et al.* 1989).

P concentration

The relationship between P concentration in shoots and dry matter production showed similar differences between genotypes on all soils. P26961 had high P



Figs 1 to 5. The effect of increase rate of phosphate on the % maximum dry matter yield (g/plant) for 5 different soil types. Mandelup = ●, Wodjil = □, Andromeda = Δ, P26961 = ○.



Figs 6 to 9. The relationship between P concentration in shoots and against dry matter production (g/plant) as a % maximum dry matter yield for four different soil types. Mandelup = ● M, Wodjil = □ W, Andromeda = Δ A, P26961 = ○ P. P concentration wasn't obtained for the Merredin soil. Not all values are contained within the filled lines; high P concentrations are ignored.

concentration in shoots and consistently high dry matter yields. Amongst the other three species, Andromeda had the lowest P concentration in shoots for a given dry matter yield. Mandelup usually had the highest P concentration in shoots at any given dry matter yield. The only exception to this was on the WHRS soil where Wodjil the highest concentration of P in shoots to reach the maximum dry matter production (Figs 6–9).

The relationship between dry matter yield and P concentration in the shoots provides an indication of the internal efficiency by which P is used to product dry matter (Brennan and Bolland, 2001). Our results indicate that, Andromeda has a higher internal efficiency than either Wodjil or Mandelup. It is difficult to assess the internal efficiency of P26961 because shoot P concentration were consistently high in this species, probably due to the high seed P content. These results contrast with those of Bolland *et al.* (1989). They showed plants grown from seed containing different level of seed P had similar internal efficiencies for P.

CONCLUSION

Lupinus .albus requires less native P or applied fertiliser P than *L.luteus* or L. *angustifolius* to produce dry matter yield during early growth. This was related to a higher internal efficiency to utilise P and not due to greater P uptake or high P content in the seed. Mandelup had a low P uptake and internal use efficiency for P and produced the least amount of dry matter when P was limiting. Further studies are required to determine if this poor utilisation of P is a trend occurring with modern *L. angustifolius* genotypes, bred with high P inputs. *L mutabilis* grew well with low limits of P in the soil mainly because of a high P content in the seed. There is a need to investigate the growth of the *L mutabilis* with a wider range of seed P levels.

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