Effect of rate and placement of phosphorus on vetch performance

Authors: Brian Dzoma[1], Nigel Wilhelm[2] and Kym Zeppel[1]
[1]SARDI Loxton Research Centre, [2]SARDI Waite Research Precinct

Peer Review: Sjaan Davey (SARDI - Waite) and Brett Masters (Rural Solutions – Port Lincoln)
Funded By: *Grains Research and Development Corporation (DAS00169)*
Project Title: *Improving sustainable productivity and profitability of Mallee farming systems with a focus on soil improvements)*
Key Words: *Vetch, phosphorus, nodules, root and shoot biomass, phosphorus agronomic efficiency*

Key Messages

- Our trial showed an increase in nodule numbers, root and shoot dry matter and leaf tissue P with increasing P rates
- Placing P shallow (banded) is key to getting early good nodulation, however deep banding will result in more biomass produced

Background

Phosphorus (P) is a nutrient which is essential for normal plant growth. Inadequate P restricts root and shoot growth and other functions which reduce N fixation by legumes. Vetch (*Vicia sativa*), a versatile pasture legume that can be used for grain, pasture, hay/silage or green manure, is being grown on naturally infertile Mallee soils which are often quite deficient in P. It struggles to achieve optimum productivity on low P soils and hence less fixed nitrogen is returned to the system. The trials reported here evaluated the impact of P rate and placement at sowing on vetch productivity and nodulation. By addressing the optimum rate and right depth to place the P at sowing, productivity gains in the form of improved dry matter production, grain yield, nodulation and N-fixation can result in multiple benefits, particularly in low rainfall mixed farming systems.

About the trial

Two replicated field trials were established in 2018 sites representative of neutral – alkaline sandy soils in the northern Mallee of South Australia (SA), a grey sand with clay underneath at Peebinga and a red loamy sand at Loxton. . Both trial sites had low background Colwell P in the top 10 cm, with Peebinga 5 mg P/kg soil and Loxton 8 mg P/kg soil. Trials were sown to Volga vetch @ 35 kg/ha on 13 June (Loxton) and 14 June (Peebinga). Different rates of P were applied as triple superphosphate, at different depths below the seed (Table 1). Plot length was 15 m and all treatments were replicated three times.

Table 1: *Treatment details*

Crop	Volga vetch
Main plot factor (P placement)	With seed
	Banded (4cm below seed)
	Deep banded (8cm below seed)
Sub-plot factor (kg P/ha)	0, 4, 8, 16, 32
Experimental design	Factorial RCBD x 3 replicates
Trace element package @ sowing (kg/ha)	10 S, 1 Zn, 2 Mn and 1 Cu

All treatments received a trace element package (Table 1) at sowing to make sure the responses to applied P were not restricted by trace element deficiencies. Emerged plants were counted on 10 July to determine plant population, and on 28 August, Clethodim @ 250 ml/ha + 1L/ha wetter was applied at both trial sites to control grass weeds. Sampling for nodulation, leaf tissue P, and early shoot and root dry matter (DM) was done on 5 September. Late flowering/early podding cuts were done on 22 Oct to determine maximum biomass. Soil sampling will be done in autumn 2019 in the 0-10 cm zone to determine residual P.

Results & Discussion

With total growing season rainfall of 116 mm (Peebinga) and 106 mm (Loxton), plant productivity was low at both sites. Visual responses to the different rates of P applied at different depths were more evident at the Loxton site than at Peebinga.

Response to P: There was a general increase in leaf tissue P with increasing soil P at both sites. The same trend was observed in nodulation and root and shoot dry matter i.e. more nodules per root, more early shoot and root biomass with increasing levels of P at both sites (Table 2). Average early shoot DM was higher at Loxton (382 kg DM/ha) than at Peebinga (317 kg DM/ha), which can be attributed to the better background soil nutrition at the Loxton site.

Table 2: *Effect of different P rates on leaf tissue P, nodulation, early shoot and root DM at Loxton and Peebinga*

Site	P rate (kg/ha)	Leaf tissue P (%)	Nodulation (# nodules/root)	Early shoot DM (kg/ha)	Root DM (mg/root)
LOXTON	0	0.27	6	168	95
	4	0.28	11.3	312	251
	8	0.27	11.3	342	431
	16	0.31	15	446	315
	32	0.33	27.8	641	456
	lsd (5%)	***0.03***	***4.8***	***123***	***190***
	p value	***<0.001***	***<0.001***	***<0.001***	***0.004***
PEEBINGA	0	0.23	8.4	241	96
	4	0.25	11.9	320	12
	8	0.27	12.6	278	138
	16	0.28	16.3	352	127
	32	0.36	19.9	396	139
	lsd (5%)	***0.03***	***6.4***	***102***	***23***
	p value	***<0.001***	***0.01***	***0.03***	***0.005***

Increasing rates of P also progressively increased flowering shoot DM at both sites (Figure 1). At both sites, the biggest response to applied P was from the nil treatment to 4 kgP/ha. The response was greater at Loxton (85%) and less at Peebinga (16%).

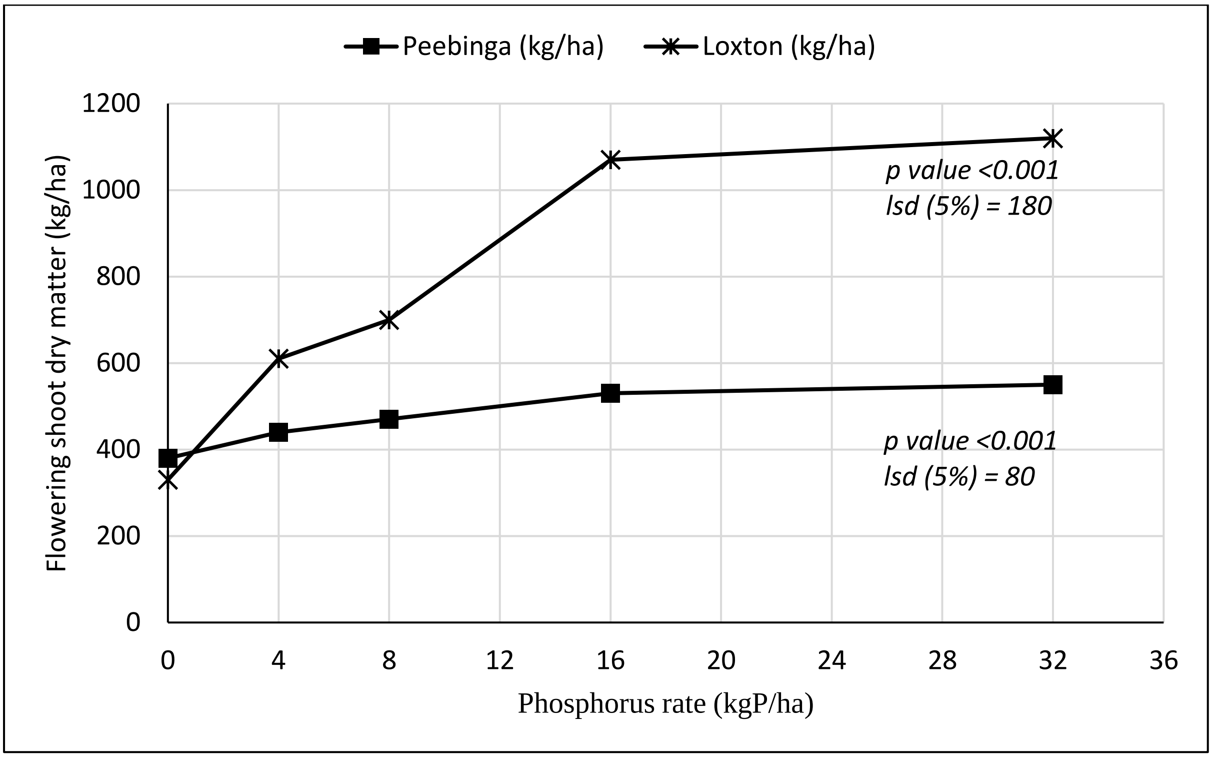

***Figure 1**: Effect of phosphorus of flowering shoot DM at Loxton and Peebinga*

Responses to P placement: There was no response in leaf tissue P at the Loxton site, however early shoot DM increased with increasing depth of P placement. Deep banding P resulted in better early biomass production but resulted in the least amount of nodules per root. At the Peebinga site there was no response to leaf tissue P, nodulation and shoot DM when P was placed at different depths away from the seed (Table 3). However, placing P with the seed at sowing showed the greatest increase in root DM. This was in contrast to the Loxton site where the response to banded placement of P was statistically insignificant.

***Table 3:** Effect of P placement on leaf tissue P, nodulation, early shoot and root DM at Loxton and Peebinga*

Site	**Placement**	**Leaf tissue P** (%)	**Nodulation** (# nodules/root)	**Early shoot DM** (kg/ha)	**Root DM** (mg/root)
Loxton	Deep banded	0.29	10.9	461	240
	Banded	0.30	17.0	385	350
	With seed	0.29	14.9	298	339
	lsd (5%)		***3.7***	***96***	
	p value	***ns***	***0.008***	***0.006***	***ns***
Peebinga	Deep banded	0.28	13.6	352	115
	Banded	0.28	12.6	309	119
	With seed	0.28	15.2	292	139
	lsd (5%)				***18***
	p value	***ns***	***ns***	***ns***	***0.02***

Phosphorus agronomic efficiency (PAE) is calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return (Fixen P et al., 2014). Mean PAE was higher at Loxton (47 kg DM/kgP) than at Peebinga (10 kg DM/kgP), meaning that the impact of applied P was greater on shoot biomass at Loxton. Deep placement of P had the largest PAE response at Loxton (55 kgDM/kgP) while placing P with the seed at sowing had the lowest response (34 kgDM/kgP). At Peebinga, banding P gave the largest PAW response (24 kgDM/kgP) with deep banding giving the lowest response (1 kgDM/kgP).

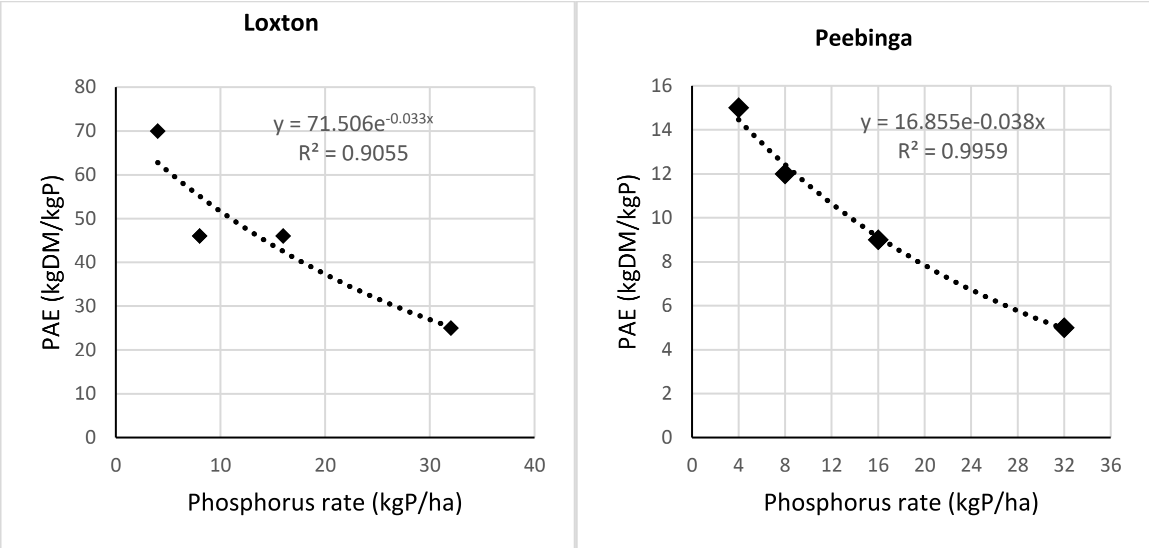

***Figure 2**: Phosphorus agronomic efficiency (kgDM/kgP) at Loxton and Peebinga*

Fitted exponential curves (Figure 2) were used to derive estimates of the rate of change of PAE with changes in P applied. At both sites, there was a similar trend of decreasing PAE with increasing rate of P applied. The rate of PAE decrease was higher however at Peebinga, decreasing by 2.68 kgDM per kilogram of P added. Comparatively, at Loxton the extrapolated decrease in PAE was 0.97 kgDM/ kgP added.

Implications for commercial practice

Vetch is now a significant legume rotation in cereal cropping systems in Australia's low and medium rainfall zones. There is limited recognition of the impacts of phosphorus on vetch productivity in low rainfall Mallee environments, and estimates of the impact of soil P levels on nodulation and N-fixation in alkaline coarse-textured soils is also poorly understood.

Our results show that there are productivity gains from applying P fertilisers when sowing vetch on soils with low P reserves. Application of 32 units of P resulted in shoot DM increases of 239% and 45% at Loxton and Peebinga respectively. P applications, however, need to be matched against expected productivity gains for different soil types and rainfall regions to make sure that the fertiliser applications are economically justifiable.

***Table 4**: Gross margin analysis for the two sites*

	P rate (kgP/ha)	**0**	**4**	**8**	**16**	**32**
	Fert cost ($/ha)	0	12	24	48	96
Peebinga	Yield (kg/ha)	380	440	470	530	550
	Fert cost c/kg DM	0.00	2.73	5.11	9.06	17.45
	Gross income @ 44c/kg hay	167.2	193.6	206.8	233.2	242
	Gross margin/ha	**167.2**	**181.6**	**182.8**	**185.2**	**146**
Loxton	Yield (kg/ha)	330	610	700	1070	1120
	Fert cost/kg DM	0.00	1.97	3.43	4.49	8.57
	Gross income @ 44c/kg hay	145.2	268.4	308	470.8	492.8
	Gross margin/ha	**145.2**	**256.4**	**284**	**422.8**	**396.8**

The calculation of the gross margin (GM) analysis (Table 4) only considered gross income from vetch hay (flowering DM) and the main variable cost i.e. cost of TSP/ha. The assumption was TSP at a cost of $600 /ton and vetch hay at $440 /ton (Agtrader.com, 2019). The GM analysis consistently shows an increase in GM ($/ha) with increasing rate of P, up to 16 kgP/ha only. Increasing P rate from 16 to 32 kgP/ha resulted in a decrease of GM of $39 /ha and $26 /ha at Peebinga and Loxton respectively.

The total number of nodules per plant also increased by 363% and 137% at Loxton and Peebinga respectively when 32 units of P were added. The results also show that deep placement of P is beneficial to early and late DM production, but can set back nodulation as the plants need the P upfront. P plays a key role in the symbiotic N fixation process by increasing shoot and root growth. This decreases the time needed for developing nodules to become active and to benefit the host legume, both; increasing the number and size of nodules and the amount of N assimilated per unit weight of nodules, and increasing the percent and total amount of N in the harvested portion of the host legume (Armstrong, 1999)

Improved nodulation and dry matter production can result in significant amounts of nitrogen returned back into the soil and also improved levels of soil organic matter and microbial activity. Cereal yields following vetch are usually at least 30 to50% higher than in continuous cropping cereals (Unkovich et al 1997). This is highly beneficial to low rainfall mixed farming systems where cropping and livestock production complement each other to result in resilient sustainable farming enterprises.

Acknowledgements

Thanks to George Gum (Peebinga), Robin Schaefer (Loxton) and their families for allowing us to set up our trials at their properties. Chris McDonough for technical support during the season. GRDC for funding this trial through the SARDI/GRDC Mallee Bilateral project - Improving sustainable productivity and profitability of Mallee farming systems with a focus on soil improvements (DAS00169-BA)and owners whose property trial work is being conducted on

References

Armstrong DL (1999). Phosphorus for Agriculture. Better crops with plant food. Volume 83, 1999, No.1. Potash & Phosphate Institute (PPI).

Fixen P, Brentrup F, Bruulsema T, Garcia F, Norton R, and Zingore S (2014). Managing Water and Fertilizer for Sustainable Agricultural Intensification. Chapter 1. Nutrient and Fertilizer Use Efficiency: Measurement, Current Situation and Trends.

Agtrader.com (2019). https://www.agtrader.com.au/item/livestock/livestock-feeding/sa/vetch-hay-350-t-435156. Accessed 1/02/2019

Unkovich MJ, Pate JS, Sanford P (1997). Nitrogen fixation by annual legumes in Australian Mediterranean agriculture. Australian Journal of Agricultural Research 48, pp. 267-293.