Legume content and sub-optimal nodulation linked to soil acidity and nutrient availability in the Mudgee region of the Central Tablelands, NSW

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Abstract: *A recent survey of pasture paddocks (n=24) in the Mudgee region of the Central Tablelands found 89% of the sub-clover plants sampled were below the industry benchmark for adequate nodulation. Soil chemical analysis of the sub-clover paddocks revealed 90% of paddocks had pH_{Ca} < 5.5 with 80% and 60% below the critical level of phosphorus and sulphur respectively. We propose that persistence and performance of sub-clover in this region is partly being limited by natural soil constraints, as well as current soil and landscape management factors.*

Introduction

Legumes are an important component of pastures and they support animal production in the extensive grazing landscapes of the Central Tablelands of New South Wales. Legumes can also contribute to the supply of nitrogen, an essential nutrient for plant growth and quality. The introduced cool season annual subterranean clover (*Trifolium subterraneum*) has traditionally been the most widely sown legume in these landscapes.

Previous botanical surveys of pastures on the Central Tablelands and slopes revealed that there are a wide variety of pasture types in this area. These range from native grass dominant swards, through degraded or naturalised mixtures to sown pastures dominated by introduced grasses (Kemp and Dowling 1991, Garden *et al.* 2000). These mixtures included subterranean clover (or 'sub-clover') as a pasture species.

In recent years, there has been much discussion on the factors which reduce the persistence and performance of legumes including sub-clover (Hackney *et al.* 2019, Nicols *et al.* 2007). For example, low commodity prices and/or drought in the period 1990–2009 resulted in reduced application of phosphorus, sulphur and lime. Seasonal condition variability and the timing of autumn rains (up to 2–4 weeks later, over the last 30 years) could also have an impact on germination, establishment and the ability of legumes such as sub-clover to produce adequate seed for ongoing regeneration (BOM 2019). Furthermore, soil conditions such as acidity have also been shown to affect legume nodulation (Hackney *et al.* 2019).

This paper reports on a legume survey in the Mudgee region in the Central Tablelands of NSW. The survey aimed to investigate the botanical composition of perennial-based pastures, the soil conditions of these pastures and the soil and pasture management circumstances in which they grow. In addition, the survey investigated legume nodulation. This paper reports on the sub-clover part of the survey.

Methods

In winter-spring 2017, 24 pasture paddocks were surveyed in the Mudgee region of NSW. Paddock criteria for the survey included that it contained legumes, the paddocks were used for agricultural purposes, and good management records were available. The methodology protocols were similar to the Hackney *et al.* (2019) survey. Of the 24 paddocks, 20 had sub-clover as the dominant legume.

A representative area of 20 m × 20 m was selected within each paddock. Sampling included pasture composition using the rod-point method (Little and Frensham 1993) for botanical composition. Fifteen legume plants were carefully removed for nodulation examination and scored for nodulation presence and amount using Yates *et al.* (2016). This 1–8 scale scoring system means a score of 4 (21–40 small pink nodules and/or 3–4 large pink nodules) is considered adequate. Twenty to thirty soil cores at two depths (0–10cm and 10–20cm) were taken using a push-tube 2 cm diameter sampler. These samples were kept cold (<4°C) and sent cold for analysis.

Soil and pasture management histories were collated from the participating landholders. This also included information on landholders' perspectives of legume performance.

Results

Botanical composition varied between paddocks, with the majority of the pastures being dominated by perennials (native and introduced grasses making up on average 45% of the pasture composition). The average sub-clover percentage was 18.9%, with a range of 2.5%–42.5%. The average number of pasture species found in the sample sites was 10.3.

As part of the landholder survey, pasture age since renovation (including time since seed broadcast) was examined. A larger percentage (> 63%) of the paddocks examined were sown more than 11 years ago, with 21% sown in the last five years. In terms of rhizobia inoculant delivery, 31% of participants used pre-coated seed, 10.5% used peat, 16% used none and a large number (42.1%) were unsure how the inoculant had been delivered. Of the surveyed paddocks, 42% had been supplied with fertiliser in the year of sampling. Only one had used lime in the last five years and another in the last ten years. Three paddocks had received molybdenum (Mo) in the past 10 years.

All soils were acidic, with 90% of the 0–10 cm samples having pH_{Ca} < 5.5 (Table 1). While there was no difference in the average pH between the two depths, when categorised into specific ranges, a larger proportion of samples had pH < 4.7 in the 10–20 cm sampling depth and average aluminium as a percentage of the CEC increasing with depth.

The majority of the soil samples taken at the 0 – 10 cm depth were less than the critical levels for pastures for phosphorus (80%) and sulphur (60%) based on Gourley et al. (2007) (Table 2 and Table 3). Phosphorus (Colwell P) averaged 29 mg/kg and sulphur (KCl40) 8.9 mg/kg. Potassium (Colwell) averaged of 245mg/kg and with one sample below 126mg/kg. The average CEC was 7.2 and had a range from 1.3 to 17.2.

The overall average sub-clover nodulation score was 2.1. Eighty nine percent of all sub-clover plants sampled had a nodulation score less than 4.

Landholders at the time of the survey were asked how well they believed their pasture legumes were currently performing. Fifty nine percent of the landholders responded that their legumes were 'about average', with 27% indicating that their legumes were either 'poor' or 'very poor'.

Table 1. Soil analysis (0–10 cm and 10-–20 cm depth) for pH_{Ca} and Aluminium (as a percentage of CEC) from surveyed paddocks in Mudgee region in 2017 (ranges of site values in brackets)

	pH_{Ca}	Percentage of pH in specific ranges						Exch. Al (%of CEC)
	Average	<4.7	4.7–<5.0	5.0–<5.5	5.5–<6.0	6.0–<7.0	>7.0	Average
0–10cm	4.85 (4.5–5.6)	40	35	15	10	0	0	6.46 (0.3–19)
10–20cm	4.87 (4.4–5.8)	47	24	12	18	0	0	11.46 (0.4–33)

Table 2: Soil analysis (0–10cm depth) for Phosphorus (Colwell) from surveyed paddocks in Mudgee region in 2017. Percentage of samples in specific ranges.

	Phosphorus (Colwell)				
mg/kg	<30	30–50	51–100	>100	Range
0–10 cm	70	10	20	0	6–82

Table 3: Soil analysis (0–10cm depth) for Sulphur (KCl40) from surveyed paddocks in Mudgee region in 2017. Percentage of samples in specific ranges

	Sulphur (KCl40)					
mg/kg	<5	5–8	8.1–12	13–60	>60	Range
0–10 cm	40	25	15	20	0	1.6–28.7

Discussion

Sub-clover in the Central Tablelands and slopes extensive livestock landscapes is an important legume for pasture growth and animal production. The cool season annual legume compliments the rainfall pattern and pasture types in the region. Sub-clover accounted for 2.5%–42.5% of the pasture composition. Pasture industry benchmarks defined legume content of 20–30% as ideal in a mixed pasture to fulfil the dual role of increasing sward quality and contributing to increasing soil nitrogen via biological N-fixation. While on average pastures surveyed contained sufficient legume (18.9%) according to this benchmark, it could be argued that the legume content would need to be higher to meet nitrogen fixation targets of 20–30 kg N/t DM due to less-than-adequate nodulation.

The average nodulation was 2.1 from the sub-clover paddocks; similar to that reported in a 225 paddock survey in Hackney *et al*. (2019). The Mudgee survey identified that only 11% of the sub-clover plants studied had adequate nodulation (score of 4 or above).

There was a large percentage of pastures sampled in this survey (>36%) that were > 30 years in age. Over 15% of the paddocks had never been sown but nonetheless contained legumes with the sub-clover having been self-sown, aerially sown or moved by livestock into the paddock. There was no difference in the average nodulation score between sown or self-sown paddocks in the survey.

This survey revealed a large range of legume component in pastures, tending towards the lower end of the acceptable range. However, composition can change rapidly through the seasons and is also strongly influenced by management. The type of grazing management and a previous large residual summer biomass of perennial grass species at germination, may also have impacted on germination and establishment of annual clovers. However, the herbage mass at the time of germination was not measured in this this survey.

The combination of lower amounts of legume and insufficient nodulation are essentially constraining the potential production and performance of these paddocks. Active pasture management to increase legume content is recommended including the additional supply of sub-clover seed, reduction of biomass through active grazing and pasture management in late-summer and early autumn (assuming there is a seed bank), and management at flowering and seed set.

From this survey, 90% of the soil samples recorded a pH < 5.5, with 40% a pH < 4.7. Sub-clover herbage yield has been reported to be negatively affected at a pH of 4.7 (Evans *et al*. 1990). An acidic pH can also affect nodulation and rhizobia function (Hackney *et al*. 2019, Drew *et al*. 2014). With one paddock being reported as having had lime applied in the last five years, and another in the last 10 years, this survey suggests that acid soils in the Mudgee area should be a high priority land degradation issue.

A Department of Agriculture New South Wales Soil Survey – Rylstone Bulletin (c.1964) reviewed soils in the local area to explain the persistence, or lack-thereof of sub-clover in pastures. The investigation examined alkaline soils as a possible cause of lack of persistence. The survey found that rainfall distribution and variability, the selection of suitable clover cultivars, fertiliser rates and acidic soils to be of concern for persistence of sub-clover. Fifty years on, and the same comments can also be made in regards to appropriate cultivars, soil nutrition and pH across the Mudgee region.

Mo deficiency has also potential impacts on legume performance. There is a well defined link between acid soils and Mo deficiency (Weir 2004). Improvement of acid soils to increase the availability of Mo or the use of fertilisers could address this micronutrient. Mo deficiency in perennial pastures in the area could be further investigated.

Soil nutrition is also important for legume growth and production with phosphorus and sulphur being two of the essential nutrients with linkages to the metabolism of rhizobia (O'Hara 2001). This survey found that 80% of paddocks had phosphorus levels which were less than the

critical benchmarks, and 60% of sites were less than the critical benchmark for sulphur. This is notable when considering that 42% of the paddocks had received fertiliser in the year of sampling.

Conclusion

This survey reflects previous surveys and highlights some of the multitude of factors that influence sub-clover and its associated rhizobia performance and persistence. In order to keep diverse and productive perennial pastures, producers should focus on assessing pH, the appropriate soil P, S & Mo nutrition, examining -topsoil and subsoil constraints, applying soil ameliorants, grazing management (especially as relates to sub-clover germination) and understanding sub-clover seed bank longevity in order to promote sustainable and productive, legume driven pastures.

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References

Department of Agriculture New South Wales Soil Survey - Rylstone Bulletin (c.1964).

BOM (2019) Bureau of Meteorology and the CSIRO - Regional Weather and Climate Guide http://www.bom.gov.au/climate/climate-guides/guides/05-Central-Tablelands-NSW-Climate-Guide.pdf

Drew E, Herridge D, Ballard R, O'Hara G, Deaker R, Denton M, Yates R, Gemmell G, Hartely E, Phillips L, Seymour N, Howieson J, Ballard N (2014) 'Inoculating legumes—a practical guide.' (Grains Research and Development Corporation: Canberra, ACT).

Evans J, Dear B, O'Connor GE (1990) Influence of an acid soil on the herbage yield and nodulation of five annual pasture legumes. *Australian Journal of Experimental Agriculture* **30**, 55–60.

Garden D, Dowling P, Eddy D, Nicol H (2001) A survey of farms on the Central, Southern and Monaro Tablelands of New South Wales: Management practices, farmer knowledge of native grasses, and extent of native grass areas. *Animal Production Science* **40**. 1081–1088.

Gourley JP, Melland AR, Waller RA, Awty IM, Smith AP, Peverill K, Hannah MC (2007) 'Making better fertiliser decisions for grazed pastures in Australia.' (Department of Primary Industries: Melbourne).

Kemp DR, Dowling PM (1991) Species distribution within improved pastures over central N.S.W. in relation to rainfall and altitude. *Australian Journal of Agricultural Research* **42**, 647–659.

Hackney BF, Jenkins J, Powells J, Edwards CE, De Meyer S, Howieson JG, Yates RJ, Orgill SE (2019) Soil acidity and nutrient deficiency cause poor legume nodulation in the permanent pasture and mixed farming zones of south-eastern Australia. *Crop and Pasture Science* **70**, 1128–1140.

Little DL Frensham AB (1993) A rod-point technique for estimating botanical composition of pastures. *Australian Journal of Experimental Agriculture* **33**, 871–875.

Nichols PGH, Loi A, Nutt BJ, Evans PM, Craig AD, Pengelly BC, Dear BS, Lloyd DL, Revell CK, Nair RM, Ewing MA, Howieson JG, Auricht GA, Howie JH, Sandral GA, Carr SJ, de Koning CT, Hackney BF, Crocker GJ, Snowball R, Hughes EJ, Hall EJ, Foster KJ, Skinner PW, Barbetti MJ, You MP (2007) New annual and short-lived perennial pasture legumes for Australian agriculture – 15 years of revolution. *Field Crops Research* **104**, 10–23.

O'Hara GW (2001) Nutritional constraints on root nodule bacteria affecting symbiotic nitrogen fixation: a review. *Australian Journal of Experimental Agriculture* **41**, 417–433.

Yates RJ, Abaidoo R, Howieson JG (2016) Field experiments with rhizobia. In 'Working with rhizobia'. (Eds MJ Dilworth, JG Howieson) pp. 145–166. (Australian Centre for International Agricultural Research: Canberra, ACT).

Weir RG (2004) Molybdenum deficiency in plants Agfact AC.4 https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/166399/molybdenum.pdf