The current and residual value of superphosphate for lupins grown in rotation with oats and wheat on a deep sandy soil

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Abstract

In a field experiment on a deep pale-yellow sand in a 600 mm per annum rainfall Mediterranean environment of south-western Australia, six levels of phosphorus (P) as superphosphate (0 up to 546 kg P ha$^{-1}$) were applied once only, to the soil surface, before sowing lupins (Lupinus angustifolius). The lupins were grown in a continuous arable cropping rotation with, in successive years, oats (Avena sativa), wheat (Triticum aestivum), lupins. Five such rotations were started in the experiment from 1985 to 1989. The experiment continued until the end of 1990.

The relationship between lupin seed (grain) yields and the level of P applied was measured in the year of P application for five successive years (1985 to 1989). The relationship had the same general form but it varied between years, largely due to different maximum yields (yield plateaux) in each year.

The residual value of superphosphate applied three years previously was measured for lupins on two occasions (1988 and 1989) relative to superphosphate applied in the current year. The residual values was different in the two years. The superphosphate applied three years previously was about 30% as effective as freshly applied superphosphate in 1988, and 12% as effective in 1989.

At each harvest, the relationship between grain yield and the P concentration in the grain differed for different species. However, for each species at each harvest, the relationship was similar regardless of when the P was applied in the previous years. Thus each species had the same internal efficiency of P use curve, and yields varied only with P concentration in tissue.

Bicarbonate-extractable soil P was determined on soil samples taken in mid-July of 1989 and 1990. These soil test values were related to grain yields at harvest. The relationship between yield and soil test values had the same general form but varied for different species within years and for each species between years. It also varied for each species within years depending on the year the P was applied.

Introduction

Soils of the Badgingarra-Eneabba (West-Midlands) area north of Perth, Western Australia, are lateritic, deep grey or pale-yellow sands with sparse ironstone gravel. These soils are acutely deficient in phosphorus (P) and nitrogen (N) when newly cleared [21]. A profitable farming system on these soils is to produce grain of lupins (Lupinus angustifolius), oats (Avena sativa) and wheat (Triticum aestivum) in rotation in a continuous arable cropping system. Superphosphate is usually applied to the soil surface before sowing lupins. It has been observed that lupin plant densities can be markedly reduced when >100 kg ha$^{-1}$ superphosphate is drilled.
with the seed, which may result in reduced grain production (unpublished data of the Western Australian Department of Agriculture). For oats and wheat, superphosphate, but increasingly ammonium phosphate fertilizer, is usually drilled with the seed while sowing the crops. Lupins improve the N nutrition of the following cereal crops [23]. Lupins followed by oats control the fungus *Gaemunnomyces graminis* which causes take-all in wheat [13]. Oats followed by lupins control root rot and leaf diseases of lupins, caused by the fungus *Pleiochaeta setosa* [24].

The response of lupins to freshly-applied and previously-applied (residual) superphosphate, grown with oats and wheat on the sandy West-Midland soils was not known, and was the reason for starting the experiment described in this paper. Soil testing for P, using a bicarbonate soil test [9], is widely used in southern Australia as a guide for estimating the current P status of the soil from previous P fertilizer dressings and to provide P fertilizer advice [2, 6, 7, 8, 10, 15]. It requires a knowledge of the relationship between future plant yields and soil P test values measured on soil samples collected earlier in the year. There are no published data for this relationship for lupins, oats and wheat grown in rotation on the sandy, West-Midland soils of Western Australia and this also was determined in the field experiment described here.

**Materials and methods**

**Location, soil and climate**

The experiment was on newly-cleared, pale-yellow sand with sparse ironstone gravel (Dy 5.81 [17]) on Badgingarra Research Station, 190 km north of Perth, Western Australia.

Some properties of the top 10 cm of the <2 mm fraction of untreated soil were: pH (1:5 soil:0.01 M CaCl₂, w/v) 5.3; total P (by digesting the soil in concentrated sulphuric acid), 60 μg P g⁻¹; bicarbonate-extractable P [9], 2 μg P g⁻¹; P buffer capacity [19], 1 μg P g⁻¹; cation exchange capacity (extracted in 1.0 M NH₄Cl at pH 7.0), 1.2 me per 100 g; organic carbon [25], 0.24%; total nitrogen (Kjeldahl method), 0.015%. Particle size analysis on the whole soil gave 1% gravel (>2 mm), 96% sand (20 to 2,000 μm), 2% silt (2–20 μm) and 1% clay (<2 μm).

The climate is Mediterranean, with hot dry summers and cool wet winters. On average, 490 mm (82%) of the 600 mm total annual rainfall falls during the May–October growing season. The total (and growing season) rainfall (mm) for the years of the experiment (1985 to 1990, respectively) were: 481(409), 614(503), 526(434), 674(559), 409(344) and 611(419).

**Superphosphate**

Granulated (0.2 to 5 mm), ordinary (single) superphosphate was used. The fertilizer was manufactured by CSBP and Farmers Pty Ltd, and contained 9.1% total P, 7.3% water-soluble P, 1.3% neutral ammonium citrate-soluble P, 0.5% acid-soluble P, 10.5% sulphur, 22% calcium, 0.5% iron, 0.4% aluminium, 20 μg g⁻¹ copper and 430 μg g⁻¹ zinc (as measured by standard procedures [1]).

**Field experiment**

Lupins, oats and wheat were grown in rotation and five such rotations were started in five successive years (1985 to 1989). The experiment was terminated at the end of 1990. All the species and cultivars grown each year are listed in Table 1.

The design of the experiment was a split-plot, comprising main and subplots, with three replications. There were five main plots, one started each year from 1986. Each main plot was sown to lupins, the first crop in the rotation in the first year (Table 1).

Each main plot was divided into six subplots. Six levels of single superphosphate were randomly allocated to the six subplots. The levels of superphosphate, applied once only to the soil surface when each main plot was started, are listed in Table 2. Basal fertilizers used are shown in Table 3. Each subplot was 40 m by 4.2 m which accommodated twenty four rows of seed of all species sown 5 cm deep, using a tined seeding machine. Lupins were inoculated with *Bradyrhizobium lupini* strain WU 425 (as commercial group ‘G’ inoculum) before being sown.