

Alfalfa Forage Production under Different Phosphorus Supply Strategies

By Marfa A. Marino and Angel Berardo

Alfalfa is one of the most important resources for high quality forage in the Pampas region of Argentina, with 1.75 million hectares (M ha) planted. Nonetheless, its yield potential is frequently restrained by inadequate soil phosphorus (P) supply.

Soils of the Pampas, typically Mollisols, commonly present low soil P availability for crops and pastures. Alfalfa is especially affected and forage yield responses to P fertilization are widespread. Adequate P fertilization will often produce a “residual effect” and increase forage productivity beyond the year of application. A fraction of the applied P remains in the soil, and depending on the soil characteristics, converts to different organic and inorganic forms having variable availability to crops (Picone et al., 2003).

Regional information about P response and its residual effect on mixed pastures or alfalfa production is insufficient. Further study would contribute to improved alfalfa management and livestock productivity. This article summarizes research evaluating the effect of P fertilization on soil P supply and alfalfa production during a 4-year period after its application to a Mollisol located in southeastern Buenos Aires Province.

Alfalfa (variety GT 13 R Plus) was sown in autumn of 1995 on a Typic Argiudoll with 10 parts per million (ppm) Bray P-1, pH 6.2, and 6.4% organic matter. Five treatments were evaluated in an experimental design with three randomized complete blocks: 0, 25, 50, and 100 kg P/ha as triple superphosphate (0-46-0) which was surface broadcast at planting, and an annual fertilization treatment using 50 kg P/ha in the initial year followed by 100 kg P/ha in each subsequent year.

Annual forage production, expressed as dry matter (DM), was evaluated with successive harvests at approximately 10% of crop flowering. Forage samples were collected to quantify plant P concentration (%) and crop P removal (Pr). Soil samples (0 to 15 cm depth) were collected during autumn to measure Bray P-1, before annual P fertilization. The P fertilization effect on soil P supply during the 4 years of experimentation and its relationship with forage production was described with regression analysis.

Precipitation during the four growing



Alfalfa production has great potential in the pampas region of Argentina, but P fertilization is an important consideration.

Table 1. Forage production (DM) and P removal (Pr) on each growth period and accumulated in the 4 years of study, Buenos Aires.

P rate, kg P/ha	1995-96		1996-97		1997-98		1998-99		Accumulated	
	DM, t/ha	Pr, kg P/ha	DM, t/ha	Pr, kg P/ha	DM, t/ha	Pr, kg P/ha	DM, t/ha	Pr, kg P/ha	DM, t/ha	Pr, kg P/ha
0	10.0	20.4	9.1	18.3	7.6	10.9	8.2	11.4	35.0	61.0
25	14.3	32.6	11.8	27.0	9.1	14.2	10.0	14.0	45.2	87.8
50	16.0	37.1	12.9	29.1	9.3	14.3	9.0	15.0	47.3	95.5
100	20.2	49.7	15.6	40.3	11.4	18.5	11.9	17.7	59.2	126.2
50 ¹ +100 ²	16.9	—	15.0	42.3	14.4	32.8	15.3	30.9	61.6	—

¹ Applied in initial year.

² Applied in the remaining years.

periods (August to March) was 678, 863, 584, and 352 mm, respectively. The local average (1966 to 1994) is 608 mm.

Phosphorus Fertilization and Forage Production

Annual and accumulated forage production (**Table 1**) showed a linear increase up to the highest P rate applied (100 kg P/ha), according to the following regressions:

$$\text{1st year: DM} = 10,887 + 97.2 \text{ P} \quad r^2 = 0.72$$

$$\text{2nd year: DM} = 9,637 + 62.1 \text{ P} \quad r^2 = 0.51$$

$$\text{3rd year: DM} = 7,776 + 34.3 \text{ P} \quad r^2 = 0.22$$

$$\text{4th year: DM} = 8,351 + 33.1 \text{ P} \quad r^2 = 0.19$$

Accumulated production (1st to 4th year):

$$\text{DM} = 36,665 + 227.7 \text{ P} \quad r^2 = 0.46$$

Linear coefficients for these P responses indicate an initially high residual effect which decreased during the years after fertilization. The magnitude of the accumulated response (227.7 kg DM/kg P) demonstrates the importance of P fertilization for soils supporting alfalfa production in this region. Similar results were obtained in the first year of alfalfa production by Vivas and Guaita (1997) and Carta et al. (2001a). These studies dealt with regions where soil P availability was reduced due to agricultural intensification without adequate P replacement.

Despite this residual effect, the treatment supplying the highest one-time P rate (100 kg P/ha) became less productive than annual fertilization after the second year (**Table 1**). It should be noted that forage production also showed a gradual decline throughout the study years, independent of P treatment. This could be attributed to restricted soil water availability and other nutrient deficiencies such as sulfur (S) or boron (B), as was previously found in alfalfa by Fontanetto (2000) and Carta et al. (2001b).



Phosphorus fertilization increased alfalfa forage production in this Argentina study. Apparent recovery of P was high in the year of application and diminished with time.

Forage P Concentration and Recovery of Applied P

Phosphorus removal data were closely related to forage production. Forage P concentration was higher in the first and second year (from

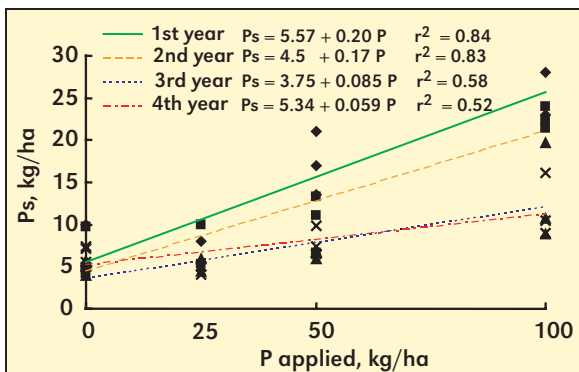


Figure 1. Relation among initial P rate and Bray P-I content (P_s) for each of the 4 years after application, Buenos Aires.

centrations for all 4 years, ranging between 0.29 to 0.20%. Alfalfa P concentrations corresponding to the highest P rate were similar to those cited by Kelling and Matocha (1990). These elevated forage P concentrations are in turn related to enhanced forage quality, animal nutrition, and livestock productivity.

Apparent recovery of P was high in the year of application and, as was observed with P response, diminished with time. Accumulated P recovery values ranged between 65 to 100%. Results with annual crops such as wheat (Berardo et al., 1997) and mixed pastures (Berardo and Marino, 2000) were similar.

Relationship of Soil P Availability and Forage Production

Phosphorus fertilization increased soil P availability, but this effect also decreased year by year. The regression between applied P and Bray P-I content (P_s) for each of the 4 years demonstrates the expected duration of any residual P effect (**Figure 1**). The coefficients obtained were similar to those found for mixed pastures on similar soils and climatic conditions (Berardo and Marino, 2000), but higher than those reported for pastures located on Vertic Argiudolls and Argillic Peluderts (Boschetti et al., 1996).

Alfalfa forage production was related to P_s (**Figure 2**). A P_s value near 25 mg P/kg corresponded to 90% of maximum yield. These values are slightly higher than those previously estimated for mixed pastures (Quintero et al., 1997; Berardo and Marino, 2000). The difference could be attributed to higher forage yields at this site.

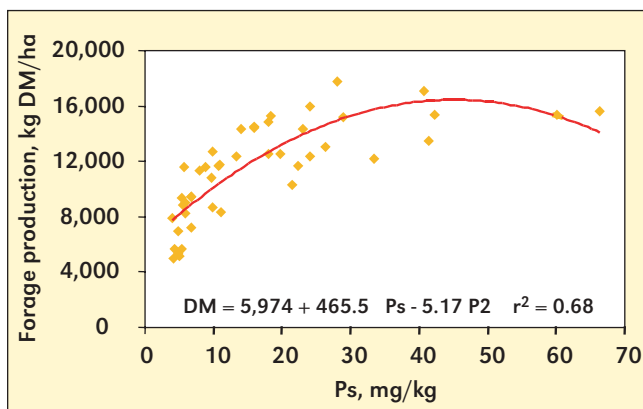


Figure 2. Relationship of Bray P-I content (P_s) and alfalfa forage production during the experimental period, Buenos Aires.

Summary

Phosphorus fertilization increased alfalfa forage production during 4 years of study with a total accumulated effect of 228

kg DM/kg P. Maximum productivity was attained in the first 2 years with the initial rate of 100 kg P/ha, but this needed to be followed by annual applications of 100 kg P/ha in the last 2 years. Phosphorus application significantly increased P plant concentration and levels of alfalfa P removal (20 to 50 kg P/ha year). Fertilization requirements for soil P replenishment will depend on harvested yield and forage P use efficiency.

Increased soil P supply, forage production, and apparent P recovery in the 4 years after P fertilization support the hypothesis of large residual effects and high P efficiency for Mollisols of the region. The relationship among soil P availability and alfalfa forage production indicates that forage production would be restricted if Ps values were below 25 mg P/kg. BC

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