MANAGING PHOSPHORUS FOR MAXIMUM ALFALFA YIELD AND QUALITY

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ABSTRACT

Maintenance of an adequate plant nutrient supply is essential for production of high-yield and high-quality alfalfa. Alfalfa production removes large amounts of nutrients from the soil than must be periodically replaced to remain sustainable. Since P has essential biochemical roles in alfalfa, both yield and quality are reduced when this nutrient is deficient. Nitrogen fixation is also suppressed when P supplies are limited. Soil P concentrations should be measured and limitations corrected prior to crop establishment. Regular P additions will likely be required to replace harvested nutrients, as guided by tissue testing. There are no major differences in P fertilizer source or form for alfalfa and a variety of application methods can be used to meet the nutrient demand of the crop.

Key Words: alfalfa, phosphorus, nutrition, placement, fertilizer

INTRODUCTION

Many factors are involved in producing a high-quality alfalfa crop. Although some factors (like rainfall and temperature) cannot be controlled, many other critical components of the production system can be carefully managed. High yields require maintenance of an adequate nutrient supply to meet the needs of the rapidly growing crop. As the demand for high-quality and high-yielding hay increases, closer examination of the role of proper plant nutrition is needed.

It is not always simple to determine the "correct" amount of fertilizer to add to alfalfa. In most regions, alfalfa growth begins in the early spring, continues through the summer and into the late fall. This very long growing season places a continuous demand on the soil nutrient supply to provide essential elements for many months under widely ranging environmental conditions. Due to this wide range of growing conditions, only general guidelines are presented here, which must be adapted to meet local needs. It should also be noted that many experiments on alfalfa fertilization were done at yield levels low by present-day standards. While these experimental results are helpful in establishing trends, they can be misleading when making fertilizer recommendations for modern alfalfa growers.

An essential component of profitable alfalfa production is achieving high yields. Lower costs of production (per ton), improved efficiency, and maximum profits are usually obtained when near maximum yields are grown. High-yielding alfalfa removes large amounts of nutrients from the field in each cutting. On average, alfalfa removes 50 lb

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N/ton, 13 lb P_2O_5/ton, and 60 lb K_2O/ton. Rapidly declining soil concentrations are regularly measured in conditions where nutrients are removed from the field in alfalfa hay, but low replacement quantities do not match crop removal (e.g. Cihacek, 1993).

Phosphorus fertilization is essential for alfalfa production and is one of the most common nutrient inputs for this crop. This nutrient is involved in many essential metabolic roles within the plant, and deficiencies result in slow growth, suppressed yields, and lost income. This brief review covers some of the recent work regarding P fertilizer management for achieving high alfalfa yields.

PHOSPHORUS FOR ALFALFA PLANT METABOLISM

Phosphorus is involved in a variety of essential reactions within the plant. Higher P concentrations are generally measured in the meristematic regions of actively growing plants. Since P is mobile within the plant, it will translocate from older to younger tissue as required.

Most of the P entering the plant rapidly becomes converted into organic compounds, where it becomes involved in a variety of essential reactions. For example, P in alfalfa is essential for formation of nucleic acids, phospholipids, and ATP; and associated with functions such as photosynthesis, protein formation, and nitrogenase activity. Low plant P frequently results in high leaf starch concentrations, which is thought to decrease leaf photosynthetic rates. Reduced leaf expansion (especially the epidermal cells) is also seen in low-P plants. Alfalfa growing with sub-optimal P concentrations typically has high root starch and root protein concentrations- however the plants are not able to utilize these organic reserves after cutting and cannot quickly regrow (Li et al., 1998). Phytic acid, a major storage form of organic P commonly found in seeds, also accumulates in alfalfa roots and crowns. Campbell et al. (1991) estimated that phytic acid P accounted for 10 to 15% of total alfalfa root and crown P.

In addition to direct nutritional benefits, other positive plant responses come from maintaining adequate P supplies. For example, Azcon et al. (1988) reported that in addition to increased alfalfa yields and tissue concentrations, P fertilization also resulted in an increased number of rhizobia nodules, larger nodule size, and greater N fixation. The stimulatory effects of added P on N fixation were clearly shown with tropical alfalfa (Table 1). Numerous other studies have documented the increase in water-use efficiency in properly fertilized crops compared with alfalfa lacking in nutrients such as P or K.

There have been frequent reports that P or K nutrition have been found to improve plant disease tolerance or resistance. This nutrient response could be due to the influence of P on plant growth and vigor, leading to improved disease resistance or tolerance, or possibly due to its direct influence on pathogen activity in the soil prior to infection. While these responses are frequently observed, the complex interaction of pathogen, environment, and time make it difficult to generalize regarding disease responses from added nutrients.

Table 1. Phosphorus additions increase nodule weight, size, and N content in alfalfa (Gates, 1974).

	P Addition (kg P/ha)				
	0	31	62	125	250
	------------------ mg ------------------------				
Nodule dry weight	0.13	0.44	1.06	3.31	8.47
Weight/nodule	13	33	28	60	57
N content	0.01	0.03	0.07	0.15	0.65

PHOSPHORUS FERTILIZER MANAGEMENT FOR ALFALFA PRODUCTION

Soils vary in their ability to supply P and visible nutrient deficiency symptoms are generally hard to detect, unless the deficiency becomes quite severe. Therefore, soil testing is generally the most effective way of predicting the potentially available nutrient supply. The recommended procedure for soil sampling and laboratory analysis varies in different parts of the country based on regional differences, so local advice should be obtained on how to best do this. Tissue testing for P is generally recommended for crop diagnostic monitoring after the alfalfa is established.

Only a portion of applied P is available to the crop during the year of application, since it becomes involved in many soil reactions that tend to reduce its solubility (Rehm and Sorensen, 1974). Fertilizer P is relatively immobile in soil when applied at normal agronomic rates, so initial P applications are most effectively placed below the soil surface in order to improve uptake by roots. Banding fertilizer P generally optimizes the P recovery, especially where the soil is very deficient and in non-irrigated conditions where moisture limitations may keep roots from utilizing surface-applied P (Malhi et al., 2001). However, surface banding P fertilizer onto established irrigated alfalfa stands may not offer yield advantages over broadcast P applications (Reid (2004).

Fertilizer guides generally recommend that P be applied prior to establishing the crop since an adequate supply of P is critical for rapid stand development. Adequate P is essential for development of strong root systems and fertilization benefits are most apparent in infertile soils and where cool weather restricts nutrient uptake. A beneficial response to added P will only occur when the roots are able to access it- which includes having sufficient soil moisture and other essential nutrients present in adequate supply.

On established stands, fall or winter applications of P are generally preferred since crop responses are often not seen until 2 to 3 months after application. Avoid applications when the soil is soft and physical damage to plant crowns is more likely to occur from field machinery. James et al. (1995) showed that soil P fertility for alfalfa can be maintained by either small annual applications or larger single applications for a multi-year crop rotation. Surface P applications are apparently effective due to the zone of high root activity near the surface and the uptake of P directly by the crown. Adequate soil moisture is essential in order for the plant to recover these surface-applied nutrients.

Many sources of fertilizer P are successfully used for alfalfa production- including both solid and liquid forms. A number of comparisons have shown that most P fertilizer sources are equivalent, when used properly (e.g. Cihacek, 1993; Reid et al, 2004). The selection of a specific P fertilizer form is generally based on local availability, ease of application, and the cost per unit of nutrient. Application of liquid P sources with irrigation water is an effective way of delivering frequent doses of nutrients, but care should be taken if applying P through sprinkler systems to avoid precipitation and plugging of the pipes. Ottman et al. (2000) found no consistent yield or quality differences between liquid or solid P fertilizers. They also reported that solution P fertilizer (10-34-0) was equally effective whether sprayed on the surface of the soil or added to the crop with the irrigation water.

Animal manures can be a good source of nutrients, but application to alfalfa does not take full advantage of the added N and may make weeds more difficult to control. Manure applications may burn leaves, reducing hay yield and quality. Field operations associated with manure application may also damage plant crowns and shorten the stand life.

Phosphorus fertilization is an essential component of alfalfa production. A soil test should be taken and the nutrient recommendation followed prior to planting to help improve seedling establishment and promote overall early vigor and competitiveness. The soil nutrient status should be monitored with tissue testing and the large amounts of P removed in high-yielding crops must be replaced when the soil P supply can not meet the plant demand. A variety of P sources can be successfully used and the application method should be chosen to maximize the efficiency of the applied fertilizer. Failure to monitor and replace the nutrients removed in the harvested hay will lead to losses of yield, plant stand, and profit.

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