Phosphorus fertilization and asparagus yield during establishment years

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Received 6 April 2004, accepted 1 April 2005

Sommerville, D. W. and Whalen, J. K. 2005. **Phosphorus fertilization and asparagus yield during establishment years.** Can. J. Plant Sci. **85**: 687–692. Adequate P is important for the production of healthy asparagus (*Asparagus officinalis* L.) plants. This study determined how varying P fertilization rates affected asparagus yields obtained 3 and 4 yr after planting 1-yr-old crowns. The P fertilizers were applied annually at 0, 50, 75 100 and 200% of the recommended rate for Québec. The recommended rates for P fertilizer are much higher in the year that the crowns are planted than in a producing asparagus field as the goal at planting is to establish soil fertility levels that will sustain production for 15 yr or longer. Marketable yields for the various P fertility regimes ranged from 2060 to 2460 kg fresh weight (FW) ha^{-1} in the first year of harvest and between 3015 and 3250 kg FW ha^{-1} in the second year. Marketable yields were not affected by P fertilization in either year, suggesting unamended soil at the test site contained adequate P (about 160 mg Mehlich III extractable P kg^{-1}) for asparagus production. The rates of P removal in the harvested asparagus spears were low compared to fertilizer P applications. All of the P fertilizer rates applied increased the Mehlich III extractable P concentration and the P saturation ratio of the soil above critical agroenvironmental limits. Further study is needed to develop P fertilizer recommendations that maintain asparagus yields and quality without contributing to environmental pollution.

Key words: Mehlich III-extractable P, P nutrient management, P saturation

Sommerville, D. W. et Whalen, J. K. 2005. **La fertilisation phosphatée et le rendement d'une aspergeraie durant la periode d'établissement.** Can. J. Plant Sci. **85**: 687–692. Le phosphore (P) est l'un des éléments les plus importants pour la production d'asperges (*Asparagus officinalis* L.) vivaces. L'objectif de cette étude fut de déterminer l'effet de la variation des taux d'application d'engrais P sur le rendement des asperges après trois et quatre ans suivant plantation de racines coronales âgées d'un an. Les engrais P furent appliqués annuellement à 0, 50, 75, 100 et 200% du taux recommandé au Québec. Pour améliorer la fertilité du sol à l'établissement et pour assurer une production durable de 15 ans ou plus, les taux recommandés en engrais P sont plus élevés lors de la plantation des racines coronales (100 kg P_2O_5 ha^{-1} à notre site) que pour une aspergeraie en production (40 à 50 kg P_2O_5 ha^{-1} à notre site). Le rendement commercial de la première récolte fut de 2060 à 2460 kg en poids frais (pf) ha^{-1}, et de 3015 à 3250 kg pf ha^{-1} à la deuxième récolte. Le rendement des deux récoltes ne fut pas affecté par les différents taux d'application d'engrais P suggérant que la concentration de P dans le sol témoin (~150 mg P Mehlich III kg^{-1}) était suffisante. Les exigences en P ont été relativement plus basses que les taux d'engrais P appliqués; seulement 2.7 à 4.8 kg P ha^{-1} y^{-1} ont été enlevés par la récolte des turions d'asperges. Toutes les applications d'engrais P augmentèrent les valeurs de P selon la méthode d'extraction Mehlich III en plus de générer une saturation des sols en P au dessus des limites agro-environnementales. Des études supplémentaires sont nécessaires pour déterminer les besoins en engrais P qui maintiennent le rendement et la qualité des cultures d'asperges sans contribuer à la pollution environnementale.

Mots clés: Exigences en P, méthode de Mehlich III, saturation en P

In 2002, there were 300 ha of asparagus (*Asparagus officinalis* L.) under management in Québec, but the amount of asparagus imported into Québec was three times higher than the quantity produced locally (Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec 2002). Despite the market demand, asparagus production in Québec is declining, partly because of competition from other countries (Mongrain 2003) and partly because of problems in Québec with root rot caused by *Fusarium* spp. Vujanovic (2003) reported that 45% of asparagus fields in Québec have suboptimal shoot production because of *Fusarium oxysporum* f.sp. *asparagi*.

To compete in the market for fresh asparagus, Québec producers have adopted male cultivars such as Guelph Millennium, Jersey Giant and Jersey Knight that are both more resistant to root rot and more productive than older varieties [Centre de Reférence en Agriculture et Agroalimentaire du Québec (CRAAQ) 2003a]. These male cultivars do not produce seeds and therefore allocate more energy to the roots and vegetative growth than mixed (male and female) cultivars. Coulombe and Lamarre (2001) found that, in the absence of asparagus rust (*Puccinia asparagi*), Guelph Millennium yields were 10 to 50% higher than other varieties tested in Québec. Guelph Millennium is now grown by about half of the producers in Québec.

Achieving optimal asparagus yield requires appropriate fertilization, yet the N, P and K fertilizer recommendations for asparagus production in Québec have not changed since 1989 (Conseil des Productions Végétales du Québec 1989;

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Abbreviations: **FW**, fresh weight

CRAAQ 2003b). It is not known whether the quantities of fertilizer recommended in the CRAAQ fertilization guide (CRAAQ 2003b) will be sufficient for new higher-yielding cultivars like Guelph Millennium. Fertilizer P is important for asparagus production because P is needed to establish a healthy root system in this perennial crop and is also required for metabolic functions such as energy relations and photosynthesis (Havlin et al. 1999). The P fertilizer rates recommended for application during establishment of the asparagus plantation are much higher than in subsequent years, as the goal is to increase the soil fertility level in the field so production can be sustained for 15 yr or longer (CRAAQ 2003a, b). In subsequent years, the placement of P fertilizer adjacent to the roots is recommended (CRAAQ 2003b). However, given the low soil mobility of P and the deep rooting habit of asparagus, the efficacy of applying P fertilizers in a band near the asparagus row after the first year is questionable. It is not known whether existing P fertilization practices for asparagus are consistent with agroenvironmental legislation aimed at reducing the risk of P pollution of waterways. The Ministère de l'Environnement du Québec (MEV) has passed legislation that will compel farmers to reduce the P saturation (P/Al ratio) to 7.6% in soils with more than 30% clay and to 13.1% in light-textured soils (≤ 30% clay) by 2010 (MEV 2002). Consequently, it is essential to develop P fertilization practices that will optimize asparagus production and quality without harming the environment.

The long-term objective of this study is to determine how P fertilization affects the yield and resistance to disease of *A. officinalis* L. 'Guelph Millennium'. This paper deals with P fertilization effects on asparagus yield and soil P levels during the first 2 yr of harvest.

MATERIALS AND METHODS

Site Description

The study was conducted at the Horticultural Centre of the Macdonald Research Farm, Sainte-Anne de Bellevue, Québec. Mean monthly temperatures at the site range from –10.3°C in January to 18.0°C in July, with mean annual precipitation of 940 mm (Environment Canada 1998). The soil is a mixed, frigid Typic Endoaquent of the Chicot series (Humic Gleysol). The soil was a loamy sand (pH = 6.0) with 530 g sand kg^{-1}, 300 g silt kg^{-1} and 170 g clay kg^{-1}, containing 48.4 g organic C kg^{-1}. In 2000, the year before the asparagus was planted, cucumber was grown at the site.

Site Preparation and Management During Establishment Years

Establishment of an asparagus plantation can take 2 to 3 yr, depending on whether the crop is planted as seedlings or 1-yr-old crowns. In this study, we used 1-yr-old crowns and had 2 establishment years, referred to as E1 (2001) and E2 (2002). The harvest years (2003, 2004) were referred to as H1 and H2, respectively.

Prior to planting, the field received a broadcast application of lime (target pH = 6.5) and fertilizers (NH_4NO_3, 110 kg N ha^{-1} and KCl, 150 kg K_2O ha^{-1}) (CRAAQ 2003b), which were incorporated to a depth of 30 cm. The K fertilizer rate was based on a soil test showing 150 mg Mehlich III K kg^{-1} in the soil. The site was then sprayed with the herbicides terbacil (Sinbar, 0.34 kg a.i. ha^{-1}) and napropamide (Devrinol, 6.7 kg a.i. ha^{-1}). In June of the establishment year E1, 1-yr-old asparagus crowns (cv. Guelph Millennium) were hand-planted 30 cm apart in 15-cm-deep trenches, with 1.75 m between rows. Triple superphosphate was banded along the bottom of the trench, approximately 3 to 5 cm from the crowns. The rates of triple superphosphate added at planting and in subsequent years are described in the next section and in Table 1. The trenches were gradually filled in during the summer. In August of year E1, 40 kg N ha^{-1} was band applied about 5 cm from the emerging shoots. During establishment years E1 and E2, the field was weeded by hand because new asparagus planting can be negatively affected by the application of post-emergent herbicides (CRAAQ 2003a). During harvest years H1 and H2, weed control was achieved by applying Sinbar and Devrinol at previously described rates approximately 1 wk before the spears emerged. In mid-June of year H1, the fungicide myclobutanil (Nova W 40, 250 g a.i. ha^{-1}) was applied to control rust (*P. asparagi*) in the plantation.

Experimental Design and P Fertilizer Treatments

The experimental design was a randomized complete block design (five blocks) with five P fertilizer treatments within each block, for a total of 25 plots. Each block was 7 m by 20 m and contained alternating guard and treatment rows (7 m by 1.8 m each). The blocks were separated by 2-m tilled alleys. In Québec, it is recommended to apply P fertilizers when planting asparagus, even on soils rich in P (CRAAQ 2003b). At the test site, the recommended P fertilizer rate was 100 kg P_2O_5 ha^{-1}, based on the initial soil P level of 147 mg Mehlich III extractable P kg^{-1} (CRAAQ 2003b). Guard rows received the recommended 100 kg P_2O_5 ha^{-1} at planting, while treatment rows received 0, 50, 75, 100 or 200% of the recommended P fertilizer rate. This corresponded to between 0 and 200 kg P_2O_5 ha^{-1} (Table 1).

About 1 wk after the shoots emerged in year E2, fertilizers were applied in a 10-cm-deep trench located about 5 cm from the row. The equivalent of 60 kg N ha^{-1} and 55 kg K_2O ha^{-1} were applied to all rows (CRAAQ 2003b). Phosphorus was added to the guard rows at 55 kg P_2O_5 ha^{-1} and to the treatment rows at 0, 28, 41, 55 or 110 kg P_2O_5 ha^{-1} (Table 1). These P fertilizer rates correspond to 0, 50, 75, 100 and 200% of the recommended P fertilizer rates, respectively.

In years H1 and H2, the equivalent of 100 kg N ha^{-1} and 155 kg K_2O ha^{-1} was band applied to all rows 1 wk after the harvest ended (CRAAQ 2003b). The recommended P fertilizer rate in year H1 was based on the initial soil Mehlich III P level at the site. We used the soil Mehlich III P results from the 100% P treatment (soils collected in August of year H1) to select P fertilizer rates for year H2. As in previous years, the guard rows received P fertilizers at the recommended rate in years H1 and H2, while the treatment rows again received between 0 and 200% of the P fertilizer recommended rates (Table 1).

Table 1. Phosphorus fertilizer applied to asparagus plots in Ste-Anne-de-Bellevue, QC, during 2 establishment years (E1 and E2) and 2 harvest years (H1 and H2)

Treatment	E1 (June)	E2 (May)	H1 (May)	H2 (May)	Total
	(kg P_2O_5 ha^{-1})				
0% P	0	0	0	0	0
50% P	50	28	25	20	123
75% P	75	41	38	30	184
100% P[z]	100[y]	55[x]	50[v]	40[u]	245
200% P	200	110	100	80	490

[z]The 100% P treatment is presently recommended in Québec (CRAAQ 2003b).
[y]Soil in the 100% P treatment contained an average of 147 mg Mehlich III P kg^{-1} in the spring of year E1. When planting asparagus crowns, CRAAQ (2003b) recommends applying 100 kg P_2O_5 ha^{-1} to soils containing 134 to 179 mg Mehlich III P kg^{-1}.
[x]CRAAQ (2003b) recommends applying 55 kg P_2O_5 ha^{-1} in the year after crowns are planted, regardless of the soil Mehlich III P level.
[v]Up-to-date soil Mehlich III P results were not available, so we assumed that soils in the 100% P treatment contained between contained 134 to 179 mg Mehlich III P kg^{-1}. CRAAQ (2003b) recommends 50 kg P_2O_5 ha^{-1} for established asparagus plantations.
[u]Soil in the 100% P treatment contained an average of 245 mg Mehlich III P kg^{-1} in August of H1, leading to the application of 40 kg P_2O_5 ha^{-1} to the 100% P treatment, based on CRAAQ (2003b) recommendations for established asparagus plantations containing >179 mg Mehlich III P kg^{-1}.

Asparagus Harvest

Asparagus shoots were harvested at 1- to 2-d intervals on a total of eight occasions from May 08 to May 18 during year H1 and on 11 occasions from May 03 to May 21 during year H2. Shoots were cut at ground level when they measured at least 20 cm in length. The total fresh weight harvested from each plot was recorded and the shoots were classified according to size and general appearance. Asparagus shoots having a base diameter of 0.4–0.9 cm were classified as small, medium shoots were 0.9–1.3 cm and large shoots were greater than 1.3 cm in diameter. Shoots that were crooked, curved or that had other visible defects were rejected, and the marketable yield for each plot was then determined.

Soil Analysis

Soil samples were collected in August of year E2 and in May and August of year H1. Seven soil cores (each 15 cm long, 3 cm internal diameter) collected from within each row in each plot were composited, dried at 60°C for 48 h, finely ground (< 2-mm mesh) and then extracted with Mehlich III solution (1:10 soil:solution) after shaking for 5 min at 130 rpm (Tran and Simard 1993). The P concentration in the Mehlich III extracts was analyzed colorimetrically within 2 h on a Lachat Quick-Chem flow injection autoanalyser, while the Al concentration in the extracts was determined by atomic absorption spectrometry. The P saturation ratio (% P/Al) was calculated from Eq. 1:

$$\% \text{ P/Al} = (\text{Mehlich III P} / \text{Mehlich III Al}) \times 1.12 \times 100\ \% \quad (1)$$

where Mehlich III P and Mehlich III Al are the concentrations (mg kg^{-1}) of P and Al in the Mehlich III extracts and the factor 1.12 is used for comparison with plasma emission spectrometry systems (CRAAQ 2003b).

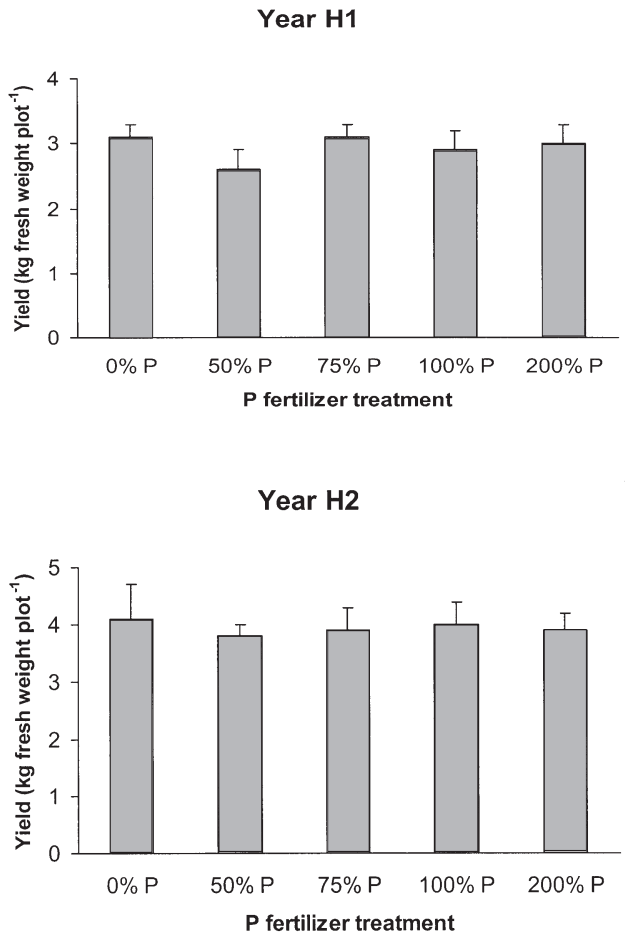

Fig. 1. Influence of P fertilizer treatments on marketable yield of asparagus shoots in harvest years H1 and H2. Bars represent the standard error from five replicates. The quantity and timing of P fertilizer applied to each treatment are described in Table 1.

Statistical Analysis

The effects of P fertilization rates on asparagus yield and soil fertility parameters were evaluated by regression analysis using the PROC REG function of SAS 6.12 for Windows (SAS Institute Inc., Cary, NC). Cumulative P fertilizer application (kg P_2O_5 ha^{-1}) represented the sum of all P fertilizer applications made to a plot before shoot harvest or soil sample collection.

RESULTS AND DISCUSSION

Asparagus Yield

The yield of marketable asparagus shoots taken at each harvest tended to increase during the first week of harvest and then remained relatively stable until the last harvest. Total marketable yields were not affected by P fertilization in either year H1 (P = 0.941) or year H2 (P = 0.556). Total marketable yield in year H1 ranged from 2.6 to 3.1 kg FW

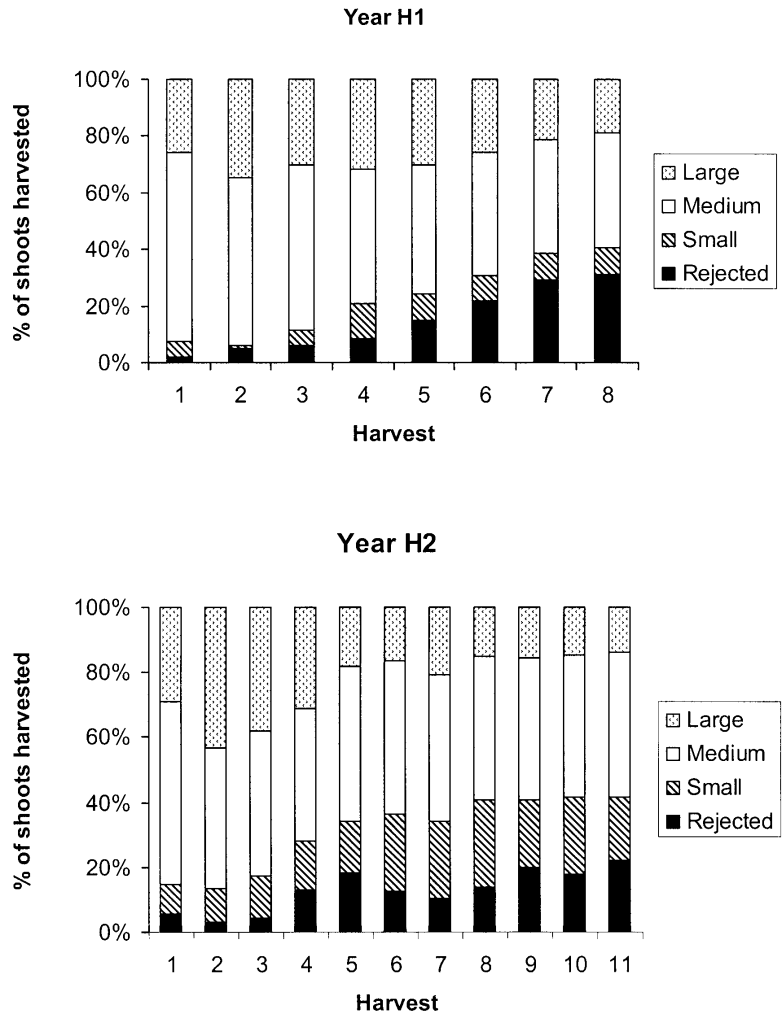

Fig. 2. Percentage of total asparagus shoots in harvest years H1 and H2 that were large (>1.3 cm base diameter), medium (0.9 to 1.3 cm base diameter), small (0.4 to 0.9 cm base diameter) or rejected as unmarketable.

per plot, while the year H2 marketable yield was between 3.8 and 4.1 kg FW per plot (Fig. 1). This corresponds to an estimated marketable yield of 2063 to 3254 kg ha^{-1} yr^{-1} during the first 2 yr of harvest. In Québec, asparagus plantations can yield from 1000 to 3000 kg ha^{-1} yr^{-1} in the first years of harvest (CRAAQ 2003a).

Between 60 and 94% of the asparagus shoots harvested in year H1 were medium to large (>0.9 cm base diameter), while 58 to 87% of the shoots harvested in year H2 were medium to large (Fig. 2). The percentage of small and rejected shoots increased steadily during the harvest period (Fig. 2). By the final day of harvest, rejected shoots accounted for 31 and 22% of the total shoots collected in year H1 and year H2, respectively. Harvesting ceased when the weight of small and rejected shoots was about equal to the weight of large shoots (S. Roy, personal communication).

Soil P levels

The Mehlich III P concentration and P saturation ratio both increased significantly ($P < 0.05$) as the cumulative P fertilizer application increased (Fig. 3a, b). The intercept of the regression line indicates that soils receiving no P fertilizer contained about 160 mg Mehlich III P kg^{-1} (Fig. 3a), which is similar to the 147 mg Mehlich III P kg^{-1} level measured at the site during year E1. The P saturation ratio in soils receiving no P fertilizer was estimated at 16.2% P/Al (Fig. 3b), which is slightly higher than the acceptable level of 13.1% P/Al for light-textured (less than 30% clay) soils set by the MEV (2002). Using the regression equation in Fig. 3b, it appears that applying P fertilizer at the recommended rate (100% P) for 3 yr (cumulative P fertilizer application = 205 kg P_2O_5 ha^{-1}) would raise the P saturation ratio to 25.3% P/Al, about twice the MEV (2002) limit (Fig. 3b).

It is not surprising that following the recommended P fertilization practices for asparagus during the establishment and harvest years increased the soil Mehlich III P concentration and the P saturation ratio. Each year, P fertilizers were applied, but P withdrawal in the form of harvested spears occurred only in the harvest years H1 and H2. As recommended, crop residues were retained on the site to protect the crowns from

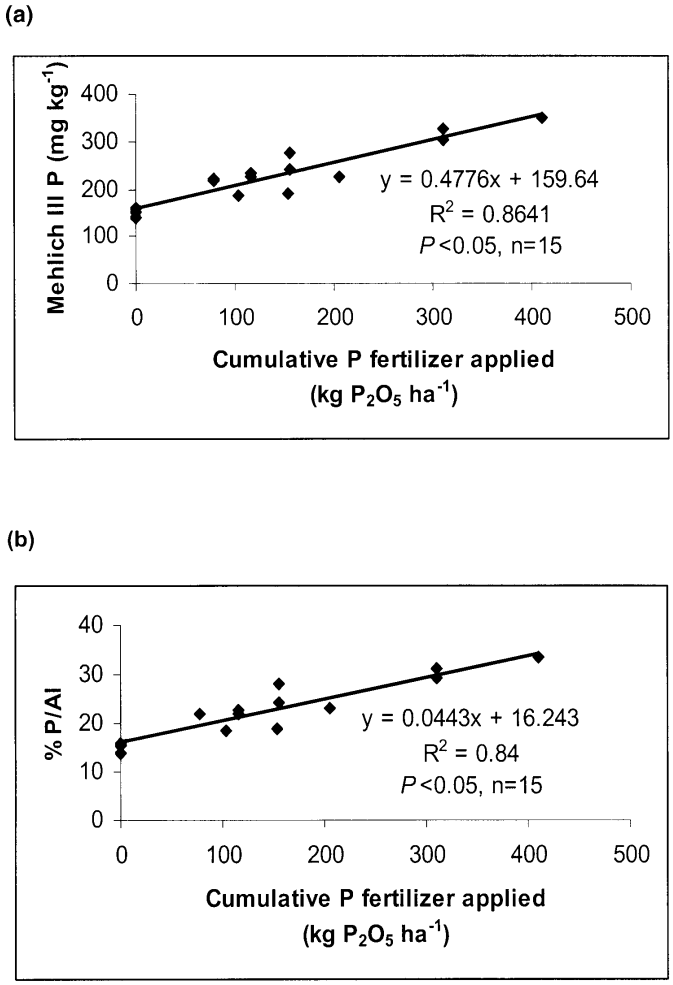

Fig. 3. Relationship between (a) cumulative P fertilizer application and the soil Mehlich III P concentration, and (b) cumulative P fertilizer application and the soil P saturation ratio (%P/Al). Soils were collected from asparagus plots in August of establishment year E2 and May of harvest year H1, after two applications of P fertilizer, and in August of harvest year H1, after three applications of P fertilizer (see Table 1). Data points are the mean of five replicates.

freezing (CRAAQ 2003a). Asparagus shoots contain between 0.70 and 0.80% P on a dry matter basis (Giroux and Chamberland 1990). Assuming that the shoot dry matter content was 8% (CRAAQ 2003b), the P withdrawal in harvested shoots (years H1 and H2) was only between 1.2 and 2.1 kg P ha^{-1} yr^{-1}. This is consistent with other reports that a relatively small proportion of nutrients applied to asparagus is removed by harvesting (Lubet et al. 1985; Giroux and Chamberland 1990; Drost 1997). In southeastern France, Lubet et al. (1985) estimated that annual P withdrawal by harvesting of established asparagus plantations was 7.4 kg P ha^{-1} yr^{-1}. Although we did not measure annual root production in our plots, we can estimate root growth based on the root/shoot ratio. Guo et al. (2002) reported a root/shoot ratio of 4.3 to 5.6 for asparagus. If we combine the root/shoot ratio of 5.6 with the highest shoot production estimated for our site (3254 kg FW ha^{-1}) and assume 8% dry matter content and 0.8% P in asparagus roots and shoots, it appears that approximately 14 kg P ha^{-1} yr^{-1} (about 32 kg P_2O_5 ha^{-1} yr^{-1}) is required for both asparagus root growth and shoot removal. The recommended P fertilizer rate supplied 90 kg P_2O_5 ha^{-1} during the harvest years H1 and H2 (Table 1), which is about 1.4 times greater than asparagus requirements (64 kg P_2O_5 ha^{-1} during years H1 and H2). Additional work is needed to verify the accuracy of these estimates, as the P content of shoots harvested from such P-rich soils could differ from published values. The impact of P fertilization during establishment years on the long-term health, productivity and fertilizer requirements of this asparagus plantation also needs to be determined.

Many commercial asparagus producers in Québec follow the CRAAQ (2003b) recommendations and apply P fertilizer each year. These fertilizer inputs are considered to be an investment in the long-term health and productivity of the asparagus plantation. At our site, annual applications of P fertilizer at the rec-

ommended rates led to a significant buildup of Mehlich III P and increased the soil P saturation ratio above the critical limits (66 mg Mehlich III P kg^{-1} and 13.1% P/Al) set by the MEV (2002). As well, P applications following planting had no impact on asparagus yield. This suggests that this fertilization practice is economically wasteful, agronomically unnecessary and environmentally undesirable. Phosphorus fertilizer recommendations during the establishment years in asparagus plantations of Québec should be further examined, considering soil types and climatic conditions. The ultimate objective is the development of P fertilizer recommendations that maintain asparagus yields and quality without compromising agro-environmental objectives.

ACKNOWLEDGEMENTS

Financial support for this project was provided by the Conseil des Recherches en Pêche et en Agroalimentaire du Québec (CORPAQ). The authors kindly thank Dr. Doug Waterer for his thorough and helpful review of the manuscript, Hélène Lalande, Valérie Campeau, Karine Desjardins, You Jiao and Arlette Lteif for assistance with the field and laboratory work, and Larbi Agdam for the french translation of the abstract.

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