P and Mg. Foliage contained between 43% and 63% of the major nutrients (Table 3), accumulation of which was consistent with other crops.

Concentrations of N, P, and K in branches and foliage generally were greater for the younger tissue, compared to 4- to 5-year-old tissue (Table 4). However, Ca concentration was highest in the older tissue. Mineral nutrient concentrations of stems and older branches were similar, with the exception of Ca, which was lower in stems. The higher concentration of mobile nutrients, such as N, P, and K, in the younger tissue indicates the relative importance of this tissue in support of metabolic activities such as photosynthesis, respiration, and protein synthesis. The greater concentration of immobile Ca in the older tissues reflects a greater degree of lignification and less metabolic activity, compared to younger tissues.

In fraser-fir Christmas trees, annual biomass and nutrient accumulation is comparable to other horticultural crops (Lorenz and Bartz, 1968). Foliage contains >50% of the nutrients at harvest (Table 3). Because fraser-fir retains a 5-year complement of foliage, there is negligible turnover of nutrients during the rotation by means of abscised foliage and dead branches. Harvesting fraser-fir Christmas trees usually produces very little above-ground crop residue. Therefore, it appears that most nutrients incorporated into the aerial portions during the rotation are removed at harvest. Intensive cropping of this nature suggests the possibility that certain elements might at some point fall below the level of sufficiency for best growth and foliage quality, particularly where heavy N fertilization tends to maximize vegetative growth over a period of years, or in successive rotations on the same site.

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Comparison of Banded Ammonium Polyphosphate and Acid Urea Phosphate as P Sources for Potatoes

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Additional index words. phosphorus fertilization, petiole analysis, *Solanum tuberosum*

Abstract. **Field studies were conducted in 1985 and 1986 to compare the effects of banded ammonium polyphosphate (APP) and acid urea phosphate (AUP) on P nutrition and yield of potatoes (*Solanum tuberosum* L. cv. Russet Burbank). The studies were conducted on a Declo silt loam containing 9% $CaCO_3$ equivalent. Soil $NaHCO_3$-P values were 6.9 and 12.1 mg·kg^{-1} in 1985 and 1986, respectively. Ammonium polyphosphate and AUP were applied at planting in bands above the seedpiece at 0, 60, and 120 kg P/ha in 1985 and 0, 40, and 80 kg P/ha in 1986. Nitrogen fertilizer was applied at a uniform rate of 240 kg N/ha. In both years, petiole P concentrations for the APP treatments were higher than those for the AUP treatments during most of the tuber growth period and tuber yields were 9% to 15% higher with APP than with AUP.**

Soils in southern Idaho commonly have high pH values and large amounts of free $CaCO_3$, which can substantially reduce the availability of fertilizer phosphorous (P) to potatoes (5). In an effort to improve P fertilizer efficiency, some fertilizer producers have promoted the use of acid-based fertilizers such as acid urea phosphate (AUP), reasoning that, by lowering the pH in the fertilizer band, P availability should increase. Since little information is available on the relative effectiveness of acid-based P sources for potatoes, we decided to compare the effects of AUP and ammonium polyphosphate (APP) on potato P nutrition and yield.

Field studies were conducted at the Univ. of Idaho Research and Extension Center, Aberdeen, on a Declo silt loam (coarse-loamy, mixed, mesic, Xerollic Calciorthid). The experiments were located at different sites each year in fields that were previously cropped to spring wheat (*Triticum aestivum* L.). The soils at the 0- to 30-cm depth contained 9.1% and 9.4% $CaCO_3$ equivalent and 6.9 and 12.1 mg·kg^{-1} $NaHCO_3$-extractable P in 1985 and 1986, respectively. Extractable P for the 30- to 60-cm depth at both sites was <2.4 mg·kg^{-1}. Soil pH ranged from 8.04 to 8.16.

The experiments consisted of five P fertilizer treatments arranged in a randomized complete block design with five replications. The liquid P sources AUP (10N–15P–0K) and APP (10N–15P–0K) were applied at 60 and 120 kg P/ha in 1985, and 40 and 80 kg P/ha in 1986. These treatments will hereafter be referred to as AUP-60, APP-60, etc. A check treatment (0 kg P/ha) was included in both studies for comparison. The 1986 P rates were reduced because of the higher soil test P value.

Seedpieces of 'Russet Burbank' potato were planted 13 May 1985 and 12 May 1986 at 0.23-m intervals in rows 0.90 m apart. Planting depth was ≈0.15 m. Individual plot size for both experiments was 3.6 (four rows) by 15.2 m. In 1985, AUP and APP were applied at planting in single bands ≈80 mm above the seedpiece. In 1986, the fertilizers were applied at planting in two bands, 80 mm above and 80 mm to each side of the seedpiece. Weeds were controlled in both years with pre-emergence applications of metribuzin 4-amino-6-(1,1 dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4H) one (metribuzin) applied at 0.45 kg a.i./ha.

Ammonium nitrate (34% N) was used to adjust preplant nitrogen (N) fertilizer to a

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Table 1. Soluble P concentration in 'Russet Burbank' potato petioles as influenced by P fertilizer treatment and sampling date in 1985 and 1986.

P source[z]	P application rate (kg·ha^{-1})	Petiole P (mg·kg^{-1})			
		1985			
		8 July	24 July	7 Aug.	30 Aug.
Check	0	900	1060	860	490
AUP	60	960	1090	810	460
APP	60	1250	1440	1080	510
AUP	120	1040	1130	840	480
APP	120	1370	1470	1080	550
Significance					
P response		**	**	*	NS
P rate (R)		NS	NS	NS	NS
P source (S)		**	**	**	*
R × S		NS	NS	NS	NS
		1986			
		16 July	25 July	7 Aug.	21 Aug.
Check	0	990	780	500	420
AUP	40	1150	840	530	430
APP	40	1470	990	540	480
AUP	80	1230	900	560	450
APP	80	1700	1100	590	450
Significance					
P response		**	**	*	NS
P rate (R)		*	NS	NS	NS
P source (S)		**	**	NS	NS
R × S		NS	NS	NS	NS

[z]AUP = acid urea phosphate, APP = ammonium polyphosphate.
NS,*,**Nonsignificant or significant at the 5% or 1% levels, respectively.

Table 2. Effect of P fertilizer treatment on 'Russet Burbank' tuber yield in 1985 and 1986.

P source[z]	P application rate (kg·ha^{-1})	Tuber yield (t·ha^{-1})				
		<114 g	114–283 g	>283 g	Malformed	Total
				1985		
Check	0	4.49	12.0	11.0	8.85	36.3
AUP	60	4.65	10.9	13.6	8.42	37.5
APP	60	4.84	11.9	15.2	9.96	42.0
AUP	120	5.21	11.2	13.7	9.69	39.8
APP	120	5.52	11.7	17.5	9.93	45.7
Significance						
P response		NS	NS	**	NS	**
P rate (R)		NS	NS	*	NS	*
P source (S)		NS	NS	**	NS	**
R × S		NS	NS	NS	NS	NS
				1986		
Check	0	4.63	20.0	5.58	3.23	33.4
AUP	40	6.08	21.6	5.30	2.67	35.7
APP	40	5.94	23.5	6.47	3.05	39.0
AUP	80	6.44	22.8	5.19	2.61	37.1
APP	80	6.64	23.9	6.63	3.12	40.3
Significance						
P response		**	*	**	NS	**
P rate (R)		NS	NS	NS	NS	NS
P source (S)		NS	*	**	NS	**
R × S		NS	NS	NS	NS	NS

[z]AUP = acid urea phosphate; APP = ammonium polyphosphate.
NS,*,**Nonsignificant or significant at the 5% or 1% levels, respectively.

uniform rate of 120 kg N/ha in all plots. The additional N was broadcast prior to planting and incorporated with a disk. All other nutrients were determined to be adequate for maximum yield (5). Three 40 kg N/ha applications of urea–ammonium nitrate (32% N) were applied via sprinkler irrigation on 12 July, 25 July, and 9 Aug. 1985 and on 10 July, 29 July, and 15 Aug. 1986. This amount, combined with the initial 120 kg N/ha provided a seasonal N application rate of 240 kg N/ha. Sprinkler irrigations were scheduled to maintain soil matric potential at the 0.20-m depth within the optimal range of −20 to −50 kPa (6).

Petioles from the fourth leaf from the growing point (4) were collected from 20 plants in each plot on 8 July, 24 July, 7 Aug., and 30 Aug. 1985; and on 16 July, 25 July, 7 Aug., and 21 Aug. 1986. These sampling dates covered the period from about 2 to 3 weeks after tuber set to the later stages of tuber growth. The petioles were dried for 48 hr at 65C, ground to pass a 1-mm screen, and analyzed for acetic acid-soluble P (1). Nitrate nitrogen was determined using a specific ion electrode (2). Vines were mechanically removed on 13 Sept. 1985 and 16 Sept. 1986. Two 10-m sections from the middle rows in each plot were mechanically harvested on 4 Oct. 1985 and 2 Oct. 1986. After harvest, yields of specific tuber grades and size classes were determined. Yield and petiole nutrient concentration data were tested by analysis of variance procedures (3).

Petiole analysis. Petiole NO_3-N concentrations for the five treatments in both experiments decreased from 22,000 ± 2000 $mg \cdot kg^{-1}$ at the first sampling in early July, to 10,000 ± 1500 $mg \cdot kg^{-1}$ at the fourth sampling in late August. However, P treatment did not significantly affect petiole NO_3-N concentration ($P = 0.05$) at any sampling date. These petiole NO_3-N concentrations indicate that N availability was adequate for maximum tuber growth (4, 8).

In contrast, fertilizer source had a signficant effect on the concentration of soluble P in potato petioles (Table 1). In 1985, soluble P concentrations for the check and the AUP-60 treatments were similar throughout the sampling period. However, the APP-60 treatment produced petiole P concentrations that were 25% to 40% higher than those for the check and the AUP-60 treatment at the first three sampling dates. Similarly, petiole P concentrations for the APP-120 treatment were higher than those for AUP-120 treatment throughout the sampling period.

Petiole P concentrations in the 1986 experiment deceased more rapidly than did those in the 1985 experiment, possibly due to the lower fertilizer rates and the use of two bands rather than one. However, P concentrations were again higher with APP than with AUP during the early stages of tuber growth. By the end of the tuber bulking period, differences in petiole P concentration among P treatments were negligible.

Research conducted in southern Idaho (7) has established 1000 mg P/kg as the critical petiole concentration for adequate P nutrition in 'Russet Burbank' potatoes. Our results show that petiole P concentrations remained above this level for a longer period with APP than with AUP.

These apparent differences in P availability for AUP and APP may be explained, in part, by the results of a study that compared changes in $NaHCO_3$-extractable P and pH in AUP and APP bands in a calcareous soil over a 75-day period (9). Extractable P concentrations in AUP bands were higher than those in the APP bands for the first 10 days, but then rapidly dropped to a level 30% to 36% below that of the APP treatment for the remainder of the sampling period. Soil pH in the bands was not affected by fertilizer source. The authors postulated that the rapid decrease in available P in the AUP bands may have resulted from the production of relatively unavailable calcium phosphate compounds from the reaction of H_3PO_4 and $CaCO_3$.

Yield. The yield results from our studies reflect the differences in petiole P concentration. In 1985, the AUP yield exceeded the control yield when applied at 120 kg P/ha, but not at 60 kg P/ha (Table 2). However, APP produced higher yields than AUP at both P rates. Yields of undersized (<114 g), midsized (114 to 283 g), and malformed tubers were not significantly affected by fertilizer treatment. Thus, the higher yields with APP resulted primarily from increased production of large (>283 g) tubers.

Yields were somewhat lower in 1986, but again the highest yield at either P rate was obtained with APP, which produced higher yields of midsized and large tubers than did AUP.

Percentages of U.S. No. 1 potatoes averaged 64% and 75.8% in 1985 and 1986, respectively. However, mean percentages for the P fertilizer treatments were not significantly different ($P = 0.05$).

The results of this study show that, during most of the growing season, potato petiole P concentrations were higher with APP than with AUP and that APP produced higher total yields by increasing the production of large tubers. By comparison, petiole NO_3-N concentrations were not affected by P fertilizer source.

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Growth and Nutrient Status of Celery Seedlings in Response to Nitrogen Fertilization and NO_3:NH_4 Ratio

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Abstract. **Celery seedlings (*Apium graveolens* L. cv. Florida 683) were seeded in multicell styrofoam trays containing a commercial peat mix. They were irrigated with nutrient solutions containing three N fertilizations (150, 250, or 350 mg N/liter) and three NO_3:NH_4 ratios (1:1, 2:1, or 3:1) in factorial combinations. Growth measurements and saturated medium extracts were obtained on days 38, 45, and 52 after seeding. Increasing N fertilization increased leaf area and shoot dry weight, but decreased root dry weight and root : shoot ratio. The lowest NO_3:NH_4 ratio had increased the percentage of shoot dry matter by the end of the experiment. Nitrogen was preferentially taken up as NH_4-N. The composition of the fertilizer solution had a greater effect on young celery seedlings than on older ones. A minimum of 250 mg N/liter at a NO_3:NH_4 ratio of 2:1 appears to be adequate for celery seedlings grown in multicells.**

The use of containerized vegetable transplants has increased yield and uniformity and allowed a more predictable timing of production relative to direct seeding (15). Nutritional requirements of vegetable seedlings were studied for lettuce (9), asparagus (1, 13), celery (2), muskmelon (3), and cauliflower (19). For celery, it was determined that high-quality transplants could be grown with nutrient solutions containing a minimum of 250N–125P–10K ($mg \cdot liter^{-1}$) (2). While K had apparently no effect, N and P modified growth of seedlings, either alone or in combination. Tremblay et al. (18) measured the effect of greenhouse CO_2 enrichment as well as N and P fertilization on growth

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