fertilizers decreased the concentration of Mg in the ear leaf of sweet corn. Seedlings grown with Ca(NO$_3$)$_2$ had lower concentrations of Zn and Mn than seedlings grown with (NH$_4$)$_2$SO$_4$, NH$_4$NO$_3$, or urea, especially at the higher rates of N fertilizers (Table 2). Viets et al. (8) reported that (NH$_4$)$_2$SO$_4$ lowered the pH of the soil and increased Zn uptake by milo (Sorghum vulgare) and ladin clover (Trifolium repens) plants.

The effects of NH$_4$NO$_3$, or especially (NH$_4$)$_2$SO$_4$, at the higher rates of N fertilizer on increasing the concentrations of a combination of elements, including total N, P, Mn, and Zn in the seedlings, may have contributed to the faster rates of growth of seedlings grown with NH$_4$NO$_3$ or (NH$_4$)$_2$SO$_4$ than of seedlings grown with urea or Ca(NO$_3$)$_2$ in this productive fine sandy loam soil (pH 7.0).

**Literature Cited**


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**Snap Bean Plant Responses to Sources and Rates of Nitrogen and Potassium Fertilizers**

Nathan H. Peck1, George E. MacDonald2, and Audrey V. Gardner3

New York State Agricultural Experiment Station, Cornell University, Geneva, NY 14456

Additional index words. Phaseolus vulgaris var. humilis, urea, ammonium sulfate, ammonium nitrate, calcium nitrate, plant tissue analysis, Rhizobium phaseoli

**Abstract.** The objective of this study was to determine the responses of 'Bush Blue Lake-47' snap bean plants [Phaseolus vulgaris (L.) var. humilis] to urea, (NH$_4$)$_2$SO$_4$, NH$_4$NO$_3$, and Ca(NO$_3$)$_2$ sources of N fertilizers at rates of 0, 4, 8, or 12 g of N/m$^2$ and to KCl and K$_2$SO$_4$ fertilizers at 5 g K/m$^2$. Dry weight of the plants was determined at the seedling, bloom, and harvest stages. Blades of recently fully expanded leaves at the bloom stage were analyzed for total N, N$\_3$-N, Cl, S, B, P, K, Na, Ca, Mg, Zn, Mn, Fe, and Cu. Snap bean plants grown with weight/ per plant and the highest yield of pods, followed by plants grown with NH$_4$NO$_3$. Plants grown with Ca(NO$_3$)$_2$ or urea had the lowest dry weight per plant and the lowest yield of pods, especially at the highest rate of N fertilizers.

Snap bean plants grown for once-over mechanical harvest of the pods for processing need a concentrated set of high-quality pods with consistent reliable production during the entire processing season. Soil properties, especially soil pH and aeration, and N and K fertilization may affect the uptake of N and nodule formation, and the vegetative growth and development of the pods (2, 3, 9-12, 15). Soil and environmental conditions favorable for growth of bean plants are also favorable for nodule formation and symbiotic N fixation by Rhizobium phaseoli (8, 14).

We determined responses in growth, development, and maturation of snap bean plants to urea, (NH$_4$)$_2$SO$_4$, NH$_4$NO$_3$, and Ca(NO$_3$)$_2$ as sources of N at several rates when combined with KCl or K$_2$SO$_4$ and when applied at planting time in a productive loam soil.

'Bush Blue Lake-47' snap beans were grown in 1986 and 1987 at Geneva, N.Y. on a Lima silt loam (0% to 3% slope, fine-loamy, mixed, mesic Glosobic Hapludalf), a productive soil derived from calcareous glacial till. Soil samples taken in May 1986 and June 1987 were analyzed for P, K, Ca, Mg, Zn, and Mn, using ammonium acetate-acetic acid extracting solution adjusted to pH 4.8 (7). Soil pH was determined in a 1: 1 soil : water (w/w) ratio and organic matter was determined by the titrimetric method (6). The soil had pH 7.2 and 3.4% organic matter. The mean concentration of elements were (in mg of element per kg of dry soil): 27 P, 90 K, 2900 Ca, 320 Mg, 20 Mn, and 1 Zn in the 0- to 25-cm depth of soil (plow layer) (3 = 3 million kg ha$^-1$).

The field was planted to sudan grass (Sorghum vulgare sudanensis) in Spring 1985, mowed in late summer when it reached a height of 80 cm, and was plowed under in the green stage. During early fall, 1.12 g (a.i.) 2,4-dichlorophenoxyacetic acid (Weedar 64) with active ingredient (dimethylamine salt of 2,4-dichloro-phenoxycetic acid) was sprayed over the entire soil surface at 33 ml water/m$^2$ to control broad leaf weeds. The field was left fallow over winter. Rye (Sedale cereale) was planted in Fall 1986 and plowed under in Apr. 1987, when 5 to 10 cm tall. No herbicide was applied in 1986. On 28 May 1987, 0.34 g (a.i.) S-ethylidihyroptiylocarbocarbons (Eptam-7E) and 0.056 g (a.i.) a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine (Treflan-4E) herbicides was sprayed over the entire soil surface at 33 ml water/m$^2$ and immediately incorporated into the top 10 cm of soil. On 27 May 1986 and 29 May 1987, 25 seeds were planted per meter of row (50 seeds/m$^2$). The seed treatment consisted of Gustafson 400-D (captan) at 1.6 ml kg$^-1$, streptomycin (Agri-Strep) at 0.56 g kg$^-1$, and Chlorpyrifos (Lorsban 50-SL) at 1.3 kg kg$^-1$.

Four sources of N fertilizers: (NH$_4$)$_2$SO$_4$ (AS), NH$_4$NO$_3$ (AN), Ca(NO$_3$)$_2$ (CN), and urea (U) were applied at rates 0, 2, 4, or 6 g of N/m of row in rows 50 cm apart (0, 4, 8, and 12 g of N/m$^2$) in a band 5 cm to the side and 5 cm below the depth of the seed at planting. Each plot, 2 m wide and 10 m long, consisted of four rows 50 cm apart on a level bed. Wheel tracks of the tractor and planter were outside.
Table 1. Effects of four sources of N fertilizers at four rates and of two sources of K fertilizers on the dry weight of snapbean plants at the seedling, bloom, and harvest stages.

<table>
<thead>
<tr>
<th>Source of N fertilizers</th>
<th>Rate</th>
<th>Seedling</th>
<th>Bloom</th>
<th>Vines</th>
<th>Pods</th>
<th>Dry wt of pods (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0</td>
<td>2.6</td>
<td>7.7</td>
<td>9.5</td>
<td>5.0</td>
<td>35</td>
</tr>
<tr>
<td>(NH₄)₂SO₄</td>
<td>4</td>
<td>3.2</td>
<td>9.7</td>
<td>11.1</td>
<td>5.2</td>
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<tr>
<td></td>
<td>8</td>
<td>3.5</td>
<td>11.0</td>
<td>11.8</td>
<td>6.0</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>3.1</td>
<td>10.3</td>
<td>12.9</td>
<td>6.1</td>
<td>33</td>
</tr>
<tr>
<td>NH₄NO₃</td>
<td>4</td>
<td>2.9</td>
<td>9.4</td>
<td>11.6</td>
<td>5.2</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>2.8</td>
<td>10.1</td>
<td>11.7</td>
<td>5.7</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>2.3</td>
<td>9.3</td>
<td>11.0</td>
<td>4.8</td>
<td>32</td>
</tr>
<tr>
<td>Ca(NO₃)₂</td>
<td>4</td>
<td>2.5</td>
<td>8.3</td>
<td>9.4</td>
<td>4.6</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>1.9</td>
<td>7.4</td>
<td>9.7</td>
<td>4.5</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>12</td>
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<td>7.5</td>
<td>10.0</td>
<td>4.2</td>
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<tr>
<td>Urea</td>
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<tr>
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<td>33</td>
</tr>
<tr>
<td></td>
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<td>1.5</td>
<td>6.9</td>
<td>9.8</td>
<td>3.7</td>
<td>27</td>
</tr>
<tr>
<td>Source of K fertilizers</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>KCl</td>
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</tr>
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<td>Level of significance</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Rate of N fertilizers (R)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Linear</td>
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<td>0.07</td>
<td>0.11</td>
<td>0.35</td>
<td>0.80</td>
<td>0.11</td>
</tr>
<tr>
<td>Quadratic</td>
<td></td>
<td>0.04</td>
<td>0.21</td>
<td>0.11</td>
<td>0.76</td>
<td>0.06</td>
</tr>
<tr>
<td>Source of N fertilizers (N)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;0.01</td>
<td></td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.71</td>
</tr>
<tr>
<td>R x N</td>
<td></td>
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<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.47</td>
</tr>
<tr>
<td>Source of K fertilizers (K)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R x K</td>
<td></td>
<td>0.03</td>
<td>0.05</td>
<td>0.22</td>
<td>0.27</td>
<td>0.03</td>
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<tr>
<td>N x K</td>
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<td>0.56</td>
<td>0.33</td>
<td>0.22</td>
<td>0.63</td>
</tr>
<tr>
<td>R x N x K</td>
<td></td>
<td>0.24</td>
<td>0.58</td>
<td>0.64</td>
<td>0.30</td>
<td>0.38</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>11</td>
<td>14</td>
<td>18</td>
<td>22</td>
<td>12</td>
</tr>
</tbody>
</table>

Fig. 1. Quadratic regressions for the interaction of four sources of N fertilizers: (NH₄)₂SO₄ (AS), NH₄NO₃ (AN), Ca(NO₃)₂ (CN), and urea (U) × four rates of N fertilizers: 0, 4, 8, or 12 g of N/m² (0, 2, 4, and 6 g of N/m of row) on the fresh weight yield of snap bean pods (g/m².)

The edge of the plot. Every plot received constant rates of P from concentrated superphosphate at 5 g of P/m². Two of the four rows in each plot received K from K₂SO₄ at 5 g of K/m². The banded fertilizers were placed between the rows of the same fertilizer treatments. All plots received Zn from ZnSO₄·7 H₂O at 0.4 g of Zn/m² and Mn from MnSO₄ at 0.4 g of Mn/m² in the band at planting. Rates and sources of N fertilizers were randomized in a Latin square design within four replications, and K sources were in a randomized split-block design within the N treatments. The plot in 1987 were on different areas in the field than in 1986.

Plants were sampled at each source and rate of N and source of K fertilizers on 30 June and 17 and 28 July in 1986 and on 30 June and 13 and 27 July in 1987 for dry weight. Sample plants were gently pulled from the soil so that the tap root remained with the plant. At the first sampling (seedling stage trifoliate leaf), eight plants from each plot were taken. At the second sampling (bloom stage) four plants from each plot were taken. At the third sampling (pod stage), two plants were selected from each plot and separated into pods and vines. At each sampling, the plants were washed in tap water to remove soil particles, blotted dry, and dried in a forced-air drying oven at 70°C for 48 hr for dry weight determination. Fresh weight was obtained on the pods. Blades of ten recently fully expanded trifoliate leaves were taken on 15–16 July 1986 and 16 July 1987 from each plot for chemical analysis. Samples were rinsed in demineralized water, blotted dry, placed in white paper bags, and dried in a forced-air drying oven at 70°C for 48 hr. Oven-dried leaf blade samples were ground in a stainless steel Wiley mill using a 850 μm screen, dry-ashed, and analyzed for P, K, Na, Ca, Mg, Zn, Mn, Fe, and Cu (5), except that the residue salts was dissolved in 1.0 M HCl. Other determinations were as follows: P by the molybdovanado phosphoric acid procedure (5); Na and K in the emission mode of a Jarrell–Ash Dial Atom-III atomic absorption spectrophotometer (Thermo Jarrell Ash Corp., Waltham, Mass.); Ca and Mg by atomic absorption after addition of lanthanum solution; Zn, Mn, Fe, and Cu directly by atomic absorption (5); Cl on a nitric acid extract of the plant material using an Orion Model 94-17 chloride solid state electrode; NO₃-N on an Al(SO₄)₃ extract of the plant material using an Orion Model 92-07 nitrate ion electrode (Orion Research, Inc.,
An aliquot of the ashed solution was analyzed for SO₄²⁻ using ammohydrogen H₂SO₄, as described by Wolf (16).

All sources of fertilizers were analyzed for N, P (PO₄), K (K₂CO₃), Na, Cl, S, Zn, Mn, Fe, Cu, and B by 1985 AOAC methods. Pods from two rows, 50 cm apart and 1 m long (1 m²) from rates of N and sources
of N and K, were hand-harvested from each plot on 28 July 1986 and on 27 July 1987. Pods were separated into sieve size grades by a Gilford–Ryder double adjustable bar-type grader (11). Sieve openings for various sizes of pods were: 2 = 5.8 mm, 3 = 7.3 mm, 4 = 8.3 mm, 5 = 9.3 mm, and 6 = 10.7 mm (11).

GENSTAT, a language developed at Lawes Agricultural Trust, Rothamsted Experimental Station, U.K., was used to compute the analysis of variance for the level of significance and the regressions were partitioned to linear and quadratic responses in the order given. MINITAB, from Minitab Inc., University Park, Pa., was used for the regression analysis.

Weather and years. The growing season weather during 1986 and 1987 was similar. From planting to harvest, the mean daily minimum and maximum air temperature was 14.5°C and 24.5°C, respectively, in 1986, with 282 mm of precipitation. The corresponding values for 1987 were 16.0°C and 26.5°C and 257 mm. There were no long periods of temperature or soil water stress on growth, development, and maturation of the snap bean plants.

Responses of the snap bean plants to sources and rates of N and K fertilizers were very similar during both years. There were very few interactions of notable significance among years × source of N fertilizers × rates of N fertilizers × source of K fertilizers on any of the plant responses. In 1986, there was an average of 33 plants/m² in 1987 an average of 29 plants/m². Snap bean plants had an average yield of 1236 g fresh pods/m² in 1986 and 1240 g pods/m² in 1987. The sieve size distribution of pods was also similar during both years. Thus, the results given are for combined years.

Growth of snap bean plants. Snap bean plants grown with AS consistently had the highest dry weight per plant, followed by AN while plants grown with CN or U had the lowest dry weight, especially at the highest rates of N fertilizers (Table 1). The interaction of sources and rates of N fertilizers affected the dry weight of the plants. The difference among dry weight of the plants increased with increased rates of N fertilizers. Sources and rates of the N had little effect on the percentage of total dry weight of the plants in the pods (Table 1). The sieve size distribution of pods was also similar during both years. Thus, the results given are for combined years.

Yield and size of snap bean pods. Snap bean plants grown with AS had the highest yield of pods, followed by AN, while plants grown with CN and U had the lowest yield of pods (Table 2). The interaction of sources × rates of N affects the yield of pods (Fig. 1). The differences among yield of pods increased with increased rates of N fertilizers. Increasing the rate of AS increased the yield of pods; increasing the rate of AN slightly decreased the yield at the highest rate of AN fertilizer; increasing the rate of CN and, especially U, decreased the yield of pods.

Fresh weight of the pods graded for sieve size (diameter of pods) shows that 81% were sizes 2 + 3 + 4, with size 4 having a high proportion of the total (Table 2). Plants grown with AS had the highest yield of size 4 pods.

Elements in leaf blades. Concentrations of some elements in the blades of fully expanded leaves at the bloom stage were affected by the sources and rates of N and by the source of K (Table 3). Increasing the rate of N increased concentrations of NO₃-N, total N, S, P, Ca, Mg, Fe, Mn, and decreased the concentration of Cl in the leaf blades. Increasing the rate of N increased the concentration of Mn more than An or U, while U had no effect on the concentration of Mn in the leaf blades.

Plants grown with KCl had a much higher concentration of Cl in the leaf blades than plants grown with K₂SO₄ (Table 3). The rate of N × source of K interaction showed that plants grown without N fertilizers plus KCl had a concentration of 6.0 mg of Cl/g dry weight in the leaf blades, while leaf blades of plants grown with the highest rate of N fertilizers plus K₂SO₄ had a concentration of only 0.8 mg of Cl. Thus, both rate of N and source of K had large effects on the concentration of Cl in the leaf blades. Increasing the rate of N also increased the concentration of NO₃-N in the leaf blades, while Cl decreased (Table 3).

Nodulation of the roots. Nodulation of the roots of the plants were visually rated at harvest in 1987. Scores were from 1 for roots with no nodules to 9 for roots with many. Plants grown with AS had more nodules than plants grown with AN or, especially, CN or U (P = 0.01). The interaction of source of N × rate of N showed that plants grown with AS had a higher visual rating than plants grown with AN, CN, or U at the highest rate of N (P = 0.05). The relationship of increased rate of AN with decreased nodulation also occurred in 1981 (12). Thus, snap bean plants grown in this productive soil obtained N from symbiotic N fixation to compensate for none or a low applied rate.

Soils, fertilizers, elements in leaf blades, and plant growth. The levels of residual available elements in the soil used for these studies were considered adequate for snap bean plants grown with banded fertilizer (12).

The fertilizers were analyzed to determine if the responses of the snap bean plants, especially concentrations of elements in the leaf blades, were directly due to sources of N or K fertilizers or to other elements as impurities in the fertilizers. For example, AS increased the concentration of Mn in the leaf blades, but there was no measurable Mn in the AS fertilizer. Thus, the effect of AS on the concentration of Mn was indirect.

The sources of N (AS) or K (K₂SO₄) that contained sulfate did not increase the concentration of S in the leaf blades compared to sources that did not contain sulfate. Increasing the rate of N decreased the concentration of Cl and increased S in the leaf blades with all sources of N.

The sources and rates of N influenced a complex of plant growth responses and concentrations of elements in the leaf blades of the snap bean plants. It is difficult to separate the individual effects of the sources and rates of N on the plant responses. For example, increasing AS rates increased the dry weight of the plants at all three stages of growth, increased the concentration of Mn and Zn in the leaf blades, but decreased root nodulation less than other sources of N. Perhaps the effect of AS was due at least in part to more uptake of elements or response of the nodules to the availability of the elements.

Literature Cited


Creeping Bentgrass Response to P and K on a Sand Medium

Jack D. Fry1, M. Ali Harivandi2, and David D. Minner3
Department of Horticulture, Colorado State University, Fort Collins, CO 80523

Additional index words. Agrostis palustris, golf green, turfgrass, fertility

Abstract. Media used in golf green construction are typically at least 75% sand by volume. This study was conducted over 8 years on a sand medium to determine creeping bentgrass (Agrostis palustris Huds.) quality response to P and K. Phosphorus (0, 5, and 11 kg ha−1) and K (0, 4, and 8 kg ha−1) treatments were arranged factorially and applied monthly to creeping bentgrass receiving uniform N (49 kg ha−1 per month). A significant (quadratic) response of creeping bentgrass quality to increasing P level was observed each year. Creeping bentgrass fertilized at 5 or 11 kg P/ha per month was similar in quality. Potassium had no effect on visual quality of creeping bentgrass. This study demonstrated the importance of P in maintaining creeping bentgrass quality on a sand-based medium.

Creeping bentgrass is widely used for turf on golf greens in the United States. To encourage drainage and minimize compaction, golf greens are typically constructed of soil mixtures containing 75% to 100% sand by volume. The use of soil media containing high percentages of sand greatly affects turf fertility programs, primarily due to increased leaching of nutrients and a lower soil cation exchange capacity. Nitrates and K are readily leached from coarse-textured soils; P tends to form complexes with other elements and is less prone to leaching.

Nitrogen has its greatest effect on turfgrass shoot growth (Beard, 1973), and encourages root development of creeping bentgrass when applied judiciously (Powell et al., 1967). Phosphorus increases turfgrass root growth and lateral stem development (Beard, 1973). Potassium encourages turfgrass root growth and increases resistance to environmental stresses (Juska and Murray, 1973; Schmidt and Breuninger, 1981).

Few data are available concerning creeping bentgrass response to P and K. Waddington et al. (1972) found inconsistent growth responses of ‘Penncross’ creeping bentgrass following K application at 0, 12, or 24 kg ha−1•year−1 on a silt loam soil. A later study (Waddington et al., 1978) conducted on similar soil revealed that, among four levels of P (0, 49, 98, and 195 kg ha−1•year−1) and three levels of K (0, 76, and 152 kg ha−1•year−1), the lowest levels of P (49 kg ha−1•year−1) and K (76 kg ha−1•year−1) had the greatest effect on clipping yield of ‘Penncross’.

This paper reports results of a study done on a sand-based medium to determine the quality response of creeping bentgrass to variable P and K application rates.

This study was initiated in 1979, but results presented here are based on data collected between Oct. 1981 and Sept. 1986. Research was conducted on a mature blend (1:1) of ‘Emerald’ and ‘Penncross’ creeping bentgrass. Turf was maintained under putting green conditions by mowing at 6 mm 5 or 6 days weekly, collecting clippings, and irrigating with ≈12 mm water every 2 to 4 days.

Granular fertilizers were applied monthly by hand from May to September in 1982, 1984, and 1985; May to August in 1983; and April to September in 1986. Water (20 to 30 mm) was applied immediately following fertilization. From 1979 to 1981 (data not presented) fertilizers were applied monthly between May and September.

Quality was determined visually before each fertilizer application using a 0 to 9 scale where 0 = brown, open turf, and 9 = optimum color, density, and uniformity. A rating of 7 was considered acceptable for putting green turf.

Phosphorus (0, 5, and 11 kg ha−1 per month) and K (0, 4, and 8 kg ha−1 per month) treatments were arranged factorially in a randomized complete block design with three replications in plots that measured 1.5 × 1.5 m. Phosphorus was applied as treble superphosphate (0N–20P–0K) and K as muriate of potash (0N–0P–53K). All plots received 49 kg N/ha per month from NH4NO3 (33N–46P–0K).

Fig. 1. Creeping bentgrass quality response to P application from 1982 to 1986. Data are the means of 12 observations in 1983; 15 observations in 1982, 1984, and 1985; and 18 observations in 1986. ○ 1982 Quality = 5.3 + 0.7 (P) − 0.04 (P2), R2 = 0.93; Δ 1983 Quality = 5.0 + 0.5 (P) − 0.03 (P2), R2 = 0.87; ○ 1984 Quality = 6.7 + 0.3 (P) − 0.02 (P2), R2 = 0.85; ○ 1985 Quality = 7.1 + 0.4 (P) − 0.03 (P2), R2 = 0.91; ■ 1986 Quality = 6.8 + 0.4 (P) − 0.03 (P2), R2 = 0.88.