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Calcium Fertilizers Fail to Affect Pod Calcium Concentration and Yield of Four Snap Bean Cultivars

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***Abstract.* To measure the effect of added Ca fertilizer on the Ca concentration of snap bean pods, four snap bean cultivars were grown during Summer 1996 and 1997 at Hancock, Wis. Fertilizer treatments consisted of 80 kg of Ca per hectare applied as Ca sulfate ($CaSO_4 \cdot 2H_2O$) or Ca nitrate [$Ca(NO_3)_2$], and the control (no Ca applied. The experimental design was a randomized complete block with a factorial set of treatments (4 × 3). Calcium sulfate was applied at planting, whereas Ca nitrate was split applied four times at weekly intervals starting 1 week before flowering. Yield and Ca concentration in pods were determined. The statistical analysis showed no significant effect of Ca fertilizers on pod Ca concentration or yield. A strong cultivar effect was detected for both parameters measured. 'Evergreen' (5.47 mg Ca per gram dry weight) had the highest pod Ca concentration and 'Labrador' (4.10 mg Ca per gram dry weight) the lowest. No significant fertilizer × cultivar interactions were observed. Results for pod Ca concentration remained consistent, even when significant year effects were found for both parameters.**

Calcium nutrition has a significant impact on human growth and health. Milk and dairy products are the main sources of Ca in the United States, with green, leafy vegetables also providing good sources of Ca (Macrae et al., 1993). Snap beans contain low levels of oxalic acid, which binds Ca. Calcium from beans is absorbed by the human body as well as or better than Ca from milk (Grusak et al., 1996). A 100-g (1 cup) serving of fresh snap beans can provide 56 mg of Ca, which accounts for ≈5% of the minimum daily requirement. Because of their nutritional value and popularity among teenagers (Pao et al., 1982), snap beans are a potentially important source of dietary Ca. Therefore, any increase in bean pod Ca concentration could positively impact human nutrition.

A 1993 evaluation of pod Ca concentration of 60 S_1 families and four cultivars of snap bean across two locations revealed significant differences among the genotypes (Quintana et al., 1996). The present study was designed to: 1) determine if application of Ca fertilizer to the soil would enhance Ca concentration in snap bean pods, and 2) compare the effects of two soil-applied Ca fertilizers on yield and pod Ca concentration.

Materials and Methods

Experimental design and treatments. A randomized complete-block design, with a factorial set of treatments including four cultivars and three Ca fertilizers with six replications, was used in 1996 and 1997 (three replications for yield). The four cultivars selected for differing ability to accumulate Ca in pods were Labrador (low accumulator), Hystyle and Evergreen (intermediate accumulators), and Top Crop (high accumulator). The Ca fertilizer treatments were: 1) $Ca (NO_3)_2$ containing 19.0% Ca and 15.5% N; 2) $CaSO_4 \cdot 2H_2O$ containing 22.3% Ca and 18.6% S; and 3) a control (no Ca applied).

Plant culture. The beans were planted on 20 June 1996 and 1997 at the Univ. of Wisconsin Hancock Experimental Station with each plot consisting of three rows 1.02 m long. In each row, 20 seeds were double-seeded and plants were thinned 2 weeks after planting to 10 seedlings per row 10.2 cm apart. Rows and blocks were spaced 91 cm apart with plot size ≈2.79 m^2. The soil was characterized as Plainfield loamy sand with 1% organic matter. Soil analysis taken prior to planting in 1996 showed a pH of 6.4 and concentrations ($mg \cdot kg^{-1}$) of 72 P, 75 K, and 500 Ca. In 1997, soil pH was 5.5 and P, K, and Ca concentrations were 129, 150, and 600 $mg \cdot kg^{-1}$, respectively.

Calcium was applied (total of 80 $kg \cdot ha^{-1}$) as: 1) $Ca (NO_3)_2$ applied in four applications each of 105 $kg \cdot ha^{-1}$ (20 $kg \cdot ha^{-1}$ Ca) at 1 week prior to flowering, at flowering, and at 1 and 2 weeks after flowering; and 2) in a single application of 364 $kg \cdot ha^{-1}$ Ca sulfate at planting time. All fertilizers were dissolved in 500 mL of water and hand-applied in bands 5 to 10 cm from the plants on both sides of the middle row and the inner sides of the outside rows. Fertilizer applications were scheduled 1 d after irrigation to minimize potential leaching. All fertilizer treatments were brought to the same rate of N (16.3 $kg \cdot ha^{-1}$) with applications of ammonium nitrate (33.5N–0P–0K) in the Ca sulfate and control plots every time Ca nitrate was applied. Standard cultural practices included preplant incorporation of the herbicide trifluralin, cultivation as needed, an additional application of 33.5 $kg \cdot ha^{-1}$ N (15 d after planting), and an irrigation schedule of 12.5 mm per week from planting time until harvest (15 Aug. 1996 and 1997).

Sampling procedures. At harvest, most pods were full and seeds were small, which corresponded to plant life stages—R_5 to R_6 (Le Baron, 1974). The middle row was used for data collection (yield and samples for determination of pod Ca concentration). Only commercial sieve size number 4 pods (8.3 to 9.5 mm in diameter) were sampled for Ca determinations. Each pooled sample consisted of 10 to 15 pods per plot.

Laboratory and statistical analysis. Calcium extractions and determinations were as described in previous studies (Quintana et al., 1996). A pooled analysis of variance was performed on the data using SAS system software (SAS Institute, Cary, N.C.). Significant treatment means were separated using LSD tests.

Table 1. Mean effects of year, Ca fertilizer treatments, and cultivar on snap bean pod yield and pod Ca concentration.

Source	Yield ($t \cdot ha^{-1}$)	Ca ($mg \cdot g^{-1}$ dry wt)
Year[z]		
1996	10.07 a[y]	4.68 b
1997	8.50 b	5.41 a
Fertilizer		
Ca sulfate	9.65[NS]	5.12[NS]
Ca nitrate	9.56	5.09
Control	9.42	4.92
Cultivar		
Hystyle	11.27 a	5.28 a
Top Crop	9.77 b	5.32 a
Evergreen	9.36 b	5.47 a
Labrador	7.77 c	4.09 b

[z]Means for nine replicates (six in 1996 and three in 1997).
[y]Mean separation within columns and sources by LSD, $P < 0.05$.
[NS]Nonsignificant.

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Results and Discussion

Calcium fertilizer effects on pod Ca concentration and yield. Neither Ca nitrate nor Ca sulfate had a significant effect on pod Ca concentration or yield (Table 1). These results were consistent with a previous study in which three rates of Ca sulfate were evaluated on 12 snap bean cultivars (Miglioranza et al., 1997). Pod Ca concentration ranged from 4.92 to 5.12 $mg \cdot g^{-1}$ dry weight. Although yield increases have been recorded in response to soil applications of Ca fertilizer on potatoes (Simmons et al., 1988) at Hancock, Wis., the soil apparently contained enough Ca to fulfill snap bean requirements for normal development.

Cultivar effects on pod Ca concentration and yield. Differences in both pod Ca concentration and yield were found among cultivars (Table 1). The concentration was highest in 'Evergreen' (5.47 $mg \cdot g^{-1}$ dry weight) and lowest in 'Labrador' (4.10 $mg \cdot g^{-1}$ dry weight) (Table 1). These results were consistent with observed genetic variation for efficiency of Ca use in snap beans (Quintana et al., 1996). Mean yield was highest in 'Hystyle' (18% above the mean) and lowest in 'Labrador' (19% below the mean). Cultivar × fertilizer interaction was nonsignificant for either variable ($P > 0.05$).

Environmental attributes. Strong year effects for pod Ca concentration and yield were observed (Table 1), but genotype × year interaction was nonsignificant for any variable ($P > 0.05$). Mass flow is the primary mechanism for supplying Ca to the root surface (Barber, 1995). Thus, higher pod Ca concentration levels in 1997 may be due to the greater precipitation (260 mm in 1997 vs. 126 mm in 1996) and subsequent water availability for Ca transport, resulting in increased root Ca influx. Similarly, higher precipitation levels in 1997 may have resulted in increased N loss through leaching.

Interactions often exist between Ca and pH, although not in soils with pH levels ≥5 because these Ca solution concentrations are high when compared to the H concentrations (Barber, 1995). Thus, pH differences between years probably did not affect pod Ca concentration. The ability of snap bean plants to accumulate Ca in pods has been associated with the plant's capacity to transport xylem sap via root pressure (Quintana et al., 1997). Root pressure is usually greater when humidity is high (Kramer, 1983); and relative humidity was higher in 1997, which possibly contributed to greater pod Ca concentrations.

Adding Ca to snap bean plants via soil fertilization did not increase pod Ca concentration or yield significantly. Cultivar effects had a greater impact than fertilizer treatments for all parameters measured, suggesting that breeding may more effective in enhancing pod Ca accumulation in beans.

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