AgriLIFE EXTENSION
Texas A&M System

L-5212
9-98

Using Soluble Calcium to Stimulate Plant Growth

Sam E. Feagley and Lloyd B. Fenn*

Research has shown that applying soluble calcium with urea, an ammonium form of nitrogen, can improve crop production. Calcium increases ammonium, potassium and phosphorus absorption, stimulates photosynthesis, and increases the size of sellable plant parts. It also makes the use of nitrogen more efficient, which improves the economics of production and reduces nitrogen contamination of the environment.

How the Research Was Conducted

Various plant species grown in greenhouses were fertilized several times during the growing season with nutrient solutions containing various calcium-to-ammonium ratios, so that the value of increasing the amount of soluble calcium could be tested. Check plants were given nitrate fertilizer with no increased amounts of soluble calcium. Most field plots were planted in 40-inch rows and most greenhouse tests were accompanied by field experiments. Greenhouse plants were grown to certain stages and then harvested. The harvested plants were weighed and divided into seeds, bulbs, leaves, stems and roots so the parts could be tested for nutrient concentrations. In the field experiments, the commercial products were harvested and the yields recorded.

Benefits of Calcium

When urea (46-0-0), anhydrous ammonia (82.5-0-0) or diammonium phosphate (18-36-0) is banded into the soil, an equivalent amount of calcium is precipitated. The plant roots cannot access nitrogen in an environment containing more than 32 percent ammonium. Roots can be killed, but usually they grow around the fertilizer bands. After the soil microbes have converted much of the banded ammonium to nitrate, then the roots can begin to use the nitrogen. When extra soluble calcium is applied with the fertilizer it lowers the pH of the fertilizer band, thus reducing its toxicity. If calcium is applied beyond precipitation requirements, it stimulates ammonium absorption by plants. Adding supplemental calcium has increased the rate at which plants absorb ammonium by as much as 100 percent. As some of the ammonium is changed to nitrate, the previously precipitated calcium is gradually resolubilized, adding to the available soluble calcium concentrations that increase yield.

The increased ammonium absorption caused by calcium has interesting results. Photosynthesis increases (Fig. 1), and greater amounts of carbon dioxide are captured by the plant from the air, which increases the plant's organic building blocks (Fig. 2). When plants absorb more ammonium, less nitrogen remains in the soil and is subject to leaching. Also, surplus nitrogen absorbed by plants is stored and is available to promote growth all season. In trials, both bermudagrass and ryegrass showed this effect, with denser growth and color (chlorophyll-photosynthesis) throughout the season (Fig. 3).

Perhaps the most beneficial effect of applying calcium with ammonium is that plants change their normal pattern of depositing energy stores (carbohydrates, metabolites) (Figs. 4, 5). As Figure 4 shows, rice plants had progressively lower leaf weight and progressively higher grain weight as calcium levels increased. This increase continued with all calcium concentrations. One report showed that adding soluble calcium to rice paddy water resulted in up to 15 percent of the flag leaf's energy production being transported to the filling seeds (as opposed to 5 percent without calcium). Rice weights increased 14 percent when extra calcium was applied at seed fill.

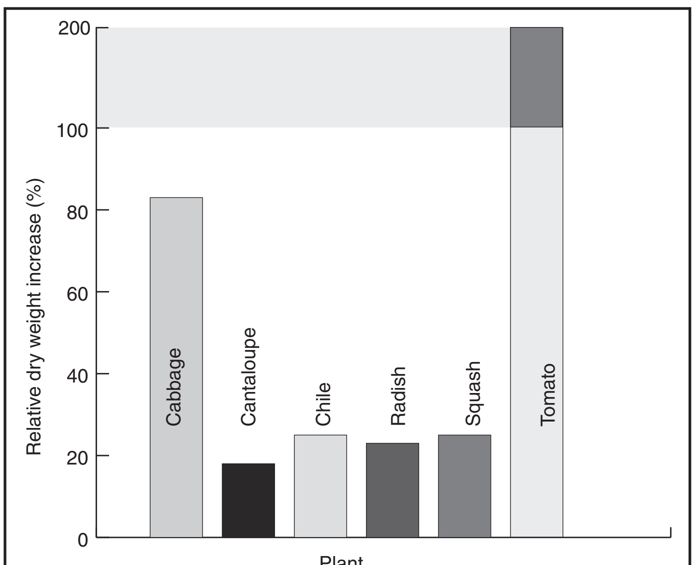

Figure 1. Increased photosynthesis results from calcium application.

*Professor and Extension Soil Environmental Specialist; and Professor, Texas Agricultural Experiment Station, The Texas A&M University System.

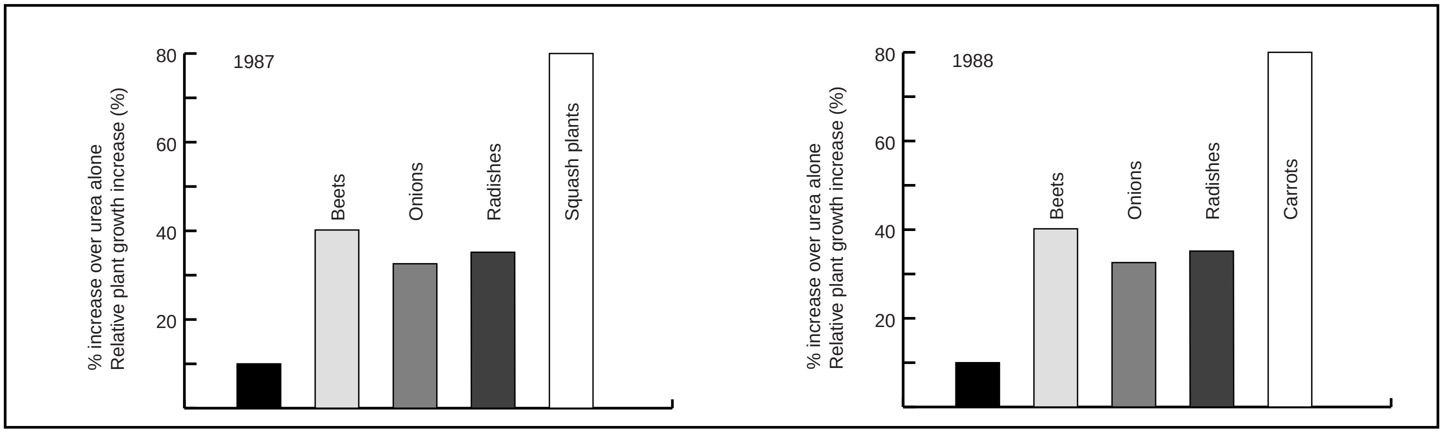

Figure 2. Relative yield of vegetables grown in the field after fertilization with urea alone and with urea plus calcium chloride (Fenn et al., 1990, 1991, 1994).

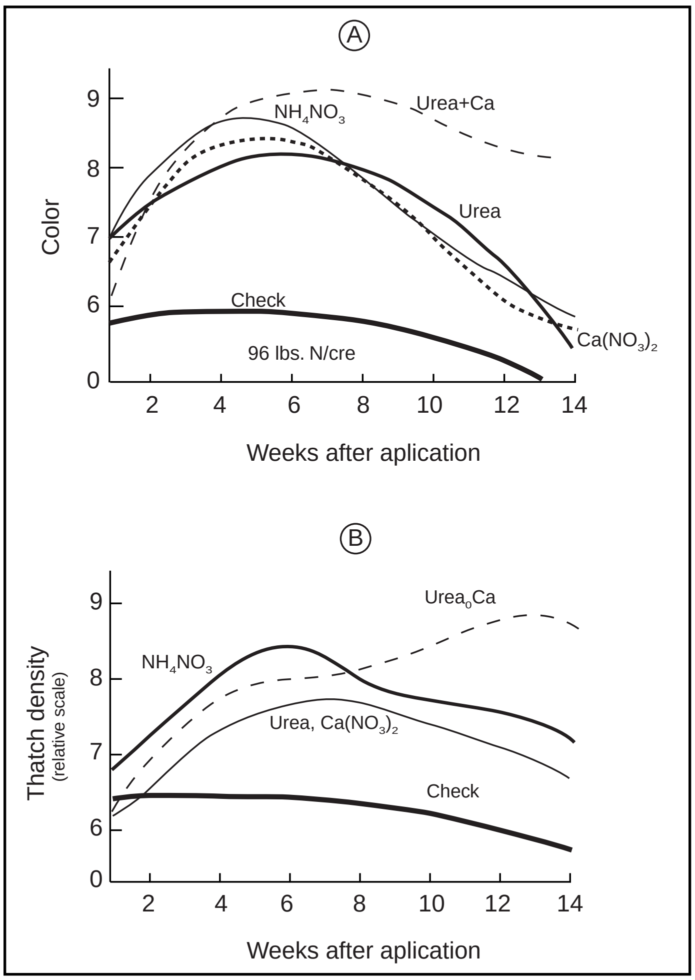

Figure 3. Bermudagrass color (A) and density (B) as affected by four nitrogen sources (Horst et al., 1985).

This same observation was made with beets, onions, wheat, oats and barley (Figs. 5, 6). Within 30 hours of application, onion and beet bulbs increased in weight by up to 50 percent over bulbs grown with nitrate (without ammonium). The weight of the entire plant, however, did not increase as much as the bulb, which means that calcium causes the carbonaceous compounds to be deposited disproportionately in the bulbs (Fig. 5).

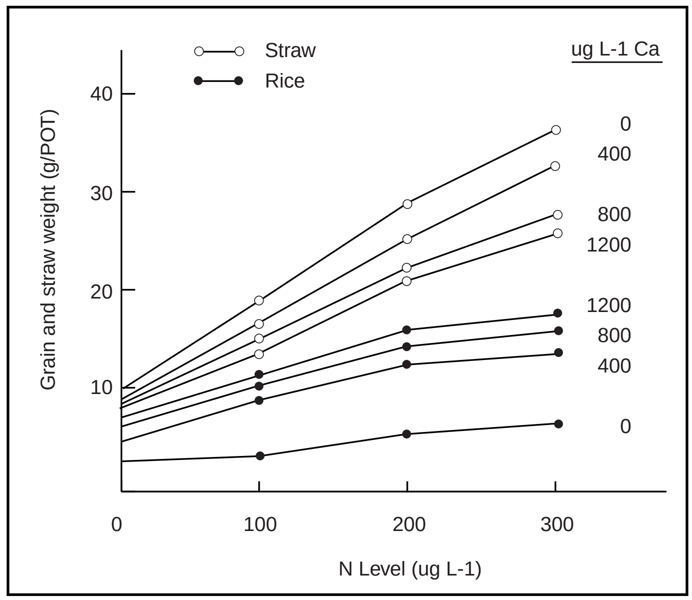

Figure 4. With increasing calcium levels, rice grain weight increases while straw weight decreases.

Incorporating calcium into fertilizers has secondary benefits to crop production as well. In irrigated soils, sodium always builds up and the continuing addition of calcium helps improve soil structure near plant root zones. In acid soils, where liming is practiced, the soluble calcium chloride will more rapidly migrate to the lower root zone, reducing the toxic effects of aluminum. Higher ratios of calcium to ammonium could be justified for this reason.

How to Use Calcium with Nitrogen Fertilizers

Nitrogen can be applied in several ways. It can be broadcast on the surface of pasture land or prepared (crop) soil and watered in by rain or irrigation. It can be banded. Or, nitrogen can be applied with irrigation water, a method that does not stimulate plant growth as much as broadcast application. Each producer should select the method that best fits the needs and economics of his production system.

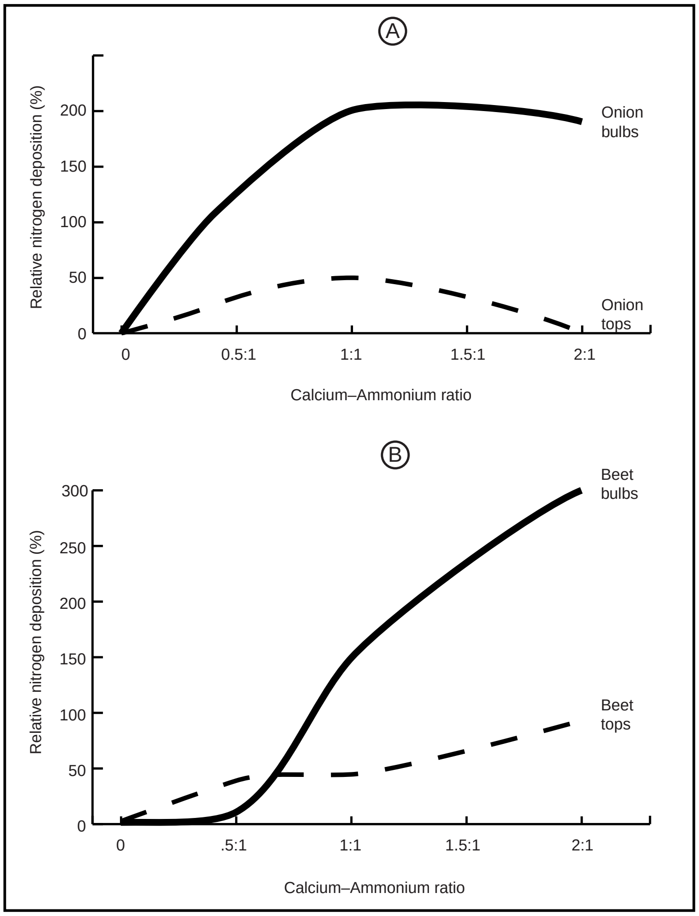

Figure 5. Calcium stimulates growth and energy deposition patterns in onion (A) and beets (B).

When nitrogen (usually ammonium in the form of urea) is applied to soils, the nitrogen can quickly convert to nitrate, especially in the summer (The presence of nitrate does not hinder the plant's use of ammonium.) Thus, the fertilizer application method and time of year could become important. The best results from the calcium-ammonium technology are obtained in the cooler weather of winter and spring, although nitrogen may need to be applied at other times. Foliar application of the calcium-ammonium is a good solution. In fact, foliar applications have produced significant benefits in research trials, at a rate of 1 to 2 pounds of calcium per acre. Logically, plant stimulation could not be expected unless soil nitrogen (probably nitrate) is present. This means that we can use calcium-ammonium, applied foliarly, as a means of extracting soil nitrate, which makes this technology an excellent environmental and agronomic tool. Furthermore, the low rate of calcium that can be used in foliar applications reduces the risk of leaf burn, yet seems to trigger the same beneficial effects as soil-applied product

Nitrogen and Calcium Rates

Nitrogen needs should be determined in the traditional fashion—soil testing. Take soil samples to determine your nitrogen need and then calculate your calcium addition at the desired ratios. It is possible that less

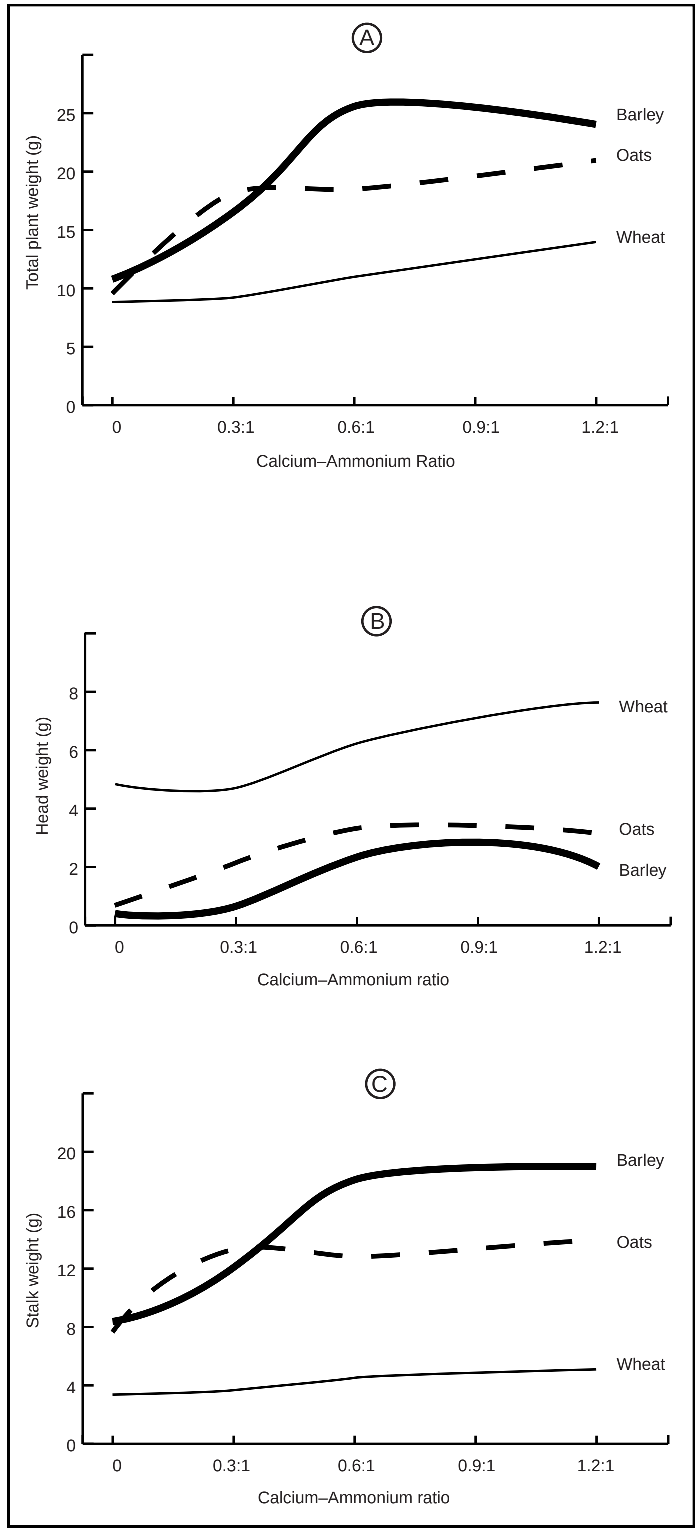

Figure 6. The effects on total plant weight (A), head weight (B), and stalk weight (C) of various ratios of calcium to ammonium.

nitrogen could be required when calcium is applied with it, as seems to be the case in sugar cane.

Research has shown that the optimum amount of calcium to apply is 1/2 to 1 pound of calcium chloride per 1 pound of urea (Fig. 6). This rate increases yields from 14 to 50 percent. However, the precise amount of calcium needed is hard to fix because when the plant absorbs ammonium it releases an equivalent amount of hydrogen. This hydrogen in turn solubilizes the precipitated lime (calcium carbonate), if present. Urea applied in a band will precipitate calcium even in an acid soil. Thus, there is a certain amount of this naturally occurring calcium that combines with supplemental calcium to stimulate plant growth.

A dditional Reading

Adams, F. 1982. A comparison of the effects of monocalcium phosphate and diammonium phosphate on phosphorus and calcium availabilities. Soil Sci. Soc. Am. J. 46:769-771.

Bailey, J. S. 1992. Effect of gypsum on the uptake, assimilation and cycling of N15-labeled ammonium and nitrate-N by perennial ryegrass. Plant and Soil. 143:19-31.

Barker, A. V., R. J. Volk and W. A. Jackson. 1966. Root environmental acidity as a regulatory factor in ammonium assimilation by the bean plant. Plant Physiol. 41: 1193-1199.

Bartlett, R. J. 1965. Importance of carbon dioxide in uptake of calcium by plants receiving only a nitrate source of nitrogen. Soil Sci. Soc. Am. Proc. 29:555-558.

Bastida, J., J. M. Llabres, F. Viladomat, R. M. Cusido and C. Codine. 1988. Free amino acids and alkaloid content in snap dragon plants grown with nitrate, urea or ammonium nutrition. J. Plant Nutr. 11:1-15.

Bennett, A. C. and F. Adams. 1970a. Calcium deficiency and ammonia toxicity as separate causal factors of (NH4)4HPO6 injury to seedlings. Soil Sci. Soc. Am. Proc. 34:255-259.

Bennett, A. C. and F. Adams 1970b. Concentration of NH3 (eq) required for incipient NH3 toxicity to seedlings. Soil Sci. Soc. Am. Proc. 34:259-263.

Fenn, L. B. and G. R. Gobran. 1998. Willow tree productivity on fertilizer solutions containing various Ca/Al ratios. Nutr. Cycling in Agroecosystems (in press).

Fenn, L. B., B. Hasanein and C. M. Burks. 1995. Calcium-ammonium effects on growth and yield of small grains. Agron. J. 87:1041-1046.

Fenn, L. B. and R. M. Taylor. 1990. Calcium stimulation of ammonium absorption in radish. Agron. J. 82:81.

Fenn, L. B., R. M. Taylor, M. L. Binzel and C. M. Burks. 1991. Calcium stimulation of ammonium absorption in onions. Agron. J. 83:840-843.

Fenn, L. B., R. M. Taylor and C. J. Burks. 1994. Calcium stimulation of ammonium absorption and growth by beets. Agron. J. 86:916-920.

Fenn, L. B. and L. R. Hossner. 1985. Ammonia volatilization from ammonium or ammonium- forming nitrogen fertilizers. In Advances in Soil Sci. New York: Springer-Verlag, Inc. pp. 125-169.

Fenn. L. B., R. M. Taylor and C. Pety. 1986. Calcium stimulation of ammonium absorption with some root crops. Agron Abst. p. 198.

Fenn, L. B., R. J. Taylor and G. L. Horst. 1987a. Phaseolus vulgaris growth in an ammonium- based nutrient solution with variable calcium. Agron. J. 79:89-91.

Fenn, L. B., R. J. Taylor and C. A. Pety, Jr. 1987b. Stimulative effects of elemental sulfur in the presence of ammonium on chile and broccoli growth in calcareous soils. J. Plant Nutr. 10:2263- 2281.

Flocker, W. J. and W. H. Fuller. 1956. Availability of calcium in calcareous soils. Soil Sci. Soc. Am. Proc. 20:387-391.

Gobran, G. R., L. B. Fenn, H. Persson and I. Al-Windi. 1993. Nutrition response of Norway spruce and willow to varying levels of calcium and aluminum. Fert. Res. 34:181-189.

Hallmark, W. B., L. P. Brown and G. L. Hawkins. 1997. Use of calcium chloride to reduce the nitrogen requirements of sugarcane. Louisiana Agr. 40:30-31.

Horst, G. L., L. B. Fenn and N. B. Beadle. 1985. Bermuda grass turf responses to nitrogen sources. J. Amer. Soc. Hort. Sci. 110:759-761.

Hunter, A. S. and W. A. Rosenau. 1966. The effects of urea, biuret, and ammonia on germination and early growth of corn. Soil Sci. Soc. Am. Proc. 30:77-81.

Jacobson, L., D. P. Moore and R. J. Hannapel. 1959. Role of calcium in absorption of monovalent cations. Plant Physiol. 35:352-358.

Jacobson, L. R., J. Hannapel, D. P. Moore and M. Schaedle. 1960. Influence of calcium on selectivity of ion absorption process. Plant Physiol. 36:58-61.

Krassesindhu, P. 1975. Nitrogen, potassium and calcium nutrition effects on ion and dry matter accumulation in rice. Ph.D. diss. University of Kentucky, Lexington.

Krasaesindhu, P. and J. L. Sims. 1972. Response of rice to nitrogen and calcium nutrition. Soil Sci. Soc. Am. Proc. 37:457-461.

Leggett, J. E. and W. A. Gilbert. 1967. Localization of the Ca-mediated apparent ion selectivity in the cross-sectional volume of soybean roots. Plant Physiol. 42:1658-1664.

Morre, D. J. and C. E. Brocker. 1976. Ultrastructural alteration of plant plasma membranes induced by auxin and calcium ions. Plant Physiol. 58:544-547.

Nielsen, T. R. and R. Overstreet. 1955. A study of the role of the hydrogen ion in the mechanism of potassium absorption by excised barley roots. Plant Physiol. 30:303-309.

Sung. F. J. M. and W. S. Lo. 1990. Growth responses to rice in ammonium-based nutrient solution with variable calcium supply. Plant Soil. 125:239-244.

Taylor, R. M., L. B. Fenn and C. Pety. 1985. The influence of calcium on growth of selected vegetable species in the presence of ammonium-nitrogen. J. Plant. Nutr. 8:1013-1023.

Taylor, R. M., L. B. Fenn and C. A. Pety, Jr. 1984. Preliminary observations of chile plant response to banded sulfur. J. Fert. Issues. 1:146-149.

Viets, F., Jr. 1944. Calcium and other polyvalent cations as accelerators of ion accumulation by excised barley roots. Plant Physiol. 19:466-480.

Produced by AgriLife Communications & Marketing, The Texas A&M System

Extension publications can be found on the Web at: http://AgriLifebookstore.org