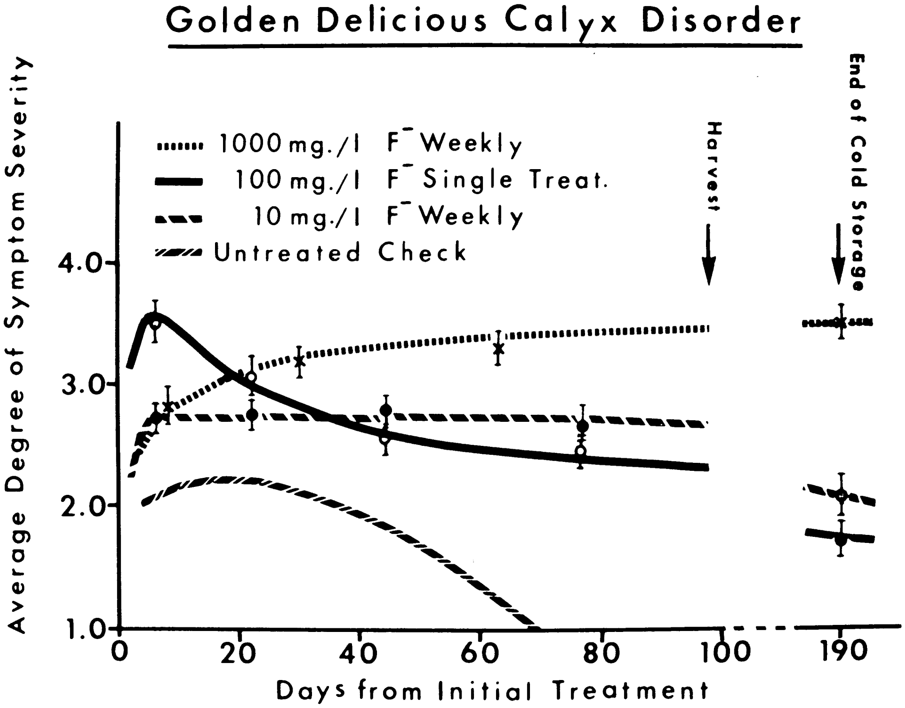

Fig. 2. Effects on symptom severity in 'Golden Delicious' of dipping immature fruits in aqueous solutions of NaF. (Vertical bars indicate SE.)

fruits to aqueous NaF solutions can thus induce symptoms similar to those occurring in limited areas in north central Washington.

It was concluded that F was the causative factor in these solutions as the Na^+ concentration was well below toxic levels. Further work is warranted to determine the form of F in the environment and if very low levels of HF over long periods of time can cause the symptoms observed. Our observations and those of Simons and Lott (8) indicate a disorder sometimes called "sheep's nose" can be caused by late spring frosts or by exposure of the fruits to NaF. However, this does not exclude other possible causes of similar aberrant developmental patterns in apple fruits.

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Fluidized Bed Material as a Calcium Source for Apples[1]

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Abstract. **Fluidized bed material (FBM), a dry, high-Ca, alkaline waste product from the combustion of coal and limestone, was used as the sole Ca source for 'York Imperial' apples (*Malus domestica* Borkh.) grown in outdoor sand cultures for one season. Leaf Ca tended to increase with increasing rates of FBM and flesh Ca was not significantly increased by FBM application, although incidence of cork spot tended to be reduced. The trees showed no visible symptoms of toxicity or altered nutritional levels from the FBM treatments.**

One of the newer, economical methods of reducing SO_2 emissions from coal-burning power plants is the utilization of the fluidized bed combustion boiler design. This process involves mixing fine grain coal and limestone (or dolomitic limestone) in a furnace with a "fluid bed" achieved by injecting air. The limestone absorbs S released during the combustion of the coal. Unlike the waste sludge produced by conventional scrubber facilities, the fluidized bed material (FBM) is dry and easily transported. Ruth (2) estimated that a 1000 MW fluidized bed power plant without regeneration of the bed material would produce about 1800 metric tons of FBM per day.

Terman et al. (6) utilized FBM both as a nutrient source for peanuts and corn and as an amendment for acid soils and coal mine spoils. They found that the material was satisfactory both as a source of crop S and as a lime material. Since FBM contains about 30% Ca and since low Ca has been associated with many fruit disorders (4), FBM may also be beneficial as a Ca source or lime substitute for apples. This report presents results of an initial study designed to examine the possible use of FBM as the sole Ca source for apples.

The FBM used was obtained from the Pope, Robbins, and Evans 0.5 MW pilot steam generator in Alexandria, Virginia. The bed materials used (Sewickley seam coal and Greer limestone) produced FBM containing about 52.4% $caSO_4$, 33.1% CaO, and 0.6% $CaSO_3$. Trace element concentrations were 1.02% Fe, 36 ppm Cu, 112 ppm B, 220 ppm Mn and 80 ppm Zn. Average particle size distribution was: < 1 mm, 31.7%; 1-2 mm, 60.7%; 2-4 mm, 6.1%; and > 4 mm, 1.4%. The material had an

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[2]Soil Scientist

aqueous pH (1:1 by weight) of 12.5.

Twelve-year-old 'York Imperial'/EM 26 apple trees in sand cultures were used to test the Ca-supplying ability of applied FBM during the 1977 growing season. These trees were used in previous nutritional studies (5). The sand cultures contained about 200 liters of quartz sand in sunken, well drained drums. FBM treatments were based on the previously determined Ca requirement of 115 g per tree during a single growing season. FBM (28% Ca) was applied at ½, 1, 2, 4, 8 and 16 times this required Ca level. This required 0.20, 0.41, 0.82, 1.64, 3.28, and 6.56 kg FBM/tree, respectively, applied April 8. Full bloom was April 13. Two additional split FBM treatments (designated split-1× and split-2×) were applied April 8 and May 4. The split-1× and split-2× treatments applied a total amount of FBM roughly equal to the 1× and 2× treatments that were applied in a single application. Two gypsum ($CaSO_4 \cdot 2H_2O$) treatments, at 1× and 2× FBM rates of Ca and a control (no Ca added) treatment were used for comparison. Seven replications of each of the 11 treatments were assigned in a completely randomized design to the field sand cultures. All trees received a complete (minus Ca) nutrient solution 3 times every 2 weeks. The nutrient solution was 3 mM $NaNO_3$, 1 mM KNO_3, 0.5 mM KH_2PO_4, 2 mM Mg $(NO_3)_2 \cdot 6H_2O$, 0.5 ppm B. 0.25 ppm Cu, 0.5 ppm Zn, 0.5 ppm Mo, 0.5 ppm Mn and 6 ppm Fe.

On July 20, 20 mid-shoot leaves per tree were sampled. Fruit was harvested September 6 and 10 apples per tree were selected for flesh mineral analyses and examination for cork spot. A composite flesh sample from the 10 apples was freeze dried and stored for analysis. Leaf and fruit flesh samples were analyzed for Ca, Mg, K, P, Cu, Fe, B, Zn and Mn by emission spectroscopy (1), for S by a Leco induction furnace equipped with an automatic titrator, and for total N by the Kjeldahl method. After harvest, sand samples were taken from duplicate drums of each treatment at 0 to 10 (surface) and 10 to 25 (subsurface) cm depths. Neutral 1N NH_4Ac, extractable Ca and pH (1:1 H_2O) were determined.

The trees showed no indications of foliar deficiency or toxicity symptoms from any treatment. Average shoot length, number of apples per tree, average weight of apples per tree, and leaf dry weight did not differ significantly among treatments (data not shown).

However, leaf tissue and fruit flesh Ca values did differ in response to treatment. FBM applications of greater than half the adequate Ca (½×) level showed an increasing trend in leaf Ca content (Table 1). However, only the 2 gypsum treatments and the 4× or greater FBM applications significantly increased foliar Ca. The split FBM applications were no more effective than the respective single applications. Only the 2 gypsum treatments significantly increased flesh Ca, although there was a trend towards higher Ca levels with increasing FBM. The greater Ca concentrations obtained in both the leaf and fruit flesh samples for the 1× and 2× gypsum treatments (Table 1) may in part be explained by the fineness of the applied gypsum (97% passing a 100 mesh sieve) compared with the coarser FBM material, which tended to form larger aggregates after application.

Table 1. Leaf and fruit Ca concentration and the incidence of cork spot in 'York Imperial' apples as affected by fluidized bed material (FBM) and gypsum treatments applied to the outdoor sand culture.

Treatment[z]	Leaf Ca (% dry matter)	Fruit flesh Ca (% dry matter)	Cork spot incidence (%)
Control – No Ca	1.15d[y]	0.020b	48[x]
FBM (½×)	1.14d	0.022ab	53
(1×)	1.27cd	0.023ab	18
(Split 1×)	1.32cd	0.024ab	28
(2×)	1.35cd	0.023ab	27
(Split 2×)	1.38cd	0.024ab	51
(4×)	1.50bc	0.026ab	28
(8×)	1.61bc	0.025ab	37
(16×)	1.75b	0.025ab	20
Gypsum (1×)	1.78ab	0.028a	2
(2×)	2.08a	0.028a	26

[z]The 1× treatment level of FBM or gypsum provided 115 g/Ca per tree, see text for details.

[y]Mean separation in columns by Duncan's multiple range test, 5% level.

[x]Incidence of cork spot is based on 70 apples per treatment.

At treatment rates above 1×, the applied FBM tended to form small, cemented aggregates, which at 16× produced a fairly continuous crust in the sand cultures (Fig. 1).

Above the ½× FBM treatment, incidence of cork spot generally decreased except for the split-2× FBM treatment (Table 1). The incidence of cork spot was relatively higher at lower leaf Ca-levels and adequate fruit flesh Ca levels than those reported by Shear (3) for similarly grown apples. Since the causal factor in the incidence of cork spot is not necessarily a lack of Ca *per se* and both FBM and gypsum generally decreased the incidence of cork spot compared to the control, the data suggests that both materials were nutritionally beneficial.

Fig. 1. The continuous crust formation observed with high applications of fluidized bed material (FBM) to the field sand cultures.

Besides Ca, 11 other elements (N, P, K, Mg, S, B, Zn, Cu, Mn, Fe and Al) were determined in the leaf and fruit flesh samples (data not shown). The gypsum treatments, especially the 2× treatment level, produced significantly higher leaf Mn, Cu, and S concentrations, compared to all other treatments. These elevated minor element concentrations were most likely due to the S additions from gypsum which aided metal solubilities. No other consistent trends were apparent in leaf mineral concentration. In the fruit, flesh P, Mg and B tended to decrease at the higher FBM levels compared with the control.

Extractable Ca tended to increase in the surface sand samples and to a lesser degree in the subsurface samples as FBM rates increased (data not shown). The pH values of the surface and subsurface samples were generally increased with increasing FBM rate while the gypsum treatments tended to reduce pH values.

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