Influence of pH and Texture of the Soil on Plant Uptake of Added Selenium

Gunnar Gissel-Nielsen

A pot experiment was initiated to measure the influence of varying pH and clay content of soils low in native selenium on the uptake of added selenium by ryegrass (*Lolium multiflorum*). The results showed a general decrease in selenium uptake with increasing clay content, and there was a strong interaction between the pH, clay content, and time. It is concluded that a somewhat smaller amount of selenite might be used on sandy soils than on loamy soils to raise the selenium concentration in farm crops to a desirable level. The results showed also an influence of pH and clay content on the relative availability of selenium and sulfur.

In an earlier experiment (Bisbjerg and Gissel-Nielsen, 1969), a negative correlation was found between plant uptake of added selenium and the clay content of the soils used. However, in the same experiment there was a correlation between plant uptake of selenium and soil pH. Many authors have described the availability of selenium from soils where these two factors varied (Davies and Watkinson, 1966; Kubota *et al.*, 1967). Geering *et al.* (1968) measured the solubility of selenium in soils as a function of pH, and they found the lowest solubility when the soil solution was slightly acid to neutral, and when there was increasing solubility at both increasing and decreasing pH. They discussed the results in terms of the presence of iron oxides and the oxidation state of the selenium. Cary and Allaway (1969) measured the uptake of added selenium in alfalfa from four soils at two pH levels (5.4–6.1 and 7.3–7.8). The plants had a higher selenium concentration when grown on sandy soils than when grown on loamy soils, and they had a higher selenium concentration when grown on higher pH treatment.

In order to study the effect of pH and soil texture further, a pot experiment was initiated using a loamy soil and a sandy soil from lithologically similar parent materials (Table I). This report presents results of the uptake of added selenium by ryegrass grown in soils with increasing clay content and increasing pH, obtained by liming and mixing various amounts of the two soils. Since there is a sulfur–selenium interaction related to the uptake of selenium by plants (Davies and Watkinson, 1966; Gissel-Nielsen, 1971) the uptake of added sulfur was measured also.

EXPERIMENTAL

The soils used in this experiment are described in Table I. The sandy soil had never been cultivated, and the loamy soil had received only acid fertilizer in the past 50 yr. Both soils had a native selenium content of 0.12–0.15 ppm Se, and the clay fractions consisted mainly of montmorillonites and illites (Jensen, 1955). The soils were mixed with ten different amounts of $CaCO_3$ and stored outside, shielded against precipitation. Soil pH's were measured 3 yr after liming, and five portions of each soil with the following pH values were selected for the experiment: 5.4, 6.0, 6.5, 7.5, and 8.0. For each pH value, mixtures of the two soils were prepared in the ratios 1:0, 2:1, 1:2, and 0:1. Then NPK 21–9–12 (21–4–10), containing 1.3% S, was mixed into the texture treatments at the rate of 0.85 g per kg of soil. The fertilizer-sulfate was tagged with ^{35}S, and labeled potassium selenite (^{75}Se) was incorporated in the fertilizer equal to 25 μg of Se per 0.85 g of NPK. Each treatment was divided into five replicates with 1.2 kg of soil in each pot, and Italian ryegrass (*Lolium multiflorum*) was sown. The pots were placed in the greenhouse and watered with deionized water. The grass was harvested five times at 2-month intervals. After each cut, 150 mg of NH_4NO_3 and 150 mg of $K_2HPO_4 \cdot 3H_2O$ in solution was added per pot. The samples were dried at 55°C, milled, and 1-g pellets were made for γ- and β-counting. Cellulose pellets containing aliquots of the ^{75}Se- or the ^{35}S-solution served as references. The ^{75}Se was measured using a NaI-well-crystal, while the ^{35}S was measured using a low background flow counter. Corrections were made for the contribution from the ^{75}Se on the β-counting, while the influence of the ^{35}-S on the γ-counting was negligible.

RESULTS AND DISCUSSION

In Figure 1, the selenium concentration in ryegrass is shown for the low clay and high clay treatments only. The selenium concentration in the ryegrass grown in the two mixed soil treatments gave results intermediate to those shown. For the first two cuts, as the clay content increased in the slightly acid soil treatment, there was a pronounced depression of the selenium concentration in the ryegrass. With successive cuts this effect was diminished, and at pH values greater than 7, even the opposite effect was seen. The loamy soil used in this experiment differed from the sandy soil not only in clay content but also in organic matter, iron content, and probably other constituents. The effect designated as due to clay content might therefore, to some degree, be due to other factors associated with the clay size fraction. Evaluation of the effect of pH on selenium concentration in this experiment was complicated because of the interaction between clay and pH. However, in the first cut at high clay content there was a significantly lower concentration at the slightly acid treatments than at higher or lower pH values. This is in agreement with the observation of Geering *et al.* (1968) except they did not see any increase in solubility of selenium before pH was lowered to about pH 4, while these data show an increase in uptake of selenium with decreasing pH from about pH 6. The difference in these observations can be due to a lower pH around the roots than in the rest of the soils. Also, time has some influence on this effect. As time increased, the agreement with the results of Geering *et al.* (1968) became better, *i.e.*, the slope became positive over the entire pH range.

The yield of dry matter was about the same in four of the five cuttings, but is was increased with increasing pH (Table II). This is reflected in the total uptake of the added selenium by a general increase with increasing pH except at the highest pH levels (Figure 2). Increasing clay content raised the yield

Agricultural Research Department, Atomic Energy Commission, Research Establishment Risø, Roskilde, Denmark

Table I. Soil Data

Soil	Origin	pH (in H_2O)	CEC (mequiv/100 g)	Ca^{2+} (mequiv/100 g)	Organic matter %	Fe extractable ($NH_4 \cdot Ac$, HCl) ppm	Clay content (% part. <2μ)
Loam	Glacial till	5.2	21.0	[illegible].6	2.1	136	18.9
Sand	Glacial outwash	4.3	16.0	1.4	3.2	28	2.3

of dry matter also (Table II), but in the first two cuts the total uptake was nevertheless lower with higher clay content (Figure 2) because the effect of the clay content on the selenium concentration (Figure 1) was stronger than the effect on yield. With the last three cuts where the uptake of selenium was much lower (Figure 2) and the influence of pH and clay content on the selenium concentration was less pronounced (Figure 1), the total uptake of selenium increased as clay content rose. The selenium concentrations in the plants decreased exponentially from the second to the fifth cut, which is in accordance with earlier observations in a field experiment with topdressing of selenite and selenate (Grant, 1965) and with the observations in a pot experiment with red clover, where the selenite and selenate were mixed into the soil (Gissel-Nielsen and Bisbjerg, 1970).

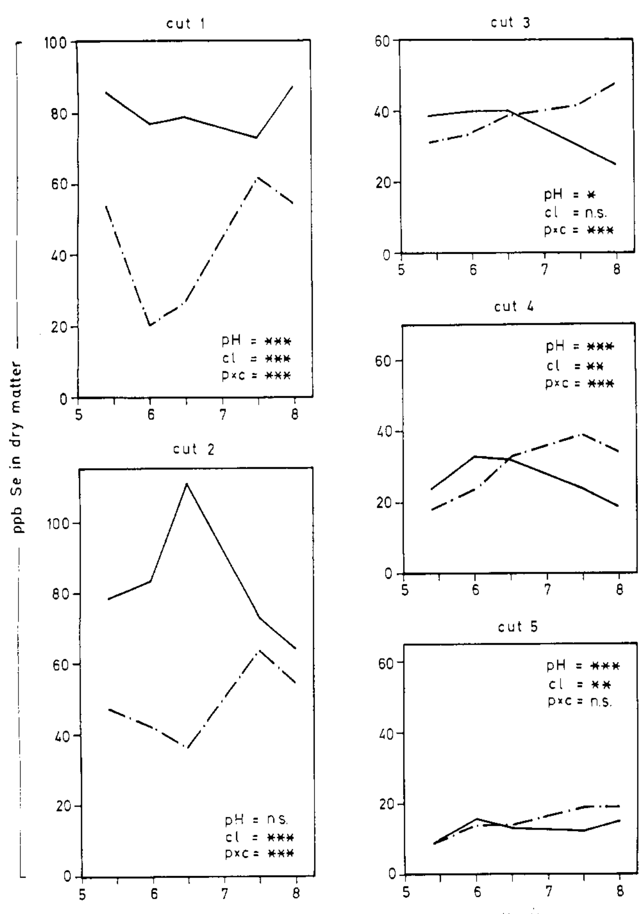

Figure 1. The concentration of added selenium in dry matter of ryegrass at increasing pH and different levels of clay in the soil. Pot experiment.

—— = 2.3% clay; —·— = 18.9% clay; pH = significance of pH influence; cl = significance of clay influence; p × c = significance of interaction between pH and clay; *, **, * = 95, 99, 99.9% levels of significance; n.s. = no significance**

Table II. The Yield of Dry Matter (g per pot containing 1.2 kg soil) in five Cuts of Ryegrass Grown in a Pot Experiment. Average of Five pH and Four Clay Content Levels

Cutting no.	Average pH levels, clay content: low	Average pH levels, clay content: high	Average clay levels, pH: low	Average clay levels, pH: high
1	2.24	3.35	2.82	3.37
2	4.51	5.07	3.82	5.26
3	2.82	3.22	2.80	3.20
4	2.92	4.56	3.73	4.18
5	2.42	5.02	3.65	4.20

The effect of pH and clay content on the uptake of added sulfur (Figure 3) was the reverse of that on selenium in the first two cuts (Figure 2). When the pH was raised, ^{35}S uptake decreased, and when the clay content increased, the uptake of sulfur increased. Consequently, the ratio between selenium and sulfur taken up by plants is influenced by the pH and the clay content of the soils. In the third cut, the activity of the ^{35}S was not sufficient to give a reliable determination of the uptake of sulfur.

CONCLUSION

The present data demonstrate a pronounced decreasing effect of the clay fraction of the soil on the uptake of added selenium in ryegrass, but this effect diminished with time as

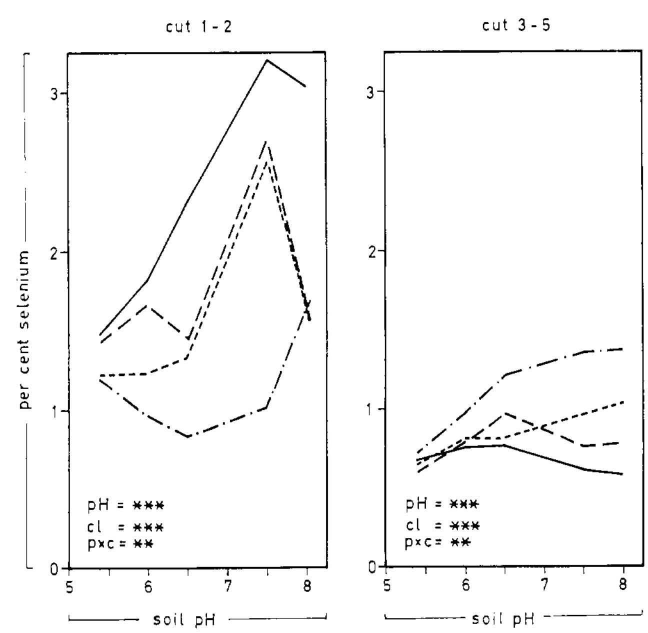

Figure 2. Uptake by ryegrass of selenium in percent of added Se at increasing pH and different levels of clay in the soil. Pot experiment.

—— = 2.3% clay; - - - = 7.8% clay; ----- = 13.4% clay; —·— = 18.9% clay

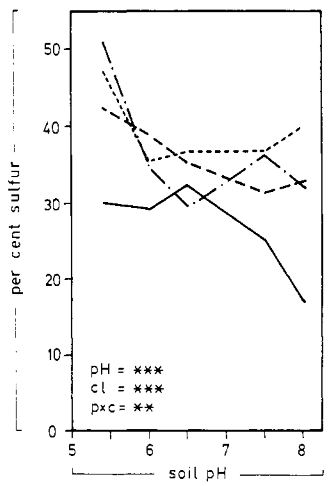

Figure 3. Uptake by ryegrass of sulfur in percent of added S at increasing pH and different levels of clay in the soil. Pot experiment. The symbols are explained in Figures 1 and 2

the selenium became less and less available. This indicates that in case of yearly application of selenite to farmland low in selenium, a somewhat smaller amount may be used for sandy soils than for loamy soils. A significant influence of pH and interaction between pH, clay content, and time was also seen. This resulted mostly in increasing concentration and uptake of added selenium by liming, but decreasing concentration from pH 5 to pH 6 in the first cut and decreasing concentration at the latest cuttings on the sandy soils. Allaway *et al.* (1967) have stated that addition of selenium to alkaline soils is likely to be much more hazardous than addition of selenium to acid soils. The present results show the same pattern, but they do not give evidence for such a strong warning except at the first cut on the loamy soil. The results demonstrated a reverse influence of pH and clay content on the uptake of added sulfur, causing a decreased sulfur-to-selenium ratio in the plants with increasing pH, but an increased ratio with increasing clay content.

ACKNOWLEDGMENT

The author is grateful to W. H. Allaway, E. E. Cary, and Joe Kubota for valuable discussions and advice.

LITERATURE CITED

Allaway, W. H., Cary, E. E., Ehlig, C. F., "Selenium in Biomedicine," A.V.I. Publ., Westport, Conn., 1967, pp 273–296.
Bisbjerg, B., Gissel-Nielsen, G., *Plant Soil* **31**, 287 (1969).
Cary, E. E., Allaway, W. H., *Soil Sci. Soc. Amer. Proc.* **33**, 571 (1969).
Davies, E. B., Watkinson, J. H., *N. Z. J. Agr. Res.* **9**, 641 (1966).
Geering, H. R., Cary, E. E., Jones, L. H. P., Allaway, W. H., *Soil Sci. Soc. Amer. Proc.* **32**, 35 (1968).
Gissel-Nielsen, G., J. AGR. FOOD CHEM. **19**, 564 (1971).
Gissel-Nielsen, G., Bisbjerg, B., *Plant Soil* **32**, 382 (1970).
Grant, A. B., *N. Z. J. Agr. Res.* **8**, 681 (1965).
Jensen, E., Yearbook Royal Veterinary and Agricultural College, Kgl. Vet.-og Landbohøjskole, Copenhagen, 1955, pp 13–32.
Kubota, J., Allaway, W. H., Carter, D. L., Cary, E. E., Lazar, V. A., J. AGR. FOOD CHEM. **15**, 448 (1967).

Received for review March 1, 1971. Accepted May 21, 1971.