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STUDIES ON SLOW RELEASE FERTILIZERS: 1. EFFECTS OF TEMPERATURE, SOIL MOISTURE, AND WATER VAPOR PRESSURE

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Using first-order kinetics we describe the release of nutrients by coated slow-release fertilizer (SRF). Plotting the logarithm of the concentration of intact fertilizer in the soil [$\log(Q_0 - Q_t)$, where Q_0 is the amount applied and Q_t is the amount released at time t] versus the time yielded a straight line, as predicted. The rate constants of SRF release at different temperatures are linearly related to the water vapor pressure:

$$K = A \cdot Pw + B$$

where Pw is the vapor pressure and A and B are constants.

We conclude that the rate-determining step in the nutrient release out of SRF is the migration of vapor from the soil into the fertilizer granule. The very mild effect of soil moisture on the rate of nutrient release is consistent with the proposed mechanism. We discuss the possibility of predicting nutrient release from SRF using the derived relationships.

A number of slow-release fertilizer (SRF) formulations have been developed during the last decades (Hauke 1972). This trend is motivated by the effort to produce and apply fertilizers so that crop nutrient needs are satisfied while a minimum of fertilizer salts is leached or wasted. This reasoning is valid considering economics (i.e., maximizing utilization of the added fertilizer) and, even more, considering environmental effects (i.e., minimizing fertilizer leaching to underground or surface water bodies). Farming activity in some parts of the world is already limited by permissible levels of nutrient release to the environment. In such situations, SRFs, if properly applied, may be the solution. An essential factor for the success of such efforts is the ability to quantitate and predict the rate of fertilizer release under different conditions. The first step toward this goal is the proper formulation of the release process.

The assumption used in this work is that the nutrient release process can be described as the decay of a fertilizer-particle population, where the decay of any given particle is randomized. As such, this process is similar to other decay processes, such as radioactive decay, and could be described using first-order kinetics (Berry et al. 1980).

$$dC/dt = -kC \qquad (1)$$

or the integrated form of such a reaction

$$\log C/C_0 = -Kt \qquad (2)$$

where C is the concentration, t is the time (C_0 is the concentration at $t = 0$), and K is the decay rate constant.

The concentration terms to be used in the present case are Q_0, the amount of fertilizer applied to the soil (in g of nutrient per kg of soil); Q_t, the quantity released up to the time t; and $(Q_0 - Q_t)$, the quantity remaining nondissolved at any given time. Equation 2 is thus formulated as

$$\log(Q_0 - Q_t)/Q_0 = -Kt \qquad (3)$$

The rate constant K, the dimensions of which are liters/day, is the parameter that describes the frequency of fertilizer-particle decay. If this constant is known, the rate of fertilizer release can be quantitatively formulated. Moreover, the effects of different environmental conditions on the rate of slow fertilizer release could be best formulated as affecting this rate constant.

The high sensitivity to temperature of the release from SRFs is known both in the field and in laboratory studies (Oertli and Lunt 1962; Ahmed et al. 1963). It is important, accordingly, to formulate the temperature effects quantitatively and relate the release rate to rigorous parameters.

MATERIALS AND METHODS

We conducted fertilizer-soil incubations with a sandy loam (Sharon sandy loam) having 92.3% sand, 1.1% silt, 6.6% clay, 0.3% organic matter, and 0.16% $CaCO_3$. The soil was neutral (pH = 7.3) and had a low salt content (electrical conductivity of saturated paste extract, 0.15 ds/m).

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