PROPERTIES OF SLOW-RELEASE FERTILIZERS

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Establishment and growth of vegetation on the materials found at reclamation sites generally requires the addition of some soil amendment or fertilizer to improve the status of the material as a medium for plant growth. The amendments in use are limestone and gypsum. While they may supply the plant nutrients calcium and sulphur they are principally used to correct an acid pH or excessive salinity problem. Fertilizers, on the other hand, are used because they contain one or more of the major plant nutrients, nitrogen, phosphorus and potassium and, in specific situations, sulphur and micronutrients. The amount and analysis to be used is dependent on the specific requirement for each nutrient element at each site. It deserves repeating that the amount and analysis is dependent on the specific requirements of a site, hence a general recommendation is about as meaningful as making a statement that a baby needs food without knowledge of the baby's age.

Over the past two decades considerable research has been directed toward development of slow-release materials. The objective of the development of a slow-release fertilizer was to obtain a material that would release to solution only a small quantity of the plant nutrient at a time, hopefully the rate of release would be equal to the rate of uptake by the growing plant. The objective can be achieved by (1) using chemical compounds having properties of slow breakdown or dissolution per se, or (2) by physically coating fertilizer pellets with semipermeable membranes or inert materials.

As was previously mentioned, fertilizers generally consist of three plant nutrients; nitrogen, phosphorus and potassium. They are manufactured by blending together the appropriate carriers of the three nutrients and as such are known as complete fertilizers. There are, however, no slow-release forms of potash on the market today; the potassium salts used in formulating fertilizers, KCl and K_2SO_4, are completely water soluble. The principal slow-release form of phosphorus is bone-meal, a by-product of the meat packing industry. Its use, however, is limited to the specialized ornamental horticulture trade because of price. One might also argue that rock phosphate is a slow-release form of phosphorus but to realize benefit from finely ground rock phosphate the pH of the medium should be 5.0 or less. All other carriers of phosphorus are not considered slow-release materials. Since rock phosphate and bone meal are not used as phosphate carriers in commercial fertilizers, it is obvious that it is only the nitrogen component of a fertilizer can be considered as a slow-release material. Therefore, by definition, a complete slow-release fertilizer does not exist but, rather, fertilizers in which part or all of the nitrogen carrier only is in a slow-release form.

There are always exceptions, and to keep the record straight reference must be made to semi-permeable membrane coatings applied to complete fertilizer pellets. One material of this type was developed in the U.S.A. and retailed under the trade name of "Osmocote".* The high cost per pound of plant nutrient limited its use and, furthermore, availability at this time is questionable.

The remainder of the paper will be concerned with slow-release nitrogen carriers: materials which may form part or all of the nitrogen component of a complete fertilizer.

The slow-release property of manufactured nitrogen carriers is basically an attempt to mimic the microbiological breakdown of the natural organic matter in the soil. The rate of release of nitrogen from soil organic matter is dependent on the activity of soil microflora an activity largely controlled by temperature and moisture. Plant growth is also largely controlled by the same two environmental factors so that as the activity of the soil microflora rises and falls, due to changes in temperature and moisture, the potential for plant growth likewise rises and falls. Theoretically, the release of N from the slow-release carrier may be considered to be 'in phase' with plant growth.

The first manufactured slow-release nitrogen carrier to receive widespread use, and which still dominates the market, is urea-formaldehyde (Table 1). The material is produced by reacting urea with formaldehyde, the solubility of the product depending on the ratio of urea to formaldehyde. The more complex the molecule, the slower the rate of decomposition, since nitrogen release is dependent on the microbiological decomposition of the molecule. Where the ratio is less than 1.0 there is strong resistance to decomposition, with preferred ratios in the range of 1.5 to 3.0. The material should have a total nitrogen content of not less than 35% and also have

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* Registered Trade Mark

an Activity Index of not less than 40 where the Activity Index is defined as:

$$AI = \frac{\% \; CWIN - \% \; HWIN}{\% \; CWIN} \times 100$$

where CWIN is the percentage of the total nitrogen insoluble in cold water (25°C) and HWIN is the percentage of total nitrogen insoluble in hot water (98°C). Nitrogen release is not influenced by granule size, is slightly greater at acid pH levels and is of limited value at soil temperatures of less than 15°C. In a recent study on turf at Guelph, a single application of urea-formaldehyde produced excessive growth in May, but was inferior by the end of the growing season, (Fig.1).

Table 1: Some Properties of Nitrogen Carriers

Carrier	Chemical Form	Nitrogen Concentration	Solubility in Water
		(%)	(g/100 ml)
Urea-formaldehyde (U.F., Ureaform)*	Organic	38	Trace
Crotonylidene Diurea (C.D.U., Floramid)*	Organic	32	.12
Isobutylidene Diurea (I.B.D.U.)*	Organic	32	.01
Blood Meal	Organic	13	0
Activated Sewage Sludge	Organic plus NH_3	5-6	Trace
Sulphur Coated Urea (S.C.U.)*	Inorganic	32	20**
Metal Ammonium Phosphates	Inorganic	8***	.05
Urea	Inorganic	46	>100
Ammonium Nitrate	Inorganic	34	>100

* Synonymous terms.
** In seven days at 38°C
*** "Mag-Am P" analysis of 8-40-0-14 (Mg).

Two other manufactured, organic, slow-release nitrogen carriers, which are also polymers of urea and aldehydes, are I.B.D.U. and C.D.U. The rate of release of both materials is increased with a decrease in granule size, lowering the pH, and by increasing soil temperature and soil moisture. The reaction involved in release of nitrogen from I.B.D.U. is thought to be a release of urea by hydrolysis of the molecule rather than microbial action. The materials are not commercially available in Canada at this time, although I.B.D.U. is being used in formulation of lawn fertilizers in the U.S.

By-products of sewage treatment and the meat packing industry may also serve as slow-release N carriers. The two main carriers are bone meal and "Milorgonite".* Both materials, while being satisfactory slow-release materials, are restricted to specialized turf or horticultural use because of price. Liquid sewage sludge from secondary treatment plants, however, may have some value where it can be utilized locally, thus keeping transportation costs at a minimum. The metal content of the sludge should be given consideration if the area of application is ever to be returned to a food production system.

During the mid-sixties the Tennessee Valley Authority developed sulphur-coated urea where the nitrogen release is controlled by microbial breakdown of a wax used in sealing the tiny holes or cracks formed in the molten sulphur coating as it cools. The rate of release is controlled by the thickness of coating, type of wax and inclusion of microbicides, soil temperature and soil moisture. The rate of release is less from surface-applied material than from incorporated S.C.U.

Work at Guelph on turf has shown S.C.U. to be superior to U.F. and sewage sludge, in terms of reducing the flush of spring growth and in prolonging the growth to the end of the season (Fig.1). Production of Reed canarygrass (Phalaris arundinacea L.) with S.C.U. was maintained into the year after nitrogen applications were discontinued (Table 2). A December application of S.C.U. was superior to a mid-May application and the residual influence continued at a higher level than where urea was used, even where split into three applications per season.

Sulphur-coated urea is now being produced on a commercial scale by Canadian Industries Limited.

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* Registered Trade Mark

Several divalent metals (Mg, Fe) form metal ammonium phosphates which have slow-release properties due to the low water solubility of the inorganic molecule. The rate of nitrogen release, however, appears to be greater than the solubility would indicate and release decreases with increase in granular size. The material would have additional advantages where phosphorus and magnesium are also required as plant nutrients, such as at the establishment stage of grasses and legumes. Cost of the material has also limited its use to the specialized interior horticulture industry.

The choice of a nitrogen carrier for reclamation work eventually must be based on one or more of the following criteria: (1) reduction in number of applications, (2) freedom from fertilizer burn of seedlings, (3) loss of nitrogen through excessive leaching in a porous medium, and (4) the cost per pound of nitrogen. The last criteria will most often be the one which tips the balance.

Table 2: The response of Reed canarygrass to time of application and nitrogen carrier. Nitrogen applications commenced in December 1970 and were discontinued in 1972.

Carrier	Time	Yield 1971	Yield 1972	Yield 1973
			(kg dry wt/ha)	
Urea*	Dec. only	9100	7580	2860
	May only	7470	7440	3320
	1/3 Dec., 1/3 May, 1/3 July	6950	8190	4740
S.C.U.*	Dec. only	5570	7380	5920
	May only	4580	7250	5710
Check		4230	2370	2990

* Nitrogen applied at 240 kg N/ha

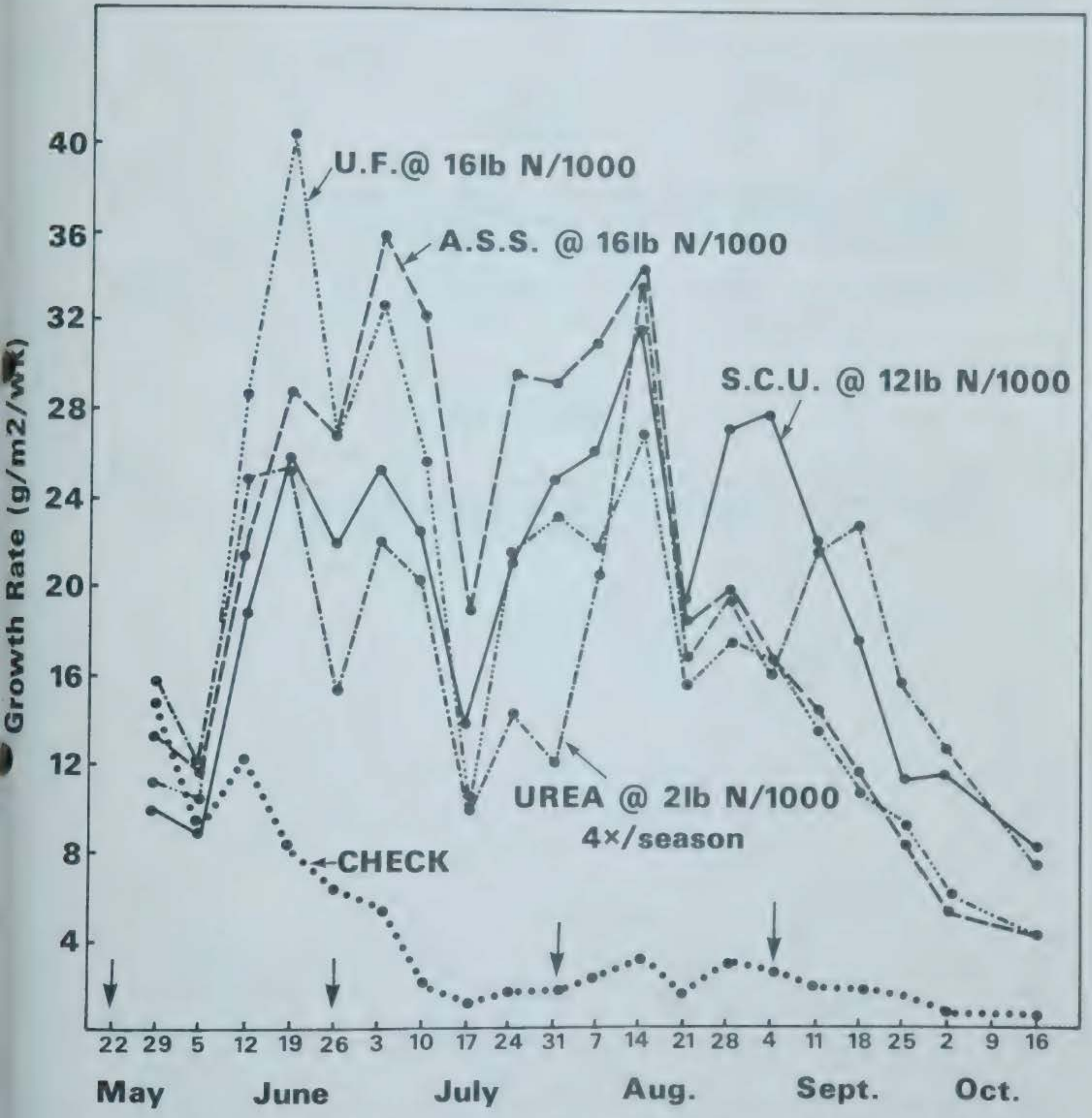

Figure 1. The growth rate of a bluegrass - red fescue turf fertilized with a single application of sulphur-coated urea, urea formaldehyde, activated sewage sludge and four applications of urea.

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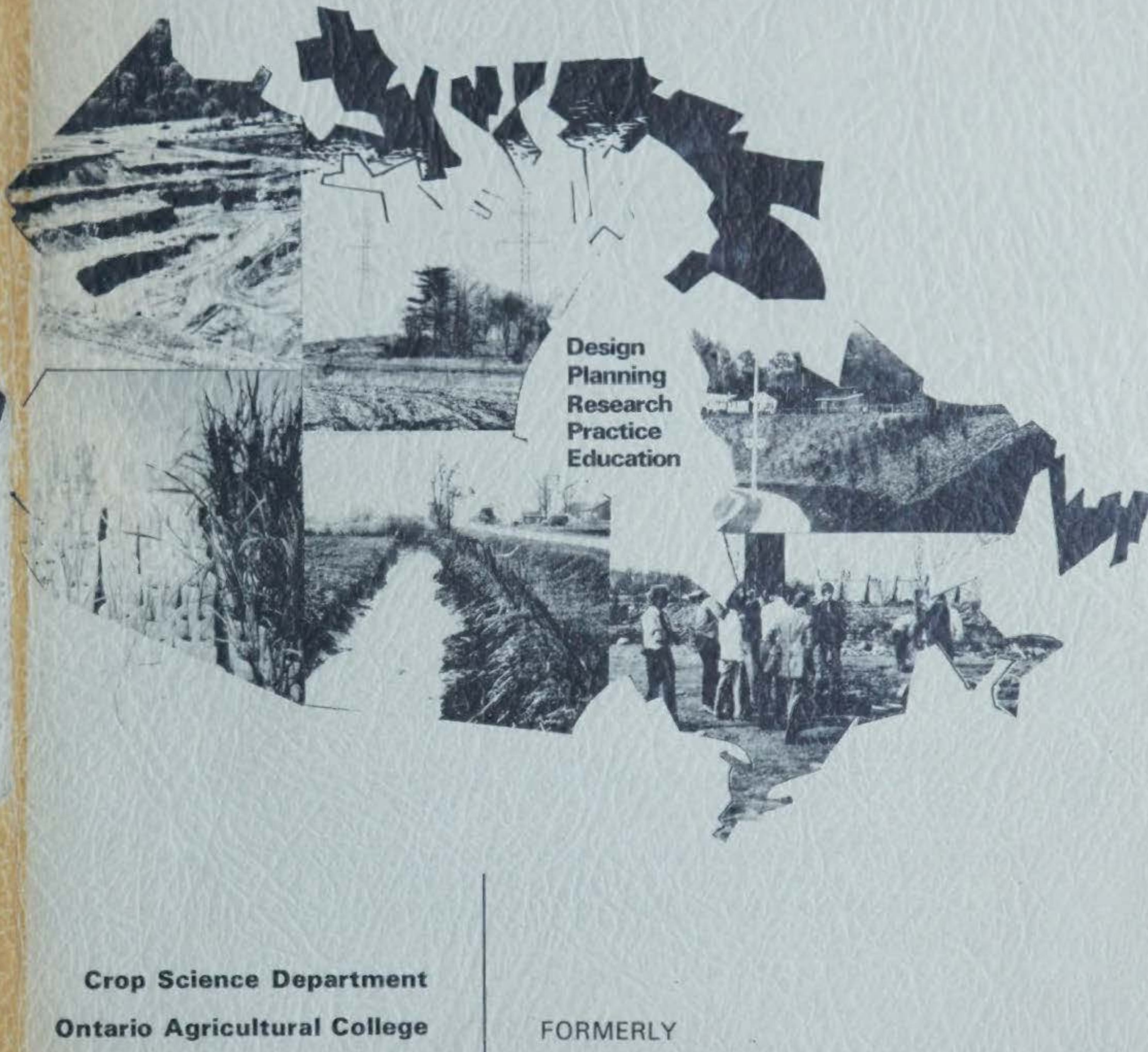

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