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Slow-release Nitrogen Studies with Spinach Grown in a Clay-Perlite-Vermiculite Medium[1]

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Abstract. **Clay foam, a recently patented clay-perlite-vermiculite potting mix that dries to a rigid, lightweight structure, has the capability of retaining nutrients, with the exception of NO_3^-, over a long period of time due to the ion exchange capacity of the clay fraction. Isobutylidene diurea (IBDU, 31-0-0), ureaform (38-0-0) and oxamide (31.8-0-0) were evaluated as slow-release N sources for clay foam, utilizing 'America' spinach (*Spinacia oleracea* L.) as a greenhouse test crop, at rates of 0.112, 0.225 and 0.337 g N/3600 cm^3 clay pot. A basic nutrient formulation, including enough soluble N to cover the lag period between application and release of the fertilizers, was added to the clay fraction prior to mixing. IBDU showed the greatest potential for use in clay foam, as indicated by fresh and dry weights, total N in the dry leaf tissue and low NO_3^- accumulation.**

Clay foam is a potting mix of clay subsoil, perlite and vermiculite with a unique combination of features: relatively low weight but enough substance to support the stems of large, top-heavy plants, high water-holding capacity coupled with good aeration, the ability to dry to a given form or shape and long-term nutrient-holding capability due to the ion exchange capacity of the clay fraction. Previous research (6) has indicated that when the plant-essential nutrients are added to the subsoil prior to mixing, no additional fertilization is necessary for an extended period of time except for N, which is included in the basic nutrient formulation in a water-soluble form readily subject to leaching. A long-term source of N that would be effective in clay foam for the length of any particular cropping period would be highly beneficial to the consumer because it would result in conservation of both time and energy.

Three slow-release fertilizers, IBDU, ureaform (as Nitroform) and oxamide, were evaluated as long-term N sources in clay foam, utilizing greenhouse-grown 'America' spinach as a test crop, at rates of 0.112, 0.225 and 0.337 g N/3600 cm^3 clay pot (the equivalent of 45, 90 and 135 kg/ha, covering the range of N fertilizer recommendations for field-grown spinach). To obtain greater uniformity of material, IBDU and ureaform were screened for particles of 0.707-1.0 mm; the oxamide was in powdered form. The clay foam contained coarse perlite and vermiculite in a 1:1 ratio by volume and 86 g of air-dry, unsterilized Putnam subsoil/1000 cm^3 of mix. Nutrients were added to the clay fraction prior to mixing according to the formulation presented in Table 1. Initial pH of the clay foam prior to addition of the slow-release fertilizers was 6.3, while cation exchange capacity was 30.9 meq/100 g (approximately 90 meq/1000 cm^3). The 9 fertilizer treatments and a control, which received no slow-release N, were replicated 7 times in a randomized complete block design. The appropriate amount of slow-release fertilizer was added to each pot and mixed in immediately before transplanting to prevent any release of N in the moist clay foam between mixing and planting time. Three weeks after seeding, the spinach was transplanted to the pots of clay foam at the rate of 3 plants/pot; the weakest of the plants in each pot was clipped out 3 weeks after transplanting, so that fresh and dry weights are based upon 2 plants/pot. The 15-week experiment was conducted in the vegetable research greenhouse at the University of Missouri-Columbia during the winter months of November, 1978, through February, 1979. Plants were grown at a minimum air temperature of 13°C and watered to the run-off point only 2-3 times weekly, thereby minimizing leaching. The dry leaf tissue was analyzed for total N (1) and NO_3^- (7) at the University of Missouri Experiment Station Chemical Laboratories.

Analysis of yield data (Table 2) revealed that the low and medium rates of IBDU were the most effective treatments, while ureaform at all 3 levels, along with the low rate of oxamide, produced yields as low as the control. Mean dry weights (Table 2) tended to follow the same pattern as fresh weights except that the oxamide treatments were no longer superior to any ureaform treatment or to the control. When mean fresh weights produced by IBDU, ureaform and oxamide across all levels were compared, the results were clear-cut: IBDU >oxamide>ureaform. When the same comparison was made using dry weights, IBDU performed better than ureaform regardless of rate, while oxamide did not differ from either

Table 1. Initial fertilization of the subsoil fraction of clay foam.

Cation added to subsoil	Amount (meq/100 g)	Anion added to subsoil	Amount (meq/100 g)
K^+	2.22	PO_4^{3-}	30.00
CA^{2+}	12.22	Cl^-	3.33
NH_4^+	7.50	NO_3^-	7.50
H^+	18.89		

Table 2. Mean fresh and dry weights of spinach (2 plants/pot) grown in clay foam treated with 3 slow-release N fertilizers at 3 rates of application.

Slow-release N fertilizer	Slow-release N/pot (g)	Mean fresh weight[z] (g)	Mean dry weight[z] (g)
By treatment:			
IBDU, low	0.112	76.1a	10.16a
IBDU, medium	0.225	75.0a	9.80ab
Oxamide, high	0.337	69.6ab	8.46abc
IBDU, high	0.337	67.9ab	8.54abc
Oxamide, medium	0.225	67.8ab	8.91abc
Oxamide, low	0.112	59.2bc	7.86bc
Ureaform, medium	0.225	58.8bc	8.07bc
Ureaform, high	0.337	58.0bc	7.61c
Control	–	53.8c	7.48c
Ureaform, low	0.112	51.4c	7.14c
By fertilizer (all 3 levels):			
IBDU	–	73.0a	9.50a
Oxamide	–	65.5b	8.41ab
Ureaform	–	56.1c	7.60b

[z]Mean separation by Duncan's new multiple-range test, 5% level.

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IBDU or ureaform. The superior performance of IBDU may have been related in part to the relatively low minimum temperature of 13°C maintained in the greenhouse. When Volk and Horn (8) compared the cold-weather responses of turfgrasses to 7 different fertilizers, including IBDU and 2 brands of ureaform, IBDU proved to be superior in that it did not show the cold-weather depression of N release characteristic of the other fertilizers. The lack of crop response to even the highest rate of ureaform was to be expected, however, regardless of soil temperature. Brown and Volk (2) compared N recovery rates of labeled ureaform and NH_4NO_3 in experiments conducted in outdoor lysimeters, greenhouse pots and laboratory incubation vessels. About 50% of the N in ureaform was almost as readily available as that in NH_4NO_3, which also means that it was subject to leaching, while as much as 15-20% of the ureaform remained unchanged, and thus unavailable to plants, after an entire year in the soil. Since powdered oxamide exhibits the ready availability of NH_4NO_3 rather than the slow-release capability associated with granular oxamide (3), its degree of effectiveness, as measured by yield, over the 15-week cropping period is somewhat surprising, though it was not so readily subject to leaching under the infrequent watering regime of winter.

The rankings of total N and NO_3^- levels in the dry spinach leaf tissue from high to low are roughly parallel (Table 3). Plants receiving high amounts of IBDU and oxamide also had high levels of total N, but this does not necessarily indicate that the high N applications evoked the best yield response. Plants fertilized at the high rate of IBDU had a mean fresh weight of 67.9 g but contained significantly more total N than plants receiving the medium rate and having a mean fresh weight of 75.0 g. Although these 2 fresh weights did not differ statistically, the association of higher N content in the leaves with lower yields may mean that plant growth was suppressed at the highest rate of fertilizer application. Nitrate levels in the dry leaf tissue also support this interpretation: the high rate of IBDU led to a greater NO_3^- accumulation than the low and medium rates and the high rate of oxamide to a greater accumulation than the low, suggesting that the high rates of these 2 fertilizers were providing more N than the plants could use. Olday et al. (5), who characterized 'America' as an NO_3^- accumulator, found substantial concentrations of NO_3^- in petioles, roots and blades (2510.9 ppm fresh weight) when fertilizer NO_3^- was applied in excess of plant requirements. Nitrate levels in the clay foam experiment were, however, relatively low: mean NO_3^- accumulation in dry leaf tissue across all treatments was only 138.5 ppm. Presence of excessive NO_3^- is a crucial factor in dealing with N applications to edible plants since high NO_3^- levels have been implicated in at least 2 very serious health hazards to humans (4).

Of the 3 fertiiizers tested, IBDU showed the greatest potential for use as a controlled-release N source in clay foam. Any initial delay in release of IBDU appeared to be adequately covered by the NO_3^- included in the basic nutrient formulation added to the subsoil before mixing. In the ranking of fresh and dry mean weights, the 3 levels of IBDU were among the top 4 means. At the amounts applied to the spinach, IBDU did not result in excessive NO_3^- accumulation in the leaves, nor did it produce a pH after cropping significantly different from that of the control. Since release rate of IBDU is related to particle size, the larger particles (>1.0 mm), which were not used in this study to insure a degree of particle-size uniformity, should be included if IBDU is used in clay foam to extend the period of time that N is available to the plant. Even though ureaform performed very poorly in clay foam at all 3 rates of application, it might be useful in combination with IBDU for the fraction that releases almost immediately and for its long-term residual effects. Oxamide actually performed quite well as an N source for spinach: mean fresh and dry weights produced by the medium and high rates of application were statistically as high as those of the IBDU treatments, though oxamide did rank lower than IBDU when yields of the 3 fertilizers were compared across all rates of application. But the efficacy of oxamide is counteracted by its unavailability on a commercial scale and in a range of particle sizes.

Table 3. Mean total N and NO_3^- content in dry leaf tissue of spinach grown in clay foam treated with 3 slow-release N fertilizers at 3 rates of application.

Slow-release N fertilizer	Slow-release N/pot (g)	Total N in dry leaf tissue[z] (%)	NO_3^- in dry leaf tissue[z] (μg/g)
Oxamide, high	0.337	4.16a	284ab
IBDU, high	0.337	4.11ab	347a
Oxamide, medium	0.225	3.71abc	171bc
IBDU, low	0.112	3.62bcd	139bc
IBDU, medium	0.225	3.56cd	119bc
Ureaform, high	0.337	3.51cd	96c
Oxamide, low	0.112	3.36cd	71c
Ureaform, medium	0.225	3.16d	73c
Control	–	3.15d	31c
Ureaform, low	0.112	3.12d	53c

[z]Mean separation by Duncan's new multiple-range test, 5% level.

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