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**75. Slow-release nitrogen fertilizers in vegetable production: a review.**

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# Slow-release Nitrogen Fertilizers in Vegetable Production: A Review

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**SUMMARY.** Slow-release nitrogen (N) fertilizers offer many potential benefits for vegetable production. In sandy soils, their use may lessen N leaching. If the slow-release fertilizer has a release pattern that matches crop needs, N uptake by the growing crop may become more efficient. Additionally, if slow-release fertilizers can be applied as a preplant application, production costs could be lessened, eliminating the need for multiple applications of soluble N fertilizer. Synthetic slow-release fertilizers can be separated into two general groups: those that are slow release as a byproduct of a chemical reaction (such as urea-formaldehyde), and those that are slow release via a sulfur, wax, or resin coating around the fertilizer prill. In vegetable crop research, much of the available literature has focused on use of sulfur coat urea and urea-formaldehyde, as they have been in the fertilizer market for 40 years. Newer research has evaluated resin-coated products. In most studies, use of slow-release N fertilizers as a preplant treatment did not decrease crop yield, but yield was rarely increased when compared with standard split applications of soluble N. Based on available research, the benefits of using slow-release N fertilizers in vegetable crop production will come from reduced environmental risk and savings in production costs.

## A brief review of slow-release fertilizer technology

Slow-release nitrogen fertilizers can be separated into three broad categories. The first is "natural" organic fertilizer, with the N contained as a part of crop residue, animal waste, or other organic waste product such as ash or biosolids. "Natural" is implied because these fertilizer sources contain N from a waste or agricultural processing step (e.g., meat or fish processing), and the N is not synthesized or created via an industrial process, such as with urea N. This review article will not examine the use of natural organic N sources, and will focus instead on those slow-release products that are slow release due to a synthetic manufacturing process. This would include the second and third categories of slow-release N sources: chemically reacted slow-release products and physically coated slow-release products (Carrow et al., 2001; Olson, 1971).

The second major category of slow-release N fertilizers includes those products formulated from urea that have been chemically reacted, making the urea slower to release into

the soil solution. There are three general groups of these products: urea-formaldehyde (UF) reaction products, isobutylidene diurea (IBDU), and triazone.

UF is made by reacting urea with formaldehyde at varying temperatures and reaction times, which produces chains of urea and carbon-hydrogen groups. Although not technically correct, UF reaction products are also often called "methylene ureas" (MU). Most correctly, MUs are one step of the UF reaction process (Olson, 1971). In part, the length of the reacted chain controls the duration of N release, with longer chains having longer times for N release (Olson, 1971). Nitrogen release occurs as microorganisms break the chains into shorter lengths, releasing urea.

IBDU is a combination of urea and isobutyraldehyde, with N release occurring as hydrolysis breaks down the reacted product. Nitrogen release is faster as particle size decreases and soil temperature increases. Triazones are cyclic compounds that contain ammonia, and are commonly sold as

a slow-release liquid. Much of the triazone research has focused on its use as a foliar fertilizer (Clapp, 1993; Widders, 1991).

The third major category of slow-release N fertilizers is those that are slow-release because of a physical coating around the urea fertilizer prill. Typical coating materials are sulfur, wax, or a plastic resin, or some combination of these materials. Older coating materials such as sulfur were developed 40 years ago (Lunt, 1968), while newer coating technologies that include resin or polymers have gained prominence in the last decade (Peacock and DiPaola, 1992; Shaviv, 1999). Nitrogen release from coated products may be dependent on soil moisture, soil temperature, microbial activity, coating thickness, orifice size in the coating, or some mixture of these variables.

Whatever the slow-release technology, slow-release N fertilizers are often associated with positive characteristics such as reduced burn, consistent release of N over a long period, and possible reductions in nitrate leaching (Shaviv and Mikkelsen, 1993; Simonne and Hutchinson, 2005). As negatives, slow-release N sources tend to be more expensive per pound of N (than soluble products), will not produce a rapid growth response, and may have N release that is difficult to predict, especially if environmental variables affect the N release rate. However, the possible advantage of reduced environmental risk, coupled with the ability to extend N availability over a growing season, has led researchers to examine slow-release N fertilizers in vegetable crop production systems (Sanchez and Doerge, 1999). This review article will summarize that body of work, discussing research in the use of slow-release N fertilizers in vegetable production.

## Materials that are slow release due to reaction

**UREA-FORMALDEHYDE.** First grouped under the generic name *ureaform*, urea was reacted with

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### Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
1.1209	lb/acre	kg-ha <sup>-1</sup>	0.8922

formaldehyde in the presence of a catalyst to form a white, odorless solid that contained about 38% N (Clark et al., 1956). Ureaforms were first sold as fertilizers in 1955 (Olson, 1971). Different UF reaction products can be produced, varying in N release as a function of the urea/formaldehyde ratio, and the time, temperature, and pH under which the reaction occurred (Kaempffe and Lunt, 1967).

Often, research studies that evaluated sulfur-coated urea (SCU) as a slow-release N source also included some formulation of UF in the study. When the UF was a slowly available N source, with little initial N release, muskmelon (*Cucumis melo*) (Wilcox, 1973) and bell pepper (*Capsicum annuum*) yields (Locascio and Fiskell, 1979) were lower than or similar to those measured in SCU, ammonium nitrate (AN), or urea treatments, regardless if the N was 100% preplant (Wilcox, 1973) or split applied (Locascio and Fiskell, 1979). Preplant applications of SCU, UF, AN, and urea produced no significant difference in strawberry (*Fragaria xananassa*) (Albregts et al., 1991), while preplant and split applications of SCU, UF, or ammonium sulfate (AS) had no effect on bell pepper or muskmelon yield (Wiedenfeld, 1986).

When UF was applied as 0%, 25%, 50%, 75%, or 100% of the total N applied, total marketable yield of tomato (*Solanum lycopersicum*) was unaffected (Csizinszky et al., 1992). However, the percentage of that total yield that was harvested early and graded as extra large increased as the percentage of UF in the N mixture increased. It was hypothesized that because early season prices for tomatoes are usually higher, the extra cost for added UF would be offset by the increased value of the tomatoes (Csizinszky et al., 1992). In other work, inclusion of UF (50% of a UF-urea mix) in a preplant fertilizer application had no effect on the yield or quality of tomatoes when compared with 100% urea treatments (Koivunen and Horwath, 2005).

**ISOBUTYLIDENE DIUREA.** Research papers that evaluated IBDU included that N source as a part of larger studies that also included SCU or UF. Because of this, those studies have been discussed previously in this

article (Albregts et al., 1991; Locascio and Fiskell, 1979; Locascio et al., 1973, 1981). In those studies, IBDU fertilizer treatments rarely significantly increased yield above that observed in SCU, urea, or other fertilizer treatments. There were never improvements in fruit quality that resulted from the use of IBDU compared with other N sources.

### Materials that are slow release due to coating

**SULFUR-COATED UREA.** Developed by the Tennessee Valley Authority (TVA), SCU was first produced by spraying molten sulfur (S) onto urea particles, and then adding a light coat of molten wax that also contained a microbicide. In later work, it was noted that use of the microbicide was often discontinued (Shirley and Meline, 1975). N release from SCU is affected by soil temperature, soil water content, microorganism activity, and coating characteristics (Jarrell and Boersma, 1980).

Research that examined the use of SCU in vegetable production first appeared in the 1970s, with the use of SCU compared with various soluble N sources. When two SCUs with varying N release rates were applied as 100% broadcast preplant treatments to muskmelon, initial N release was not great enough to promote adequate vine development for highest total fruit yield (Wilcox, 1973). In this study, the highest fruit yield was associated with 100% preplant application of soluble N (AN). A watermelon (*Citrullus lanatus*) study found comparable results, although it was noted that split applications might be warranted in wetter years (Locascio et al., 1973). In tomato research, preplant applications of broadcast SCU provided no additional yield benefit over similar preplant applications of AN or a 75/25 SCU/AN mixture (McArdle and McClurg, 1986). Total strawberry yields were unaffected by preplant N source, which included various combinations of SCU, AS, IBDU, and urea (Albregts et al., 1991; Clay et al., 1984).

Later research found that preplant SCU often produced yields equal to that produced in treatments receiving split applications of soluble N (Brown et al., 1988), especially in conditions where nutrient leaching

was a concern (Waddell et al., 1999, 2000). For example, when SCU was applied to potato (*Solanum tuberosum*) as a single application 1 month after planting, yield of potato from SCU-treated plots was equal to that obtained from urea-treated plots in 2 of 3 years (Liegel and Walsh, 1976). In 1 year, potato yield from the SCU-treated plots was significantly higher than yield from the one-time urea application, a result of excessive rainfall in that year, which likely leached the one-time urea application from the rooting zone. Splitting the urea into three applications reduced this loss, and potato yield from that treatment was equal to that in the 100% preplant SCU plots (Liegel and Walsh, 1976). In other work, yield of watermelon was significantly increased when SCU was the N source, during one very wet season (Locascio et al., 1978). In the other three seasons of the study, watermelon yield from SCU-treated plots was equal to that obtained from plots in which urea was applied in two or three split applications (Locascio et al., 1978). Others obtained similar results with turnip greens (*Brassica campestris*), cabbage (*Brassica oleracea* var. *capitata*), and tomatoes, noting that although crop yield from use of SCU may not have exceeded that from split applications of soluble N, savings could be found through reduced labor costs due to less frequent N application (Sharma et al., 1976).

Slow-release N fertilizer work is often difficult to compare because the blanket term "SCU" covers many products, all with varying N release rates (Locascio et al., 1978, 1981). Thus, research studies often included several different forms of SCU, with differences in crop yield often attributed to the N release patterns of the SCUs. In trellis tomato production, three SCU sources were compared with preplant and split applications of AN (Shelton, 1976). At N application rates of 392 and 560 kg·ha<sup>-1</sup> N, marketable yield of tomato from some SCU-treated plots was greater than that from split or preplant AN-treated plots (Shelton, 1976). There were differences due to the release rate of the SCU formulation, however, with the SCU with the slowest N release (11.5% of total N released in 7 d) producing the significant yield

increase mentioned previously. When SCUs with more rapid N release (21.5% and 29.3% of total N released within 7 d) were used, tomato yield did not differ from that measured in the 100% preplant AN treatments (Shelton, 1976). Similar results were observed in a bell pepper trial, where rapid-release SCU formulations (35% and 44% in 7 d) had yields similar to that measured in split broadcast applications of urea (Locascio and Fiskell, 1979). Higher yield of bell pepper was observed when preplant IBDU and SCU were compared with urea, AN, and AS, a result of more continuous release of N during the crop season (Locascio et al., 1981). SCU fertilizers used in that study had N release rates of 27% to 37% of total N in 7 d. In these studies, it was hypothesized that SCUs with slower N release rates did not provide sufficient N for the growing crop (Locascio and Fiskell, 1979; Locascio et al., 1981).

**RESIN-COATED UREA (RCU).** Newer to the slow-release N source field, polyolefin resin- (or polymer) coated fertilizers are a relatively new research topic. Developed in the late 1970s, granular urea is covered with resin, and N release occurs as water moves into the coated prill, with N release as the urea solution diffuses out into the soil (Hummel, 1989). An even newer technology is reactive layer coating (RLC), where a mixture of diisocyanate and polyol are reacted, producing a coating that bonds to a urea prill (Peacock and DiPaola, 1992). These newer technologies create the possibility for the manufacture of N sources that have controlled and long-term N release, from 70- to 270-d release patterns (Hummel, 1989). Nitrogen release is dependent on coating characteristics and soil temperature (Christianson, 1988).

A slight twist on RCU is the combination of a sulfur-coat and a resin layer, typically called polymer sulfur-coated urea (PSCU) (Csizinszky, 1994). RCU, PSCU, UF, AN, and potassium nitrate were applied as preplant treatments at two N rates (195 and 293 kg-ha<sup>-1</sup>) for tomato production. Because potassium rates and sources were part of this study, a resin-coated potassium nitrate treatment was also included. Over the length of the study, earliness to harvest, fruit size, and marketable tomato yield were not improved by

the use of the resin-coated N sources (Csizinszky, 1994). This result differed from earlier research, where earliness to yield and fruit size were improved by use of a slow-release UF N source (Csizinszky et al., 1992). Because that same UF source and rate were included in the 1994 study, differences were hypothesized to be due to time of year. The 1994 study was a spring study, and the 1992 work was conducted in the fall.

A study that evaluated RCU in bell pepper production systems also observed few effects on bell pepper yield or quality (Guertal, 2000). Preplant SCU, RCU, and split (drip irrigation) application of AN were all applied as part of a raised bed, plastic mulch pepper production system. In 1 year of 3 years, peppers harvested from the SCU treatment had a lower total marketable yield than peppers from the RCU or drip-applied AN treatments. In 2 years of the 3 years, N source did not affect total marketable yield of pepper, indicating that slow-release N sources might be viable if N injection systems were not available (Guertal, 2000).

## Conclusions

Likely a factor of its greater lifespan in the fertilizer market, slow-release N fertilizer with vegetable crops has focused primarily on SCU. Following that is a significant body of work that examines the utility of UF, followed by IBDU. Less researched are the newer coating technologies of RCU (and potassium nitrate), and reactive layer coatings.

Typically, research studies evaluated preplant application of slow-release materials and compared yield and quality parameters to treatments of 100% soluble N sources or some type of split application over the cropping season. In most of the research, yield was rarely significantly increased when slow-release N fertilizers were compared with soluble materials such as urea or AN. This was especially true when the soluble N sources were applied in split applications.

Thus, if a yield benefit is not widely demonstrated, other benefits such as reduced N leaching, increased N use efficiency, and decreased production cost must be demonstrated. Additional research that examines combinations of soluble and slow-release materials would also be

warranted, helping to determine the precise ratio that provides soluble N for crop uptake, while minimizing soil N prone to leaching. Because there is a body of research that amply demonstrates that slow-release N sources do not negatively affect vegetable crop yield, continued research should explore the economic and environmental benefits that could develop as a result of their use in vegetable crop production systems.

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