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SULFUR-COATED UREA ABSTRACTS

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SULFUR-COATED UREA ABSTRACTS

Prepared in cooperation with
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FOREWORD

Developing and introducing new fertilizer products are important functions of the Tennessee Valley Authority's National Fertilizer Development Center. Nitrogen efficiency is critical in the United States and world agricultural systems. In search of better nitrogen efficiency, TVA developed controlled release sulfur-coated urea and introduced it to farmers through land-grant universities and the fertilizer industry. TVA has continued to monitor related manufacturing efforts, distribution channels, and agronomic results.

This bulletin is a collection of abstracts of published findings and a listing of research projects dealing with sulfur-coated urea. Many of the abstracts have already appeared in *Fertilizer Abstracts*, a journal published monthly since 1968, by NFDC. The sulfur-coated urea abstracts are divided into three sections: Technology, Marketing, and Use. Research projects in the United States that were ongoing in a survey conducted in 1979 are listed by states. Author and subject indexes are provided in this bulletin.

TABLE OF CONTENTS

	Page
TECHNOLOGY	1
Production Techniques	1
Chemical and Physical Characteristics	6
USE	13
Field Crops	13
Grasses	30
Fruits and Vegetables	38
Ornamentals and Turf	45
Forest	47
Miscellaneous	48
MARKETING	51
Economics	51
Cost	52
Supply-Demand	53
RESEARCH PROJECT LISTINGS	55

TECHNOLOGY

PRODUCTION TECHNIQUES

1 Sulfur Coated Fertilizers. In *New Developments in Fertilizer Technology. 5th Demonstration* (held TVA, National Fertilizer Development Center, Muscle Shoals, Alabama, Oct. 6-7, 1964). *Muscle Shoals, Alabama: TVA, National Fertilizer Development Center*; pp 31-2 (1964). A S-oil coating for soluble fertilizers was developed after it was found that a coating of molten S alone had microscopic openings. Although the addition of oil gave good results in the laboratory, it was not effective in actual use in the soil because capillary forces removed part of the oil. Tests with S-petrolatum coatings showed that petrolatum resisted capillary action. Best results were obtained with a 20 wt % S and 2-4% of petrolatum. The S, as a melt, was applied by spraying on the granules in a rotary drum. Molten petrolatum then was sprayed onto the S-coated granules. White U.S.P. petrolatum with a melting point of 130°F was quite satisfactory. Coating applied to 30-10-0 and urea granules were tested in the greenhouse during the fall and winter months. The tests showed that: (1) S coatings prevented seedling toxicity when the seeds and fertilizer were placed in the soil together, (2) coated urea gave greater yields than uncoated urea when surface applied, and (3) a single application of coated 30-10-0 gave a longer effective period of fertilizer release than did uncoated materials when tested with ryegrass. The feasibility of incorporating micronutrient compounds in the S coating by suspending them in the molten S prior to spraying onto the fertilizer particles was demonstrated.

2 Method of Making Sulfur-Coated Fertilizer Pellet Having a Controlled Dissolution Rate. G. M. Blouin and D. W. Rindt (to Tennessee Valley Authority). *U.S.* 3,295,950, Jan. 3, 1967, Appl. May 3, 1965; 8 pp. A process is described for the treatment of solid fertilizer particles to make them H_2O resistant, reduce caking tendencies, reduce hydroscopicity, and to produce a fertilizer product which has a controlled rate of dissolution when applied to the soil. The treating agent serves to supply a secondary nutrient as well as a pellet coating. An oily subcoating material selected from petrolatums, petroleum softwaxes and oils, wood rosins, and paraffins is applied to fertilizer particles in quantities of 1-8 wt % based on fertilizer wt. This quantity is sufficient to fill surface voids, cracks, and capillaries of the fertilizer particles. A coating of elemental S is applied to the oil-coated fertilizer in amounts of ~ 5-50 wt % based on the finally coated fertilizer. A topcoating with additional subcoating material is applied in amounts of 1-5 wt %. The viscosity of molten S is decreased and spraying and spreading characteristics are enhanced by the addition of halogens in amounts of 1-5 wt %. The addition of 1-10 wt % of powdered siliceous material to the molten S increase plasticity and strength. If desired, 1-30 wt % of powdered compounds of the micronutrients Fe, Zn, Cu, Mn, Mg, Mo, and B may be added to the molten S. In some instances the subcoating and/or the topcoating may be omitted.

3 Sulfur-Coated Fertilizer Pellet Having Controlled Dissolution Rate and Inhibited Against Microbial Decomposition. G. M. Blouin and D. W. Rindt (to Tennessee Valley Authority). *U.S.* 3,342,577, Sept. 19, 1967, Appl. Dec. 12, 1966; 9 pp. Continuation-in-part of *U.S.* 3,295,950. A coating of elemental S is applied to fertilizer pellets in an amount to provide ~ 5-50 wt % of the coated fertilizer pellet wt. The coated pellets are topcoated with an oily selant selected from petrolatums, petroleum softwaxes and oils, wood rosins, paraffins, and mixtures thereof. The quantity of oily material is sufficient to impregnate any cracks and voids in the S coating. It provides ~ 1-8 wt % of the total wt. The process is improved by dissolving in the sealant ~ 0.1-4 wt % (based on total wt) of a microbially toxic agent such as pentachlorophenol, coal tar oil, camphor, cresol, or mixtures thereof. This addition reduces the harmful microbiological activity on the coating when the fertilizer is in the soil. A subcoating of the sealant material may be added prior to the S coating.

4 Nitrogen Fertilizer That Lasts. Fred Myers (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Furrow 75*, 18-19 (Nov.-Dec. 1970). Sulfur-coated urea (SCU) is produced experimentally by TVA by spraying urea granules with molten S, sealing with wax containing a microbicide, and conditioning. Rate of dissolution increases with decrease in coating thickness, increase in soil temperature, and with mixing into the soil as compared to surface placement. Sulfur-coated urea results in better seasonal distribution of growth and protein content of grass forage than do single applications of soluble N fertilizers. It also results in less burning of seedlings and may result in less leaching loss of applied N fertilizers.

5 Sulfur-Coated Fertilizers for Controlled Release: Pilot Plant Production. G. M. Blouin, D. A. Rindt, and O. E. Moore (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *J. Agr. Food Chem. 19* (5), 801-8 (Sept.-Oct. 1971). The continuous S coating of urea to produce controlled-release fertilizer was studied by TVA in a 300-lb/hr pilot plant. Molten S and a molten wax sealant (containing coal tar microbicide to prevent degradation in soil) were sprayed in successive layers onto a rolling bed of heated fertilizer. The waxed material was cooled and dusted with conditioner to obtain a free-flowing product. A typical coated product contained 17% S, 3% wax, 0.2% coal tar, and 1.8% conditioner. The substrate dissolution rate in water at 100°F was 15% in 1 week and 0.5%/day during the second week. The operating conditions that represent departures from previously reported batch laboratory work were: continuous operation; use of several spray nozzles rather than one; and higher atomizing air pressure in the S spray nozzles. Estimated costs should permit use on long-term crops in some areas.

6 Sulfur-Coated Urea. A. R. Shirley and R. S. Meline (to Tennessee Valley Authority). *U.S. Pat. Off. Defensive Publication* T912,014, July 24, 1973, Appl. July 3, 1972; 32 pp. A process is described for applying a precisely uniform solid coating of fluid material onto solid substrate particles preheated in a rotary drum having a radiant heat source such that the surface irregularities of the particles are smoothed out by a combination of surface melting and tumbling action. The preheated particles are fed to a second rotary drum where multiple, thin, concentrically formed layers of the coating material are applied by cascading the substrate particles beneath a plurality of sequentially applied, closely controlled sprays of the coating material. In particular, the process allows the coating of granular urea with molten S applied under precise spraying temperatures and conditions in such a manner that the molten S evenly coats the particles and solidifies with the desired physical characteristics to form a slow-release N

fertilizer at an economical cost without the use of subcoats, seal coats, microbicides, parting agents, or plasticizers. Further, it is shown by examples that the operational conditions and techniques presented constitute a substantial improvement in the process for the production of S-coated urea where additional coatings consisting of materials other than S are used. A unique spray header for pneumatic atomizing spray nozzles is described which includes the installation of an orifice immediately external to each nozzle. The flow rate of liquid is proportional to each nozzle based on the area of the opening in each orifice. The coated product is rapidly cooled to control crystal structure of the applied coating material.

7 Sulfur-Coated Urea by Improved Method. A. R. Shirley, Jr. and R. S. Meline (to Tennessee Valley Authority). *U.S.* 3,903,333, Sept. 2, 1975. Appl. Mar. 8, 1974; 33 pp. A continuous process is described for applying S to urea granules to produce a slow-release N fertilizer consisting only of a coating of commercial-grade S on commercial-grade granular urea. A precisely uniform solid coating of fluid S is sprayed onto the surface of solid urea granules at 170-203.9°F in a horizontal rotary coating drum of length ~ 1.5-10 times its diameter filled to ~ 3-10% of its capacity, and rotating at ~ 30-80% of its critical speed. In one embodiment the surface of the granular urea is preheated and smoothed by superficial fusion and rolling in a rotary drum. Multiple, thin, concentrically formed layers of the fluid S then are applied by cascading the urea granules beneath a plurality of sequentially applied, closely controlled pneumatic sprays of the fluid S in the rotary drum. In a second embodiment, hydraulic spray nozzles are utilized in a manner wherein the requisite preheating is not required. Special operating conditions are specified which allow the production of a slow-release urea fertilizer coated only with S. Proper temperature control is maintained during the process to assure that the S solidifies in the proper crystalline structure to impart significantly improved tensile strength characteristics to the coating. Each embodiment has characteristically different operating conditions, specifically temperatures, which result in decisively different coating characteristics.

8 Method and Apparatus for Applying Coatings to Solid Particles. G. M. Blouin (to Tennessee Valley Authority). *U.S. Patent Office Defensive Publication* T927,005, Oct. 1, 1974. Appl. July 24, 1973; 26 pp. An apparatus and a process are described for [illegible] effectively coating materials for granulation as well as controlled release. Specific applications are directed to S-coated urea. The primary object is to provide random motion of the particles with respect to each other, thereby producing a truly homogeneous moving mass of particles in a simple, conventional horizontal rotary drum to ensure that all particles are equally exposed to a liquor or molten spray material as they pass through the drum regardless of range of size or shape. This is accomplished by a unique modification of the existing prior art of flighted horizontal rotary drum coolers and driers. An enlarged sprayable area of moving particles is produced and consists of the surface of the natural rolling bed and a falling cascade of moving particles concentrated to one side of the drum into a dense, homogeneous, narrow stream of particles that covers only 1-10% of the cross-sectional area of the drum. This continuous cascade is formed by positioning, by means of fixed supports extended into the end openings of the drum, a stationary longitudinal deflector pan above the rolling bed in the interior of the drum. The deflector pan extends the length of the drum and is sloped downward across its width toward the high edge of the rolling bed so that showers of particles being discharged by the lifting flights are caught by the deflector pan, the effective horizontally projected width of which may be 40-80% of the drum diameter, where they combine and slide off the lower edge of the pan to form the dense, homogeneous cascade that strikes the rolling bed near its high side and along its entire length.

9 Method for Applying Coatings to Solid Particles. G. M. Blouin (to Tennessee Valley Authority). *U.S.* 3,991,225, Nov. 9, 1976. Appl. July 24, 1973; 10 pp. Division of U.S. 3,877,415 and continuation-in-part *U.S. Patent Office Defensive Publication* T927,005. A process is described for the formation of coated rounded particles of substantially uniform size. Material to be coated is introduced into the inlet end of a rotating drum maintained in a generally horizontal position in which a bed of rolling discrete nuclei particles of the substance to be coated are in contact with each other. The rotating drum has lifting flights on the inner surface acting to elevate portions of the bed from the bottom to a higher point therein. The elevated portions of the bed on the lifting flights are released and cascade onto substantially the full upper surface of a deflector which is fixed in space in the upper hemispherical section of the drum and extends substantially therethroughout. It comprises two generally horizontally inclined planes defining a generally inverted V configuration, moving the particles away from the apex of the inverted V and toward each of the two bottom edges. Each edge juxtaposed a sidewall of the drum wherefrom the particles free-fall back to the bed of nuclei juxtaposed the bottom of the chamber. Localized portions of the particles are sprayed after their release from the bottom edges of the inclined planes, thereby ensuring that at least a portion of the coating material so sprayed is directed upon a dense cascade of particles which are substantially homogeneous in particle size. At least a portion of the resulting spray-coated particles is removed from the outlet end of the drum. The process ensures that the localized portion of particles, which is sprayed to effect coating, is substantially homogeneous in particle size, thereby effecting substantially uniform coatings on each particle released from the lifting flights. In examples of coating granular urea with molten S, the use of this process and apparatus resulted in a 100% increase in capacity over equipment that did not include the cascading apparatus.

10 Apparatus for Applying Coatings to Solid Particles. G. M. Blouin (to Tennessee Valley Authority). *U.S.* 3,877,415, Apr. 15, 1975. Appl. Feb. 1, 1971; 10 pp. Continuation-in-part *U.S. Patent Office Defensive Publication* T927,005. An apparatus is described which provides a homogeneous (with respect to particle size), dense, mass of sized particles in random motion so that highly uniform coatings of the same or of different solids can be applied to each particle by conventional spray-coating with the liquified coating material(s). The apparatus is a horizontal rotary drum containing lifting flights. A novel deflector pan is fixed in space inside the upper section of the drum which deflects particles falling from the lifting flights to the side of the drum where they form a narrow, dense falling cascade. The coating material is sprayed onto the cascading particles, preferably as they free-fall after leaving the lower edge of the pan. If desired, some or most of the coating material may be directed onto the top edge of the moving bed including the juncture of the cascade therewith. In examples of coating granular urea with molten S,

the use of this cascading apparatus resulted in a more uniform and effective coating of S and increased the capacity by 100% over equipment that did not include the cascade apparatus.

11 Sulfur-Coated Urea, Technical Update. Fred Myers, D. A. Russel, and R. D. Young (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Muscle Shoals, Alabama: TVA, National Fertilizer Development Center,* Circular No. Z-2-102; 4 pp (Dec. 1979). The basic S-coating process involves precision application of three coatings to urea granules (1) S, which is the basic coating material; (2) a wax-like sealant, which provides a moisture barrier; and (3) conditioner, which absorbs excess sealant and gives the product good handling and storage characteristics. Urea granules (-6 + 10 mesh) are preheated in a fluidized bed unit and pass through a rotating drum where flights lift the warm granules from the bed of material and drop them onto a tilted collecting pan. When granules roll off the pan they strike a deflector plate which forms then into a thin vertical curtain onto which molten S is sprayed. This "falling curtain" arrangement minimizes segregation and provides fast movement of the granules for efficient, uniform coating. The granules discharge into a revolving drum into which is sprayed a mixture of molten polyethylene and oil. The granules are cooled and conveyed to another drum where they are coated with diatomaceous earth. Sulfur-coated urea fulfills the objectives of a controlled-release N fertilizer which are: (1) increasing efficiency of fertilizer use, (2) reducing nutrient losses, (3) reducing toxicity, (4) reducing application frequency; and (5) satisfying S requirements. Agronomic test results for various crops are given.

12 Sulfur-Coated Urea: TVA's New Pilot Plant. *Sulfur Inst. J. 8* (4), 6-8 (Fall 1972). For several yr, TVA has studied the encapsulation of soluble fertilizer granules and prills to impart controlled-release properties to them. Following extensive bench-scale work, a small-scale pilot plant was built and demonstrated in 1968 and 1970. A new pilot plant was constructed in 1971 with a design production capacity of 1 ton/hr. It has been operated to obtain process data, to identify and optimize process variables, to obtain scaleup information for design of a larger plant, and to provide material for agronomic testing. A flowsheet of the sulfur-coating process is given and the equipment is described in detail.

13 TVA Sulfur-Coated Urea—Its Pilot-Plant Development and Scope of Agronomic Testing. A. R. Shirley, Jr. and R. B. Diamond (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 155 (1974). Sulfur-coated ureas produced in TVA's pilot plant at rates from 1 to 2 tons/hr have been tested in 48 states and 42 foreign countries. The products have various slow-release characteristics and have demonstrated the following advantages in comparison to single applications of soluble fertilizer reduced leaching losses, less excessive consumption, reduced burning, and a longer-lasting effect. Volatilization losses are much lower in comparison to straight urea. Urea particles are preheated in a rotary drum and fed to a second drum where multiple thin, concentrically formed layers of sulfur are applied. The molten sulfur is sprayed onto the granules by high-pressure hydraulic atomizing nozzles oriented to spray the sulfur on a falling curtain of particles. Operating conditions are maintained such that the sulfur coats the particles with uniformity and solidifies with the desired physical characteristics. Sulfur-coated granules are fed to another rotary drum where a petroleum base seal coating is sprayed onto them. They are subsequently quick cooled in a fluid bed cooler and lightly dusted with conditioner. Storage and handling properties of sulfur-coated urea are excellent.

14 Sulfur-Coated Urea From a One-Ton-Per-Hour Pilot Plant. A. R. Shirley, Jr. and R. S. Meline (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *New Uses of Sulfur Advances in Chemistry Series,* No. 140, *Washington D.C.: Am. Chem. Soc.;* pp. 33-54 (1975). Molten S is applied to urea granules by either pneumatic or high-pressure hydraulic atomizing spray nozzles to prepare a controlled-release fertilizer containing 37-40% N. In a continuous process, urea particles are preheated in a rotary drum. Multiple, thin, concentrically formed layers of S are applied in a second rotary drum. Wax is applied in a third drum to seal minute imperfections in the S coating. The granules are quick-cooled in a fluid bed cooler and lightly dusted with conditioner. Operating conditions and processing temperatures depend on the S atomization process. Some major advantages of hydraulic spraying include an up to 98% decrease in S dust and mist in the S-coating drum and doubled plant production capacity. Sulfur-coated urea is being tested in 50 states and 54 countries and shows significant advantages with several crops.

15 Experience of Tennessee Valley Authority with Sulfur-Coated Urea and Other Controlled-Release Fertilizers. F. O. Huffman, A. R. Shirley, Jr., G. M. Blouin, and B. P. Dana (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Muscle Shoals, Alabama: TVA, National Fertilizer Development Center,* Circular Z-59; 8 pp. (Aug. 1975). In early searches for a controlled-release N fertilizer, the potential of many N compounds were explored. The few compounds exhibiting the desired dissolution characteristics proved too costly or otherwise unsuitable for agricultural use. A study of control of the rate of nutrient release by application of coatings to fertilizer granules led to the selection of S as the least expensive coating agent with the potential for control of the rate of N release from urea. A process for coating urea granules with S has been developed through the pilot-plant stage. Preheated urea granules are sprayed with molten S as they fall from special flight arrangements in a rotary drum. In another rotating drum, the S-coated granules are sprayed with a wax to seal flaws in the coating. The material is then cooled to 43° in a fluidized-bed apparatus. In a third drum, the cooled material is conditioned with diatomaceous earth to prevent caking and to make the granules sink when placed in H_2O, as in flooded rice culture. The usual product contains 15-19% of S, 2% of sealant, and 2.5-3% of conditioning agent. Process variables are discussed, and optimum operating conditions are presented. Production cost for granular S-coated urea (SCU) is estimated to be about one-third more per ton of N than for uncoated urea; the cost for coating the smaller prilled urea is somewhat higher because more S is required. In many agricultural situations, the S in itself is a needed addition to the soil. Agricultural evaluations show favorable benefit-to-cost ratios for SCU on rice under delayed and intermittent flooding, pineapple, sugarcane, fruits, and vegetables on sandy soils, turf, and forage crops. An analysis of the market potential for SCU favors its commercial production. TVA will soon begin construction of a plant to produce 200 mt/day of SCU.

16 Sulfur-Coated Urea Fertilizer and Method of Making. A.

W. Green (to Mississippi Chemical Corp.). *U.S.* 3,313,613, Apr. 11, 1967, Appl. Feb. 27, 1964; 4 pp. Elemental S is combined with urea to produce a stable, uniform, free-flowing mixture in which the S has substantially greater exposed surface area than the urea. Finely powdered S (< 200 mesh) is moistened with formaldehyde and mixed with solid urea prills or granules to form a uniform blend of S particles adhering to the urea particles. The amount of formaldehyde is ~ 4-15 (preferably ~ 7-12) % of the S wt and the S wt is ~ 2-30 (preferably ~ 4-15) % of the urea wt. A fertilizer composition is formed consisting on a dry wt basis of ~ 75-95% urea, ~ 22-4% elemental S, and ~ 3-0.2% formaldehyde.

17 Sulfur Encapsulated Fertilizer Pellets. Thiokol Chemical Corp. *Brit.* 1,171,255, No. 19, 1969, U.S. Appl. July 24, 1967; 17 pp. Fertilizer pellets are subcoated with a finely divided (< 0.1 micron) powder, such as C black or coal dust, then with molten elemental S. A hydrophobic sealant, such as 0.1-5.0% wt of soft wax, may be added on the surface. For example, 1600 g spheroidized (6-10 mesh) urea was mixed 30 minutes with 8 g C black. A 50-g portion, in a rotary pan at 95°, was sprayed with 3 g molton S containing 5% wt of polysulfide plasticizer. The bed temperature was dropped to 90° and 0.6 g soft wax was added. The 24-hr dissolution rate of the coated pellets was 12%. The product is useful as a slow-release N fertilizer.

18 Sulfur-Coated Urea. Robert Powell. In *Urea Process Technology, Park Ridge, New Jersey: Noyes Development Corp.* pp. 315-16 (1968). The effectiveness of S as a coating agent can be enhanced by the addition of a S-plasticizing agent thereto prior to coating the fertilizer granules. Conventional S-plasticizing agents such as polymerized vinyl mercaptans and polysulfite compounds are suitable for this purpose. The plasticized sulfur coating produces sulfur-coated fertilizer granules that are more resistant to attrition or damage during manufacture, storage, and handling.

19 Sulfur Coating. Robert Powell. In *Controlled Release Fertilizers 1968, Park Ridge, New Jersey: Noyes Development Corp.*, pp. 183-98 (1968). Variables that have significant effects upon the sulfur-coating efficiency are molten S temperature, temperature of atomizing air to the spray head, pellet temperature, pressure of air at sprayer, coarseness of S spray, and distance of spray nozzle from moving bed of pellets. The temperature and coarseness of the S spray at the time of contacting the particles appear to be the most important factors. The use of 2 to 10% by wt of plasticizers, finely powdered inert solids, or of 1 to 30% of one or more of the finely divided micronutrient compounds in the S significantly improves the coatings. This improves the spreading and fusing of the individual droplets of S and reduces the degree of crack formation in the sulfur shell.

20 Sulfur Slow-Release Nitrogen. A. V. Slack. In *Fertilizer Developments and Trends 1968, Park Ridge, New Jersey: Noyes Development Corp.* pp. 164-5 (1968). Sulfur is of interest as a coating for N-containing fertilizer, such as urea, because it can be applied conveniently as a melt, the cost is relatively low, and it is a secondary plant nutrient. Neither S alone or with a petroleum oil applied to the S coat to seal cracks and pores were effective in soil burial tests. A sealant was identified that resisted soil effects. Plasticizers were tested but were less effective. Tests made in a rotary drum to give a tumbling bed of granules against which molten S was sprayed resulted in improvement of coating effectiveness. A 26% coating on urea gave a dissolution of ~ 2% during a 30-day burial test. Improvement was obtained by including a small amount of a microbicide, such as coal tar oil or pentachlorophenol, in the coating to inhibit attack from soil organisms. Urea with ~ a 20% coating, containing a microbicide resisted dissolution in the soil for 42 days.

21 Nitrogen Production and Use. John Pesek, George Stanford, and N. L. Case. In *Fertilizer Technology and Use, 2nd Edition.* Editors, R. A. Olson *et al. Madison, Wisconsin: Soil Sci. Soc. Am., Inc.*; p 231 (1971). A slow-release N fertilizer may be prepared by coating granular or prilled urea with S and a sealant wax. The addition of 0.5% coal tar or pentachlorophenol to the sealant wax apparently retards degradation of the coating by soil microorganisms and results in a product with an even slower N release. Solid urea is preheated to 65-70°, molten S at 143° is atomized and sprayed onto the urea in a tumbler, followed by a spray of the molten wax-microbiocide or mixture. Heated air flowing through the tumbler keeps the urea temperature high in order to give a uniform coating. The coated material is then cooled and coated with clay to give a finished product containing urea, 76; S, 19; wax, 3; coal tar, 0.5; and clay, 1.5%. The N content is ~ 35%.

22 Coating Fertilizers with Sulfur to Control Dissolution. P. S. Fleming (to Thiokol Chemical Corp.). *U.S.* 3,576,613, Apr. 27, 1971, Appl. July 24, 1967; 14 pp. In using a spray of molten S to produce a coating on fertilizer granules, the S solidifies to form a semipermeable shell having low impact strength. Unless the surface is completely covered with S the substrate will dissolve quickly in water. Because molten S does not easily "wet" the surface of most fertilizer granules, a relatively heavy coating is required to obtain a suitable barrier for slow dissolution. This problem is solved by first dusting the uncoated granules with 0.2-3% of a powdered material such as carbon black, Zn borate, carbonate, chromate, or sulfide, Mg hydroxide or silicate, and other compounds. The powder coating decreases the contact angle between the granule and the molten S which makes possible the production of satisfactory coatings of S using much less S, namely 5-10%. Examples (7) describe the application of S coatings to commercial granular urea, 29-14-0, 20-10-10, and 18-46-0. Data from agronomic tests are included.

23 Controlled Release Fertilizer. K. E. Fersch and W. E. Stearns (to The O. M. Scott & Sons Co.). *U.S.* 4,042,366, Aug. 16, 1977, Appl. Apr. 5, 1976; 7 pp. A controlled release fertilizer composition in particulate form is described. Each particle comprises a core of H_2O soluble N nutrient, preferably urea, with a 5-40 wt % S coating which has an additional coating of microcrystalline wax. The inner portion of the wax coating is free of H_2O soluble additives and completely covers the S coating to form a H_2O barrier between the S coating and the outer portion of the wax coating. The outer portion of the wax coating contains at least one H_2O soluble P or K salt embedded therein and the wt ratio of the inner wax coating:outer organic coating is between 0.2:1 and 4:1. The additive has a particle size of 325 to 30 mesh, preferably 200 to 65 mesh, and the wt ratio of additive:total wax is < 8.1. The wax has a melting point of 55-85°, a needle penetration at 25° of 10-30, and a viscosity at 99° of 50-125 Saybolt Universal seconds.

24 Coating Fertilizer Granules with Supplemental Materials. J. T. Dilday (to Olin Corp.). *U.S.* 3,580,715, May 25, 1971, Appl. Apr. 16, 1969; 3 pp. Tenaceous coatings of S, micronutrients, or pesticides are produced on fertilizer granules by applying 0.5-5% mineral oil until the granules are uniformly coated. Then 0.1-5% calcium lignosulfonate is applied as aqueous solution followed by application of the powdered supplement. For example, 25-lb urea prills were tumbled in a cement mixer while adding 1% used motor oil. After tumbling the mixture for 1.5 min, 1% of an aqueous 50% calcium lignosulfonate solution was added, followed by adding 10% -325 mesh S. All the S adhered to the prills and, on screening, less than 1% of the S was shaken off.

25 Coated Fertilizer. J. T. Dilday. *U.S.* 3,697,245, Oct. 10, 1972, Appl. Aug. 12, 1970; 3 pp. Tenacious coatings of supplemental materials are applied to granular fertilizers in motion by adding in order 0.5-5% of a mineral oil, 0.1-0.5% of Ca lignosulfonate as an aqueous 50% solution, and 1-20% of the supplemental material as fine particles passing through a 200 mesh screen. The granules are maintained in motion during and after each addition until the supplemental material is uniformly coated on the granules. In an example, 1760 lb of urea prills were tumbled in a cement mixer while adding 20 lb of used motor oil. After tumbling for 1.5 minute, 20 lb of an aqueous 50% solution of Ca lignosulfonate was added and tumbling was continued for 1 minute. Then 200 lb of elemental S, 98% of which passed through a 325 mesh screen, was added with additional tumbling for 2 minutes. The product, containing N 40.5 and S 10%, was bagged and stacked 10 bags deep in warehouse storage; after 3 months, the product remained completely free-flowing.

26 Production, Marketing, and Use of Sulfur Products. J. D. Beaton and R. L. Fox. In *Fertilizer Technology and Use, 2nd Edition.* R. A. Olson *et al*, Editors. *Madison, Wisconsin: Soil Sci. Soc. Am., Inc.* pp. 342-3 (1971). Sulfur-coated urea (SCU) has been produced on a pilot-plant scale at TVA. The basic process involves the formation of a S shell around each urea particle by spraying atomized molten S on a rolling bed of urea particles and then adding a light coating of a petroleum wax (also applied in the molten state) to seal the microscopic pores and cracks in the S coatings. The wax contains a small amount of microbicide to prevent its being attacked by soil microbes. Finally, a small amount of conditioner is added to give good product handling characteristics. The analysis of a typical SCU product is 35% N, 19% S, 3% wax, 0.5% microbicide (coal tar), and 1.5% conditioner. Details of the pilot-plant process are given. Also, a brief description of field tests results and economics of the product are presented.

27 Technology of Sulfur Containing Fertilizers. A. G. Briones (Union Explos. Rio Tinto S. A., Madrid, Spain). In *Use Sulphur Containing Products Agric., Proc. Symp.* (held Seville, Spain, May 17-18, 1978). *London, England: Sulphur Inst.*, pp. 76-85 (1978). Production technology of K_2SO_4, $(NH_4)_2SO_4$ and S-coated urea is discussed briefly. Potassium sulfate is prepared by the reaction of KCl and H_2SO_4 or by reaction of KCl, SO_2, and O_2. The latter saves production costs of H_2SO_4, uses polluting excesses of SO_2, and saves heating costs since the reaction is exothermic. Ammonium sulfate is a residual product of various manufacturing processes. It can be granulated for use in bulk blending. The TVA and spouted bed processes for production of S-coated urea are described (11 ref, 6 fig).

28 Production of Sulfur-Coated Urea by the Spouted Bed Process. A. Meisen and K. B. Mathur (Univ. British Columbia, Vancouver, B.C., Canada). In *Products Techniques Plant Nutrient Efficiency, London, England: British Sulphur Corp. Proc. 2nd Int. Conf. Fert.* Paper No. XIV; 1-18 (1978). A process for manufacturing S-coated urea in a spouted bed has been developed and tested in batch operation in a small-scale pilot unit (0.15 m diameter, 0.90 m high). The results of the pilot plant tests have been interpreted with the aid of a mathematical model. The dependence of the product quality on urea pretreatment, coating temperature, S feed rate and product cooling, and the effects of certain additives for strengthening the S coat have been examined. Preliminary product field tests have been conducted in the Vancouver area. The mathematical model has been used to develop designs for two commerical-size units producing 0.25 and 5 mt/hr of S-coated urea (containing 25 wt-% S). Their economic, operational, and environmental aspects have been assessed. Present indications are that the spouted bed process compares favorably with the rotary drum process developed by the Tennessee Valley Authority (10 ref).

29 Research and Development of Slow-Release Fertilizers. Ching-Tsun Chiang (Taiwan Fertilizer Company, Taipei, Taiwan, Republic of China). *J. Agric. Assoc. China*, No. 113; 11-21 (Mar. 1981) (Ch). Fertilizers that release the plant nutrients slowly throughout the growing season continue to attract the attention of agronomists. Potential advantages include: increased efficiency of uptake by plants; minimizing leaching, runoff, denitrification, and volatilization losses; decreased cost of application due to fewer applications; elimination of luxury consumption; avoidance of fertilizer injury to the vegetation or seedlings; and prevention of environmental pollution, such as ground water, streams, and lakes. Research and development on slow-release fertilizers are in three broad categories: (1) the chemical synthesis of compounds with desired solubility characteristics (UF, IBDU, CDU, GU, potassium silicate, potassium metaphosphate, MAP), however, the relative high cost of these products tends to limit their consumption to special uses. (2) Through coating of impermeable (Osmocote, Nutricote, CSR) or semipermeable (SCU, sulfur-coated KCl, sulfur-coated compound fertilizer, supergranule fertilizer) membrane or mixing with sparingly soluble or insolube compounds as a matrix, which will delay the rate of release by a physical barrier. There has been a surge of research activity on these coated fertilizers. (3) Biological approaching by chemical additives (nitrification inhibitors, microbicides, metabolic inhibitors), to prevent their mineralization, and thus to provide an effective method for controlling or delaying their nutrient release. Many slow-release fertilizers will not satisfy the requirements for all cropping situations, but coating may be approaching this goal. Research and development work has been shifted to the application of coatings to conventional soluble fertilizer granules. The advantage of coating fertilizers with slowly soluble material is that the low-cost and readily available fertilizers can be used.

30 Statistical Evaluation of Thermally Modified Sulfur as a Coating Agent for Urea Granules. K. R. Waerstad and G. H. McClellan (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *J. Agric. Food Chem. 28* (5), 1000-3 (Sept.-Oct. 1980). The recently developed technology of using S as an effective coating material for fertilizers to provide controlled release of the plant nutrients represents a potentially large-scale commercial use of the element. Because S is

needed in only small amounts as a plant nutrient, ways to reduce the total coating wt in production of slow-release fertilizers are of interest. The effect of heat treatment as a method to modify the properties of commercial-grade S are evaluated. Particular interest is focused on the effect of thermally induced changes in the S on the dissolution rates of S-coated urea (SCU) granules.

CHEMICAL AND PHYSICAL CHARACTERISTICS

31 Characterization of Sulfur Coatings on Urea. G. H. McClellan and R. M. Scheib (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Sulphur Inst. J.* 9 (3-4), 8-12 (Fall-Winter 1973). Textural and solid-state characteristics of S coatings on urea were investigated in laboratory studies to identify factors that control the physical characteristics of the coatings and how these characteristics affect the dissolution mechanism of S-coated urea as a controlled-release N fertilizer. Scanning electron microscopy and supplemental examinations by optical microscopy and x-ray diffraction techniques were used to obtain complete characterization. The effects of coating uniformity, thickness, and texture; bonding of S to the urea surface; particulate conditioners on the urea, types of defects in the S coatings; and the function of the wax sealant were evaluated in products prepared in TVA pilot plants. Comprehensive details of the coating structure and the effects of dissolution on this structure are shown in 20 photomicrographs.

32 Texture of Sulfur Coatings on Urea. G. H. McClellan and R. M. Scheib (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *New Uses of Sulfur, Advances in Chemistry Series*, No. 140, *Washington, DC: Am. Chem. Soc.*; pp. 18-32 (1975). A study using a scanning electron microscope shows that pressure- and air-sprayed S coatings, applied to control the release rate of urea as a N fertilizer, are mixtures of orthorhombic and polymeric S. The observed S textures vary with the thermal history of the coatings and can be correlated with the performance of the product as a controlled-release N fertilizer. The satisfactory performance of some S coatings and the unsatisfactory performance of others are related to the presence of desirable S textures and the absence of controllable defects. The principal mechanism of controlled N release is through pores in the coatings. Sealants can minimize the effects of coating defects.

33 Characteristics of Sulfur Texture on Sulfur-Coated Urea. R. M. Scheib and G. H. McClellan (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Sulphur Inst. J.* 12 (1), 2-5 (Spring 1976). The texture of S coatings applied by pressure atomization to urea granules was studied by scanning electron microscopy. The effects of varying temperatures of S application and cooling rates of the coated products were studied also. Sulfur coatings formed by hydraulic spraying have a mosaic texture of crystalline and amorphous S somewhat similar to that of air-sprayed products. The main differences are that pressure spraying causes more variation in the textures observed and the polymeric S appears to be somewhat less elastic. The main variables affecting the texture of the coatings seem to be the temperature of S application and the rate of cooling the coated product. Slow release mechanisms of the pressure-sprayed coating seem to be the same as those of the air-sprayed coatings; pinhole capillary pores appear to be the principal path for release of urea from well-coated products.

34 Rapid Method for Determining Dissolution Rates of Controlled Release Fertilizer Materials. R. M. Scheib and G. H. McClellan (to Tennessee Valley Authority). *U.S. Patent Office Defensive Publication* T952,001, Nov. 2, 1976, Appl. Feb. 17, 1976; 14 pp. A rapid quality control method is described for determining the long-term release rate of controlled release fertilizer material. The accepted industry method for testing S-coated urea (SCU) is the 7-day release rate test. The instant method was developed to give a release rate which correlated with the 7-day release rate test: 50 g of freshly prepared SCU is put in a cylindrical vessel of ~ 50 mm diameter, ~ 80 mm height and having a hemispherical bottom with 100.0 mL of H_2O. The tip of a probe-type ultrasonic generator is immersed ~ 2-3 cm into the H_2O and offset from the vertical center line of the vessel about 10 mm. The slurry is subjected to 1.0 minute (0.5 to 2 minutes) of ultrasonic vibration at 20,000 Hz (10,000-100,000 Hz) at 200 watts; the slurry is then transferred to a 600-mL Erlenmeyer flask which is attached to a wrist action shaker such that the bottom half is submerged in a 70° (60-80°) H_2O bath and shaken for 10.0 minutes. The refractive index of a filtered portion of the slurry is determined; the urea released can be determined from an appropriately constructed graph or from the formula: $[(10649.863 - 16630.54622n_D + 6482.844917n_D^2)/(50 \% \text{ coating weight}/2)] \times 100 = \%$ urea released where n_D = refractive index of urea solution.

35 Quality Control Methods for Sulfur-Coated Urea Production. R. M. Scheib and G. H. McClellan (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Sulphur Inst. J.* 12 (2), 5-7 (Summer 1976). The development of methods for determining the total coating wt and the dissolution rate of sulfur-coated urea (SCU) that can be completed in ≤ 0.5 hr are described together with some results obtained from their application. Use of the microwave oven to rapidly dry coating residues from slurrying SCU samples in a high-speed blender greatly reduced the time required to determine the total coating wt. A rapid ultrasonic method involving the measurement of the refractive index of a filtered slurry of SCU is described for estimating the seven-day dissolution rate of freshly produced SCU.

36 Application of SEM to Chemical Fertilizers. R. M. Scheib and G. H. McClellan (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Scanning Electron Microscopy/1977 Vol. 1* (Proc. Workshop on Materials and Component Characterization/Quality Control with the SEM/STEM). *Chicago, Illinois: IIT Research Institute*; pp 147-54 (Mar. 1977). The scanning electron microscope (SEM) is used to evaluate chemical fertilizer products, byproducts, and processes. Urea-granule strength is correlated with the internal structure and texture of the particles. The SEM shows well-formed urea crystals at the contact zones and on the surface of caked urea granules. The crystals are formed by release of moisture from within the granules. The formulation mechanism of the coatings on sulfur-coated urea (SCU) fertilizer is accretion of individual S droplets from the spray application. A mosaic-like composite of crystalline S and polycatena S is formed on the urea surface; the composite texture is a function of S and substrate temperature and cooling rate. Urea is released from SCU through pinholes associated with voids in the S hulls formed during the coating process. Interpretation of reactions in various zones of a foam, wet-process H_3PO_4 pilot plant is aided by viewing the $CaSO_4 \cdot 0.5H_2O$ sampled from the reactor.

37 Influence of Nitrification Inhibitors and Slow-Release Nitrogen Materials on Transformations of Fertilizer Nitrogen in Soils of Fluctuating Moisture Content. Rajendra Prasad and G. B. Rajale (Indian Agr. Res. Inst., New Delhi, India). *Soil Biol. Biochem. 4* (4), 451-7 (Nov. 1972). A laboratory study was made of N transformations in a sandy clay loam given either urea with and without nitrification inhibitors or slow-release N fertilizers. Moisture conditions were field capacity, continuous flooding, and alternate flooding and drying. Urea N was mineralized and fairly well conserved in soil either at field capacity or under continuous flooding, but was rapidly lost under alternate flooding and drying. Denitrification losses were reduced with nitrification inhibitors. Oxamide, isobutylidene diurea, and S-coated urea were as effective as the inhibitors in reducing losses under alternate flooding and drying.

38 Effects of Temperature, Microbial Activity, Salinity, and pH on the Release of Nitrogen of Sulfur-Coated Urea. J. J. Oertli (Univ. California, Riverside). *Z. Pflanzenernaehr. Bodenk. 134* (3), 227-36 (1973). A series of laboratory experiments were conducted to evaluate the release characteristics of S-coated urea (SCU). Effects of temperature, microbial activity, and external solute concentration were studied on SCU containing 25.7% N, 40% S, and 40% wax. At 34° about 100 days were required to release all the N from a 10-g sample of SCU that had been placed in a 250-mL Erlenmeyer, eluted with 150 mL of a mixture of KH_2PO_4, $MgSO_4$, $CaCl_2$, and $FeSO_4$, and stirred continuously by a forced stream of air. At 14° complete release would require 5-6 yr. The release of urea and its hydrolysis to ammonium ions was strongly inhibited by the addition of thymol (sterile conditions) whereas inoculation with *Thiobacillus thiooxidans* increased the yield of urea at 34° and inhibited the hydrolysis of urea under all conditions. High product levels (urea, ammonium ions) had relatively small effects. High levels of urea tended to decrease the release of urea, and there appeared to be an optimum urea concentration at which rates of hydrolysis were at a maximum. Low pH values, produced by *T. thiooxidans*, were correlated with a strong inhibition of urea hydrolysis and often with an increase of N release. It was concluded that the sensitivity of the urea release to temperature could make it difficult to apply fertilizers that were sufficient but nontoxic under all conditions.

39 Gaseous Loss of Ammonia From Sulfur-Coated Urea, Ammonium Sulfate, and Urea Applied to Calcareous Soil (pH 7.3). M. Prasad (Caroni Res. Stn., Carapichaime, Trinidad, West Indies). *Soil Sci. Soc. Am. J. 40* (1), 130-4 (Jan.-Feb. 1976). Laboratory incubation experiments were conducted to study the comparative volatilization loss of NH_3 in a calcareous soil from S-coated urea (SCU) with fast (F), medium (M), and slow (S) dissolution rates, $(NH_4)_2SO_4$ (AS), and urea, at two temperatures 22 and 32°, and at three soil moisture levels 25, 50, and 80% of the water-holding capacity of the soil. The effect of the addition of organic amendment (filter press mud) to soil on NH_3 loss from these N-sources was also studied. Losses were studied up to 21 days. At both temperatures increasing soil moisture levels led to reduction of NH_3 loss regardless of the N-source, despite the fact that the soil analysis showed higher dissolution of N. Higher temperature increased the NH_3 losses. Losses usually followed the order of urea > AS > SCU(F) > SCU(M) > SCU(S). At 32° losses from uncoated urea as AS at low, medium, and high moisture were 20.6 and 16.7%; 14.5 and 13.1% and 8.4 and 6.6% of the N application rate, respectively. Losses from SCU(F) and SCU(M) varied from 7.0 and 5.4% at low moisture, 4.2 and 3.3% at medium moisture, and 2.4 and 1.9% at high moisture, of the N application rate, respectively. At 22° losses from uncoated urea and AS at low, medium, and high moisture were 11.1 and 10.2%, 7.7 and 8.8%, and 4.2 and 3.5% of the N application rate, respectively. Losses from SCU(F) and SCU(M) at three moisture levels were 2.9 and 1.9%, 1.4 and 0.8%, and 1.0 and 0.7% of the N application rate, respectively. Incorporation of filter press mud to the soil resulted in reduction of volatilization loss of NH_3 from all N-sources which was partly due to exchange reaction and biological immobilization of NH_4-N and partly due to reduction of urease activity.

40 Ammonia Volatilization and Nitrogen Utilization From Sulfur-Coated Ureas and Conventional Nitrogen Fertilizers. J. E. Matocha (Texas A&M Univ., College Station). *Soil Sci. Soc. Am. J. 40* (4), 597-601 (July-Aug. 1976). Ammonia volatilization was measured on acid and calcareous soils receiving S-coated ureas (SCU) and highly soluble N fertilizers. Surface and mixed applications of SCU-30 (30% dissolution rate), SCU-20 (20% dissolution rate), uncoated $(NH_2)_2CO$, NH_4NO_3, and $(NH_4)_2SO_4$ were made with and without lime to a fallowed acid fine sand. Without lime, top dressed NH_4NO_3, SCU-20, SCU-30, and $(NH_4)_2SO_4$ lost < 1% while $(NH_2)_2CO$ lost 18.5% of added N in 14 days. Topdressing lime with N caused more NH_3 loss from $(NH_4)_2SO_4$ than from $(NH_2)_2CO$ during the initial 48 hours. However, accumulative losses for 14 days were 51.5, 22.5, 9.0, and 1.7% from $(NH_2)_2CO$, $(NH_4)_2SO_4$, SCU-30, and SCU-20, respectively. Incorporating the lime with the soil prior to N addition reduced NH_3 loss > 50% as compared to surface application, but mixing N with the limed acid soil did not reduce NH_3-N losses. Mixing SCU with the soil appeared to increase release rate of N over topdressing, but this effect was not detected in plant response. Nitrogen uptake by corn (*Zea mays* L.) on the acid soil substantiated some of the conclusions regarding measured NH_3-N losses. Ammonia losses from N mixed with the finer textured calcareous clay loam were generally insignificant. Surface applied $(NH_2)_2CO$ and $(NH_4)_2SO_4$ lost significant amounts of NH_3-N, while losses from SCU and NH_4NO_3 were negligible.

41 Utility Studies on Controlled Release Nitrogenous Fertilizers and Nitrification Retarders in Maize. K.P.P. Nair and V. P. Sharma (Pant Univ. of Agriculture and Technology, Pantnagar, India). In *Comptes-Rendus, 4e Colloque International sur le Controle de l'Alimentation des Plantes Cultivees, Gent, September 1976, Vol. II* (A. Cottenie, editor). *Gent, Belgium: Rijksuniversiteit;* pp. 531-41 (1976?). *Soils Fert. 41*, 694. Sulfur-coated urea, shellac-coated urea, IBDU, and the nitrification inhibitors 2-amino-4-chloro-6-methylpyrimidine, and neem cake were tested in a pot experiment. *Nitrosomonas* activity was at a peak 22 days after sowing of maize, when all fertilizer was applied at sowing. *Nitrobacter* activity was at a peak about 6 weeks after fertilizer incorporation. Neem cake was effective when applied on an equivalent wt basis with urea. In field studies, application of neem cake gave increased grain yields.

42 Effect of Nitrate Inhibition and Slow Release Nitrogen Fertilizers on Nitrification Rates in Some Trinidad Soils. C. Shand and N. Ahmad (Univ. West Indies, St. Augustine, Trinidad, West Indies). *Trop. Agr. 51* (2), 167-78 (Apr. 1974). Nitrification of added N and its inhibition was studied on four

Trinidad soils. Nitrification of added N was evident and uniform on an alkaline soil regardless of N source, but was more pronounced in the case of three acid soils in the presence of moderate or high dressings of lime. Nitrite accumulated considerably in the presence of lime or where the N source elevated the soil pH. In one fine sandy loam soil (Las Lomas Fine Sandy Loam) in the presence of three N sources [urea, ammonium sulfate, and S-coated urea (SCU)], SCU nitrified best. The nitrification inhibitor 2-amino-4-chloro-6-methylpyrimidine (AM) retarded the production of NO_3-N with as low a concentration of 5 ppm AM on an alkaline soil, but its inhibitory effect was only observed on the three acid soils with urea as the source of N. The belief, that once nitrification is inhibited within a particular soil zone resumption of the process is quite slow, appears to be confined to very acid soils.

43 Mineralization of Urea and Urea Derivatives in Anaerobic Soils. M. S. Islam and J. W. Parsons (Bangladesh Agric. Univ., Mymensingh, Bangladesh). *Plant Soil 51* (3), 319-30 (1979). Urea, urea phosphate, and S-coated urea were hydrolyzed rapidly and, even at the highest level of application, had disappeared in just over 8 days. The presence of the phosphate anion depressed pH in the early stages. Hydrolysis of the less soluble organic derivatives of urea, isobutylidine diurea, ureaform, and glycoluril was very much slower and in the case of glycoluril a lag period of 8-16 days occurred before hydrolysis began. In the initial stages the system was anaerobic but between days 8 and 16 a change to partial aerobic conditions occurred. At this stage nitrification commenced and at day 16 nitrite was detected. Reduction of Fe(III) increased with time, reaching a maximum at day 32. More Fe(II) was produced in the presence of organic derivatives of urea than with the other fertilizers, possibly due to stabilization by organic ligands. From day 16 nitrification, denitrification, and reduction of Fe(III) proceeded together even through Eh values indicated that oxidation of Fe(II) would be expected. This did not occur until after day 32. Once nitrification began denitrification quickly followed so that for all six fertilizers, except at the highest level of application, virtually all the mineralized-N had been lost by denitrification at the end of the experiment.

44 Studies on the Mineralization of Urea, Coated Urea, and Nitrification Inhibitor Treated Urea in Soil. R.N.S. Reddy and R. Prasad (Indian Agric. Res. Inst., New Delhi, India). *J. Soil Sci. 26* (3), 304-12 (1975). A laboratory incubation study was conducted with a sandy clay loam soil (pH 7.8) at New Delhi to study the mineralization of urea, coated urea (sulfur-coated urea, shellac-coated urea), and urea treated with nitrification inhibitors (N-Serve, sulfathiazole), a general purpose microbicide (coal tar), and neem (a nonedible oil-seed) cake. Coated fertilizers mineralized much slower than urea; urea-N from these materials remaining in soil after 2 weeks of incubation being two to three times that from untreated urea. However, most N from coated fertilizers was mineralized after 4 weeks. Nitrification inhibitors were quite effective in retarding the nitrification of urea; N-serve being much more effective than sulfathiazole. Neem cake and coal tar extract were less effective than sulfathiazole in controlling nitrification of urea but they did retard it for 2 weeks.

45 Mineralization and Field Effectiveness of Ordinary and Coated Urea, Urea-Aldehyde Condensation Product, and Urea Treated with Nitrification Inhibitor. K.P.P. Nair and P. B. Sharma (G. B. Pant Univ. Agric. Technol., Pantnagar, India). *J. Agric. Sci. 93* (Pt. 3), 623-7 (Dec. 1979). A laboratory incubation study followed by a field experiment was made in a silty clay loam soil (pH 6.9) at Pantnagar, India, on the effectiveness of ordinary urea, coated urea (sulfur and shellac-coated), urea-isobutyraldehyde condensation product (isobutylidenediurea, IBDU), and urea blended with nitrification inhibitor AM (2-amino-4 chloro-6-methylpyrimidine) and neem (a nonedible oil seed obtained from *Azadirachta indica*) cake. Whereas untreated urea and IBDU hydrolyzed rapidly leaving no trace of urea-N after 2 weeks, sulfur-coated urea mineralized quite slowly and retained urea-N for as long as 4 weeks after incubation. Urea blended with neem cake was intermediate: Of all of the materials tested, sulfur-coated urea showed maximum nitrification inhibition. A combination of one third sulfur-coated urea at planting + two thirds ordinary urea 30 days later yielded 12.3% more maize grain than ordinary urea in the same proportion at the same times of application (12 ref).

46 Respiration and Nitrogen Immobilization in Forest Soil Treated with Sulfur and Urea. P. O. Salonius and M. K. Mahendrappa (Can. For. Serv., Fredericton, New Brunswick, Canada). *Soil Sci. 127* (6), 358-64 (June 1979). Respiration and N immobilization of the fresh organic layer of an acid podzol were studied, after pretreatment with S, to simulate S treatment of microsites when S-coated urea is applied to the soil. The laboratory incubations were done at 10 and 20° with several levels of urea application. Urea hydrolysis was slowed down considerably at 10° in materials that had been pretreated with S. Sulfur pretreatment modified the increase in pH and respiration caused by urea application but had little influence on the availability of NH_4-N. The lower temperature allowed adequate fertilizer N recovery from moderate application rates that produced a pH lower than neutrality. At the higher temperature, fertilizer N recoveries were very poor. At higher pH, a large part of the immobilization of N appears to be nonmicrobial (25 ref).

47 Mineralization of Slow-release Nitrogen Fertilizers at Varying Moisture Levels. G. B. Rajale and Rajendra Prasad (Indian Agr. Res. Inst., New Delhi, India). *Fert. News 15* (5), 38-9 (May 1970). The rate of mineralization of some slow-release N fertilizers was studied in the laboratory. A sandy clay-loam soil with a pH of 7.4 and organic C and total N content of 0.922 and 0.089% respectively was used. Soil with N fertilizers was incubated for 40 days in glass jars under field capacity moisture or waterlogged (2 cm standing H_2O) under laboratory conditions (minimum temperature 20 ± 1°, maximum temperature 36 ± 5°). At field capacity moisture conditions, the rate of mineralization was of the following order: oxamide isobutylidene diurea > S coated urea > N enriched coal. The fastest rate of the slow-release fertilizers was with oxamide with 67% mineralization after 40 days of incubation. The mineralization rate for the slow-release fertilizers was higher under water-logged conditions except with S coated urea where the reverse was the case.

48 Nitrogen Release Characteristics of Sulfur-Coated Urea. V. J. Kilmer (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1975 Annual Meetings* (held Knoxville, Tennessee, Aug. 24-30, 1975). *Madison, Wisconsin: Am. Soc. Agron.*; p. 173 (1975). A rapid release of the first increment of N from sulfur-coated urea (SCU) applied to moist, warm soil reflects coating

imperfections in the form of thin spots, cracks, and pin holes. The amount released in this fashion is generally 15% to 25% of the total, and N is supplied immediately to the plant. Subsequent N release depends upon coating thickness, uniformity, and composition, as well as temperature, moisture, and granule placement in the soil. Sulfur-coated urea releases N very slowly under warm, dry conditions, but N movement from the granule is accelerated under warm, moist conditions. Granules appear to be quite stable at soil temperatures ranging from 30 to 50°F. Coatings of FeS tend to form on SCU applied to flooded soils, resulting in a lower release rate of N. Sulfur-coated urea is more effective on intermittently flooded than on continuously flooded rice. One application of SCU may be as effective as several applications of a rapidly soluble N source during the growing season. To be economical, the extra cost of SCU material should not exceed the cost of multiple applications of uncoated urea.

49 Preliminary Evaluation of Agramid and Agroform as Fertilizers. W. Grzesiuk *et al* [Inst. Agric. Chem., Olsztyn (Kortono), Poland]. *Pol. J. Soil Sci. 10* (1), 79-85 (1977). Effectiveness of agramid (sulfur-coated urea) and agroform (urea-formaldehyde) was investigated in pot experiments over 2 yr. Nitrogen from these fertilizers was utilized mainly in the 1st yr, followed by lesser effects later. Agramid gave higher N utilization than did agroform. Fertilization effect of agramid was more favorable in nonacid soils.

50 Slow-Release Nitrogen Fertilizers. J. B. Porter (Texas A&M Univ., College Station). *Crops Soils 24* (2), 12-13 (Nov. 1971). Water-soluble N fertilizers are disadvantageous because of easy leaching of N, seedling and plant damage from too much soluble N luxury consumption, and, for some N sources, losses of N by volatilization. Controlled-release N fertilizers reduce these problems. TVA has done extensive research on developing controlled-release N fertilizers via a coating process. Urea has been more amenable to coatings with elemental S than other fertilizers.

51 Sulfur-Coated Fertilizers. In *Developments in Technology of Fertilizer Production, 4th Demonstration* (held TVA, National Fertilizer Development Center, Muscle Shoals, Alabama, Aug. 7-8, 1962). *Muscle Shoals, Alabama: TVA, National Fertilizer Development Center*; pp 43-4 (1962). One means of reducing or eliminating fertilizer loss or plant foliage damage when applying soluble fertilizer compounds, is to coat the individual granules with an insoluble or slow soluble material. Thus, immediate dissolution of the granule in the soil solution is prevented but the solution penetrates slowly to release soluble nutrient to the soil and plant at an adequate rate. Such a procedure might give other advantages also, such as improved physical condition and convenience in supplying secondary nutrients and micronutrients. Elemental S is an effective and economical coating agent and also is a secondary plant nutrient. The S has been applied by spraying either a liquid melt or a solution of S in liquid anhydrous NH_3 or CS_2 onto a bed of vigorously moving fertilizer granules in a small rotary drum. Best results were obtained when the spray was in the form of very small droplets. Sulfur coatings were applied to urea prills and to granules of KCl, NH_4NO_3, and ammonium nitrate sulfate. The degree of resistance to dissolution increased with the amount of coating. The dissolution of urea prills after 24 hr immersion in H_2O with 0-35 wt % S was 100-10 and 100-15 wt % when coated with CS_2-S solution and NH_3-S solution, respectively. Coatings applied as a molten spray have not been as effective as those applied as S solutions; however work is being continued on melt coatings. Greenhouse tests made with S-coated urea prills (30% S) indicated that the coating reduced toxicity at high application rates, reduced apparent gas losses in surface application, and extended the availability over a longer growing period in drilled placement at intermediate levels of applications.

52 Slow-Release and Amended Fertilizers. In *Fertilizer Technology and Use, 2nd Edition*, R. A. Olsen *et al*, Editors. *Madison, Wisconsin: Soil Sci. Soc. Am., Inc.*; pp. 458, 469-71, 475-6 (1971). Nitrogen release rates from SCU can be varied by controlling coating weights which range from 15 to 25% (plus about 5% sealant and conditioner) in the product containing 32 to 37% N. Release rates of N from sulfur-coated ureas (SCU) are determined by measuring either the decrease in particle weight or the amount of solubilized urea when weighed amounts of material are placed in water at 23 ± 2° or 37.5°. Thiokol and TVA methods, respectively, for time periods up to several weeks. Most SCU products contain about 10-15% imperfectly coated particles, from which nutrient rapidly diffuses. After the first 24-48 hr, release rates from single particles are approximately linear with time and may be as low as 1% of the contained urea per day for periods up to 100 days. Release rates are partly dependent on coating thickness and partly on the coating technique used even for particles with similar coating weights. Urea release from Thiokol products was found to be slightly greater in soils than in distilled water. Soil water content had little effect. Nutrient release was slightly faster in acid than in alkaline soils. Urea release from TVA sulfur-coated ureas was found temperature dependent, that is, dissolution from one product was complete within 6 weeks at 30° but almost nil at 10°. Sulfur coatings appear to be more stable in waterlogged than aerated soil systems. In waterlogged soils, particles of TVA sulfur-coated urea became coated with ferrous sulfide after 2-4 weeks. Drying the soil to about field capacity caused oxidation of this second coat. Reflooding the soil caused ferrous sulfide to again be formed, and this apparently sealed the particle surface so that little urea was subsequently released.

53 Effect of Coating Properties on the Nitrogen Release From Sulfur-Incapsulated Urea. J. J. Oertli (Dept. Soil Sci. Agr. Eng., Riverside, California). *Agrochimica 18* (1-2), 3-9 (1973). Nitrogen release characteristics from heavy-coated (40% S) and light-coated (13.5% S) urea fertilizer were studied in elution experiments. At 14 and 24°, N release from the heavy-coated materials was slower; at 34° the release was more equal for the two products. Inoculation with *Thiobacillus thiooxidans* stimulated N release from both fertilizers; sterile conditions produced by additions of thymol inhibited the release of N from both fertilizers. The rate of hydrolysis of urea to NH_4^+ was lower with the light-coated fertilizer, presumably because of a microbicide that had been added to the S coating by the manufacturer. Removal of the 4% wax from the heavy-coated fertilizer greatly enhanced the release of N. Soil microorganisms that utilize the wax as a substrate were isolated, but inoculation with these organisms failed to stimulate N release in elution experiments. Thus, release control can readily be modified by changing coating properties.

54 Behavior of Sulfur-Coated Urea in Soil Under Different Water Management. C. W. Hong and Y. J. Lee (Inst. Agric.

Sci., Suweon, Korea). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 150 (1974). Soil solutions collected from columns containing 200 g of water-logged soil which received 100 mg of N/100 g as standard urea or different grades (TVA grade C or E) or SCU were periodically analyzed. In urea treated soil, the N concentrations of the solution dropped sharply and remained at levels less than 10 ppm in later stages. In soils with SCU, the concentrations of N varied with time in the range of 50-100 ppm (within first 10 days), 20-30 ppm (after 20-50 days) and 50-150 ppm (after 50-90 days). Soils were kept in 200 mL polyethylene bottles under moistened conditions with 20% of water after they received 200 mg of N/100 g as urea or different grades (C or E) of SCU. Periodically collected soil samples were extracted with 10% NaCl solution to analyze NO_3^- and NH_4^+. In soils which received urea, the recovery of N markedly decreased with time indicating a loss of available N from the system. In soils with SCU, recovered N increased from 20 mg/100 g (after 7 days) to 70-110 mg/100 g (after 107 days). Under moistened soil conditions, the extracted N was dominated by NO_3^- in soils with urea, while in SCU systems the ratio of NO_3^-:NH_4^+ was nearly 1:1.

55 The Pattern of Nitrogen Release from Sulfur-Coated Urea. C. M. Hunt and S. E. Allen, (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 150 (1974). Soil columns 20 cm deep and containing 500 g of Lakeland sand were fertilized with sulfur-coated urea (SCU) and release of N was estimated by measuring nitrate in the leach water periodically for 18 weeks. Experimental variables included: (1) variations in SCU coating procedure, (2) presoaking the granules in H_2O to remove soluble N, (3) incubation at 25 or 37°, and (4) comparison of leaching with comparable cultures cropped with bermudagrass (*Cynodon dactylon* L.) clipped at 4-week intervals. Release of N was much more uniform from SCU sealed with microcrystalline wax than from SCU without wax. However, the amount of N remaining in undissolved granules after 18 weeks was greater from SCU without wax. Presoaking removed readily soluble N and resulted in a delay of N release to grass or leach water. Early release of N was greater at 37 than at 25°, while the pattern was reversed later. Recovery of N was more uniform and the total recovered was greater from leached than from comparable cropped cultures. The difference was attributed to incomplete dissolution of SCU, as well as accumulation of N in unharvested crop residues.

56 Mechanism of Release of Urea from Sulfur-Coated Urea (SCU). Isao Hashimoto and R. C. Mullins (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 149-50 (1974). The release of urea from individual SCU granules immersed in water was monitored by a colorimetric determination of dissolved urea at 2- to 3-day intervals, and the wt loss from a single granule suspended in water was continually recorded by means of Cahn electrobalance. Granules with imperfect coatings began losing urea immediately upon immersion, following essentially a theoretically predicted diffusion pattern: about 50% was lost at a constant rate and the remainder at a rate that diminished logarithmically. The time for complete dissolution ranged from a few days to several weeks. Some granules began releasing slowly only after many days of immersion. After a constant rate of release for some time, many granules showed a sudden large release of the remaining urea. The recovered sulfur shells invariably contained a crack. This release pattern, however, has not been reproduced on the electrobalance tracings. A third fraction of granules seemed to be so effectively coated that no measurable release occurred in 120 days.

57 Dissolution of Individual Granules of Sulfur-Coated Urea (SCU) in Soil. Isao Hashimoto and J. D. Hatfield (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1976 Annual Meetings* (held Houston, Texas, Nov. 28-Dec. 3, 1976). *Madison, Wisconsin: Am. Soc. Agron.;* p. 190 (1976). Soil columns containing a single granule of waxed sulfur-coated urea were leached with water at weekly intervals and the eluates were analyzed for urea, ammonium, and nitrate nitrogen. Simultaneous transformation and assimilation of the released urea and solubilization of the native N resulted in complex elution patterns. Over the 16-week test period, the dissolution behavior of twenty randomly selected granules could be divided into three categories: (1) the entire urea content of 13 of the granules was released in 7 to 10 weeks; (2) four of the granules released the urea slowly but somewhat steadily throughout the test period; and (3) three of the granules released very little urea in 16 weeks. The first group of granules probably would dominate the overall release pattern of this product. There was an incubation period of up to several weeks of relative inactivity that preceded the release of urea. The incubation period in soil was shorter than that observed in tests conducted in pure water. The soil leachates contained more nitrate than ammonium N and rarely contained significant amounts of urea.

58 Release of Nitrogen From Sulfur-Coated Urea as Affected by Soil Moisture, Coating Weight, and Method of Placement. M. Prasad (Caroni Res. Stn., Carapichaima, Trinidad, West Indies). *Soil Sci. Soc. Am. J. 40* (1), 134-6 (Jan.-Feb. 1976). Information on the release of N from S-coated urea (SCU) as affected by soil moisture in the aerated range is lacking. Laboratory incubation experiments were therefore conducted on two soils to study the release of N as affected by soil moisture in the aerated range, coating weight (SCU-28 and SCU-9), and method of placement (on one soil only). In the calcareous Princes Town soil the release of N from SCU increased with increasing moisture throughout the 9 weeks of study. In acid Talparo soil similar trends were present up to 3 weeks, but at 6 and 9 weeks maximum release of N occurred at medium moisture (soil moisture at pF 2.4) and minimum release at low moisture (soil moisture at pF 3.5). In Princes Town soil the difference in release of N from SCU-28 and SCU-9 (heavy coat) released more N at high moisture level (soil moisture at pF 1.0) than SCU-28 (light coat) at low moisture. In Talparo soil the effect of coating weight on the release of N at three moisture levels was considerably reduced from 6 weeks onwards. Ammonia volatilization losses were recorded only with Princes Town soil but they never exceeded 2.5% of the total N applied. The release of N from SCU was faster when the granules were mixed with the soil rather than surface applied. This difference between surface and mixed application was greater at high soil moisture levels.

59 Nitrogen Release From Granules of Sulfur-Coated Urea. W. M. Jarrell (Oregon State Univ., Corvallis). *Diss. Abstr. Int. B 37* (9), 4247 (Mar. 1977). Sulfur-coated urea (SCU) is a slow

release N fertilizer manufactured by the Tennessee Valley Authority. Urea granules are sprayed with molten S, then holes in the S coating are sealed with a layer of wax sealant. The S coatings are mixtures of amorphous and crystalline allotropes of S. Coating thickness varies over the surface of each granule. The distribution of coating thickness among granules in a given lot of SCU depends on the conditions under which it is manufactured. A model was constructed to predict the rate at which urea is released from SCU as a function of time. Theoretical equations were developed which predict that diffusion of urea through small holes in the coating occurs in two stages. The initial release rate was shown to be constant. After all the urea has dissolved, the rate of release decays exponentially. To test the theory, granules of SCU-31 were immersed in water and the rate of release of urea from these granules was measured for 70 days. It was found that the cumulative amount of urea released was an exponential function of time. Urea was released 1.25 times faster at 35° than at 5°, while the theory predicted that release should be 2.33 times faster at 35° than at 5°. The large variability in hole sizes among open granules may account for the difference between predicted release rates and those measured experimentally. Granules of SCU-31 which were alternately wetted and dried at 35° released more urea than granules which were constantly immersed. Granules in water, the temperature of which was varied between 5 and 35° each day, released urea at the same rate as samples maintained at constant temperature. To establish a relationship between the amount of coating removed and the fraction of granules which have been opened, granules were dipped in benzene for 1 to 10 minutes to remove portions of their coatings. The amount of coating removed was measured and the percentage of open granules was determined. Based on this experiment, SCU granules fall into three classes: (1) granules are initially open and release urea immediately upon exposure to water, (2) sealant must be removed from openings in the S shell before urea is released, and (3) S must be removed from the coatings before urea is released. The relationship between the amount of coating removed and the number of granules opened was linear for both Class 2 and Class 3 granules. A computer program was written which predicted the rate at which urea is released from SCU as a function of time. To test the accuracy of these predictions, release of urea from SCU-4, SCU-20, SCU-30, and SCU-23 was measured at the soil temperatures of 25 and 35° in soil at -0.3 bar soil water potential for 100 days. Release from SCU-4 was also measured at 5 and 15° and in soil at -15 bars soil water potential. The agreement between predicted and measured release indicated that, for the temperature and soil water conditions studied, the rate of release was accurately predicted using the computer program.

60 Nitrogen Release Characteristics of Controlled-Release Fertilizers During a Four-Month Soil Incubation. A. J. Patel and G. C. Sharma (Alabama A&M Univ., Normal). *J. Amer. Soc. Hort. Sci. 102* (3), 364-7 (May 1977). Fertilizers were mixed in Morrison sandy loam at 250 and 500 mg N/500 g soil. Columns were kept under uniform environmental conditions and eluted at 3, 5, 7, 14, 21, 28, 35, 49, 63, 77, 91, and 121 days to evaluate their N-release characteristics. During the first week, N leached ranged from a low of 2% for S-coated urea (SCU) to a high of 12% for $MgNH_4PO_4$ (MagAmp). Nitrogen released during the 17-week period in descending order was Precise (12N-2.6P-5.0K and 8-4.8-4.1), Osmocote (14-6.1-11.6 and 18-2.6-9.8), MagAmp (fine, 7-17.5-5), SCU (36-0-0, 26% N 1st week), Osmocote (18-2.2-9.1), SCU (36-0-0, 10% N 1st week), MagAmp (coarse, 7-17.5-5), Nitroform (38-0-0), IBDU (isobutylidene diurea) (31-0-0), Uramite (39-0-0), Agriform (14-1.7-5), and Agriform (20-4.4-4.1). The recovery of leached total N ranged from 77% for short to 13.5% for long-duration fertilizers for the 17 weeks.

61 Characterization of the Thickness and Uniformity of the Coatings of Sulfur-Coated Urea. W. M. Jarrell, G. S. Pettygrove, and L. Boersma (Oregon Agr. Exp. Stn., Corvallis). *Soil Sci. Soc. Am. J. 43* (3), 602-5 (May-June 1979). The objective of this study was to develop a test to predict the contribution of coating characteristics to the control of release rates of urea from SCU granules. Concentric layers of coating were removed in successive increments by dipping granules in benezene and determining at each step the percentage of granules rendered available to water penetration due to exposure of cracks or pinholes. Five SCU materials were used with a range of coating characteristics. For materials which were coated with both S and sealant, the results could be explained by postulating the existence of three classes of granules: Class I granules, which have unobstructed holes through the coating, Class II granules, with holes through the S coating which are plugged with sealant, and Class III granules, which have S coatings with no holes through them. Class I granules begin to release urea as soon as the sealant is broken down or removed, and Class III granules begin to release urea as soon as the S coating is penetrated by removal of parts of it (16 ref).

62 Dissolution of Sulfur-Coated Urea in Soil. I. Wax-Sealed Sulfur-Coated Urea. Isao Hashimoto and R. C. Mullins (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Soil Sci. Soc. Am. J. 43* (6), 1165-8 (Nov.-Dec. 1979). The release of urea from three wax-sealed, sulfur-coated urea (SCU) samples was tested. These samples were of nearly matched 7-day dissolution values but had different amounts of total coatings. Soil-SCU mixtures were incubated for varying times up to 18 weeks at different temperatures, pH (liming), and microbial (sucrose) levels. The release of urea from all samples increased markedly with increasing temperature but only slightly with increasing pH or microbial levels. Their time-release patterns were different in spite of their similar 7-day dissolution test values (11 ref).

63 Model for the Release of Urea by Granules of Sulfur-Coated Urea Applied to Soil. W. M. Jarrell and L. Boersma (Univ. California, Riverside). *Soil Sci. Soc. Am. J. 43* (5), 1044-50 (Sept.-Oct. 1979). The objective of this study was to develop and experimentally evaluate a mathematical model which makes it possible to forecast the release of urea from sulfur-coated urea (SCU) granules as a function of time. Equations were formulated to describe the rate at which soil microorganisms remove coatings from initially intact granules, the rate at which holes appear in the coatings as a consequence of this removal, the rate of diffusion of urea through these holes into the soil, and the effects of temperature and soil water content on each process. These equations were incorporated into a computer program which calculated the amount of urea released on consecutive days over periods as long as 120 days. The effects of temperature and soil water content on the growth and activity of microorganisms were formulated on the basis of literature data. Temperature corrections for the diffusion process were based on the temperature dependence of the solubility of urea and the diffusion coefficient. The model was validated by comparing predicted rates of release

with experimental results. The predictions made by using the model conformed with experimental results. The model calculations responded accurately to changes in temperature, soil water content, and differences in coating thickness and coating composition. The use of the model clearly points to the need for a more precise assessment of the factors which affect the release of urea from SCU granules (24 ref).

64 Release of Urea by Granules of Sulfur-Coated Urea. W. M. Jarrell and L. Boersma (Oregon State Univ., Corvallis). *Soil Sci. Soc. Am. J. 44* (2), 418-22 (Mar.-Apr. 1980). Urea diffuses through holes in the coatings of granules of sulfur-coated urea (SCU) into the surrounding soil. The ability to predict the rate at which urea is released from SCU granules aids in matching the slow release characteristics of the fertilizer to specific climatic and soil conditions. When openings are small and the concentration of urea immediately outside each opening is very low, a two-stage release pattern is proposed. During the initial stage, solid urea is dissolving and urea diffuses out of the granule at a constant rate. When all of the urea inside the granule has dissolved, the rate of release decreases logarithmically with time. The equations describing rates of release during the two stages are $dm_r/dt = (D/M_o)\ (A_p/\Delta x_p)C_{sat}$ for the constant rate period, and $dm_r/dt = (D/M_o)\ (A_p/\Delta x_p)\ (1\text{-}m_r)_p$ for falling rate period, where $m_r = m/M_o$ with m being the amount of urea released and M_o the amount of urea initially present in the granule, D is the diffusion coefficient, A_p is the cross sectional area of the pore through which diffusion occurs, Δx_p is the length of the pore, $_p$ is the density of urea, and C_{sat} is the solubility of urea. The diffusion coefficient D and the solubility of urea C_{sat} are temperature-dependent, according to $D = (5.55 \times 10^{-5})\ t\ \exp(-2135/T)$ cm^2/sec, and $c_{sat} = [(6.96 \times 10^{-3})\ T_c + 0.45]\ g/cm^3$, where T is absolute temperature and T_c is temperature in degrees centigrade. The temperature dependence of the release rate during the constant-rate period as determined by experiment agreed well with that predicted from theory. These equations may be used to predict the rate of release provided the physical properties of the given SCU are known (19 ref).

65 Sulfur Coated Urea. In *New Developments in Fertilizer Technology. 8th Demonstration* (held TVA, National Fertilizer Development Center, Muscle Shoals, Alabama, Oct. 6-7, 1970). *Muscle Shoals, Alabama: TVA, National Fertilizer Development Center*, Bull. Y-12 pp. 12-13 (1970). Greenhouse and laboratory studies show that release of N from S-coated urea (SCU) may be controlled by coating wt, placement, microbicides, time, and temperature. In the range 15-25% coating wt on granules of -6 +10 mesh, dissolution was more rapid with light coatings mixed with the soil and slowest with heavy coatings in surface placement. Addition of microbicides to the wax sealant further delayed release of N mixes with the soil, but had little effect on the dissolution of surface-placed granules. Tests conducted with soil in controlled environment regimes showed that SCU (20% coating wt) remained almost intact for 16 weeks at 10°, while dissolution was nearly complete in 5-8 weeks at 20° and 30°. Similarly, flooding the soil, as in the rice culture, very much decreased the rate of dissolution of SCU, as compared with its dissolution in well-aerated soil. Results from long range crops, such as sugarcane and pineapples, show potential for SCU in situations normally requiring several split applications of soluble N sources during growth cycles as long as 2 yr. Similarly, results suggest that SCU may be useful for paddy rice production, where nitrates are largely lost by denitrification following flooding. However, a lighter coating may be required since SCU products showing controlled-release properties in well-aerated soils tend to degrade too slowly in flooded soils.

66 Soil Moisture and Temperature Effects on Nitrogen Release from Sulfur-Coated Urea. G. S. Pettygrove *et al* (Oregon State Univ., Corvallis). In *Agronomy Abstracts 1976 Annual Meetings* (held Houston, Texas, Nov. 28-Dec. 3, 1976). *Madison, Wisconsin: Am. Soc. Agron.*, p. 192 (1976). Sulfur-coated urea (SCU 4 and SCU 31 with wax sealant) was surface-applied to Woodburn silt loam soil and incubated at 5, 15, 25, or 35°. Four samples of SCU at 25° were maintained isopiestically at water potentials of -3, -5, -7, -15, or -30 bars. Release of urea approached an asymptote of 70% of the total SCU 31 and 10% for SCU 4. The Q_{10} for this initial phase was 1.2 to 1.4 for SCU 31, consistent with a diffusion process. After 40 days at 25 and 35°, a second phase of release began at a steady rate of 0.8%/day for SCU 4, approaching another asymptote when about 60% of the total had been released. At 5 and 15° after 100 days the second phase had not begun. Percent cumulative release of urea from SCU 4 at 25° after 60 days at -3, -5, -7, -15, -30 bars, and in a moist, sterile SCU soil system was respectively: 53, 51, 43, 35, 16, and 17%. Alternative wetting and drying of soil appeared to result in slower N release than occurs in continually moist soil. The data suggest that SCU coatings are degraded by microorganisms which are temperature-sensitive and which maintain some activity at -15 bars water potential.

67 Release of Urea from Sulfur-Coated Urea: a Model. W. M. Jarrell *et al* (Oregon State Univ., Corvallis). In *Agronomy Abstracts 1976 Annual Meetings* (held Houston, Texas, Nov. 28-Dec. 3, 1976). *Madison, Wisconsin: Am. Soc. Agron.*; p. 191 (1976). A mathematical model is proposed which predicts the release of urea from a given sulfur-coated urea product (SCU) as a function of time. The model describes the rate of breakdown of the coating by microorganisms in the soil. This breakdown rate is determined by the nature and thickness of the coating and factors which control the rate of growth and activity of microorganisms. Important among these factors are soil temperature and soil water content. Experiments were conducted to establish the relationship between the percentage of granules opened in a given lot of SCU and the amount of coating removed. This relationship, used in combination with mathematical expressions for the rate of growth and activity of microorganisms as functions of temperature and water potential, allows the prediction of the release of urea by SCU granules as a function of time. The model was validated by comparing the rate of release from SCU products applied to the soil under controlled temperature and water content conditions with predicted release curves.

68 Evaluation of Potting Media for Commercial Nursery Production of Container Grown Plants. V. Patterns of Release of Nitrogen Fertilizers in Different Media. K. M. Goh (Lincoln Coll., Canterbury, New Zealand). *N. Z. J. Agric. Res. 22* (1), 163-72 (1979). Release patterns of total N, ammonium-N, nitrate-N, urea-N, and organic-N from two rapid-release (urea and nitrolime), three synthetic (osmocote, S-coated urea, IBDU or isobutylidenediurea), and one natural slow-release fertilizers (poultry manure) in five nursery media (peat, sand, peat-sand, peat-sand-sawdust, peat-sand-soil) were determined over a period of 14 weeks using leaching columns. The N from urea and nitrolime was recovered almost completely (83-100%) in the first two leachates. However, with slow-release

fertilizers, rates of release of total-N and various N forms varied accordingly to the media used. About 30-75% of the N was released over a period of 7-10 weeks. Urea-N, when present, was released first followed by ammonium-N and nitrate-N. The contribution from organic-N form was generally insignificant and inconsistent. The significance of the results is discussed in relationship to changes that occurred in potting media under commercial nursery conditions.

69 Comparison of Modified Urea Fertilizers and Estimation of Their Availability Coefficient Using Quadratic Models. H. R. Tejeda, C. W. Hong, and P.L.G. Vlek (Int. Fert. Development Center, Muscle Shoals, Alabama). *Soil Sci. Soc. Am. J. 44* (6), 1256-62 (Nov.-Dec. 1980). A procedure to compare N fertilizers based on comparing complete response curves simultaneously represented by a quadratic multifertilizer response model (MRM) is discussed. A modified version of the MRM, called fertilizer testing model (FTM), is used to test differences among response curves. The FTM describes the response curve to a fertilizer selected as a standard as well as the additional effect of test fertilizers over the response to the standard. In case of different response curves, an approximate test to decide whether the curves have equal limiting yield is introduced. Finally, a procedure to estimate the availability coefficient from quadratic response curves having equal limiting yield is derived. A quadratic multifertilizer response model and a fertilizer testing model were employed to analyze six field experiments conducted over a 3-yr period in Korea using three varieties of rice (Tongil, Jinheung, and Milyang 23) and three fertilizers (urea and two S-coated ureas) applied at four or five levels of N. Two out of six experiments showed a significant effect from SCU-A (25% release/7 days) beyond that of split-applied urea, whereas SCU-B (14% release/7 days) showed significant additional effects in three out of five experiments. However, in four of these six experiments, the limiting yield of the response curves of SCU was significantly higher than that of urea, precluding a valid estimation of the availability coefficient. Possibly, the proper combination of N rate and timed release of N from SCU in these experiments translated into grain yields unmatched by split applications of urea (19 ref).

70 Sulfur-Coated Urea and Other Controlled-Release Nitrogen Fertilizers. J. L. Rubio (Inst. Agroquim. Technol. Aliment., Jaime Roig, Valencia, Spain). *Rev. Agroquim. Technol. Aliment. 19* (2), 153-60 (1979) (Span). A review is given of the potential advantages for controlled-release nitrogen fertilizers with descriptions of the two general types: soluble compounds with physical barriers that slows their dissolution and compounds with inherent slow solubility. The characteristics, brief history of development, and achievements of TVA's sulfur-coated urea are emphasized (13 ref).

USE

FIELD CROPS

71 Uses of Sources of Slow-Release Nitrogen in Fertilization of Rice. W. H. Freeman, J. C. Katyal, and K. G. Pillai (All-India Coordinated Rice Improvement Project, Hyderabad, India.) In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 149 (1974). Field and greenhouse studies were carried out to investigate the efficiency of nitrogen fertilization from urea and sulfur-coated urea. Losses of N were more from urea than from sulfur-coated urea under poor water management conditions. Results from multi-location trials of the All-India Coordinated Rice Improvement Project have proved sulfur-coated urea to be a better source than urea when both were applied as basal. A combination of sulfur-coated urea and urea when applied as basal and topdressing, respectively, gave 15% more yield than all urea application at both timings. Topdressings with sulfur-coated urea at later growth stages gave poor results.

72 Comparison of Coated and Regular Urea on Rice by Using a Nitrogen Availability Coefficient. H. R. Tejeda and C. W. Hong (Int. Fert. Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1978 Annual Meetings* (held Chicago, Illinois, Dec. 3-8, 1978). *Madison, Wisconsin: Am. Soc. Agron.;* p. 197 (1978). Two forms of coated urea, at various rates of application, were compared with regular urea in five experiments with two rice varieties under two flooding conditions in Korea. Two alternative statistical procedures were used to analyze the experiments and test the performance of the N fertilizers. The traditional procedure consists of using analysis of variance to test the significance of the experiments, and subsequently using the Duncan test to identify significantly different treatments. The alternative procedure consists of using a regression model with dummy variables to test differences among response curves for each fertilizer, and subsequently expressing the differences by a numerical index called the availability coefficient. The availability coefficient is the ratio of the efficiency (yield per unit of applied nutrient) of the fertilizer being tested with respect to the efficiency of the standard fertilizer. The advantages of the alternative procedure are illustrated through the analysis of the five rice experiments.

73 Sulfur-Coated Urea Effectiveness as a Nitrogen Source on Yields of Lowland Rice Grown in Indonesia Under Several Water Managment Regimes. Soetjipto Partohardjono and J. B. Fitts (Int. Rice Res. Inst. Int. Program Indonesia, Bogor, Indonesia). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 153 (1974). Sulfur-coated urea and urea were compared as N sources on the yields of lowland transplanted rice (*Oryza sativa* 'IR-5'). A split-plot design replicated three times was utilized at several locations during 1973 dry season. Water management regimes (main-plot) were: continuously flooded, 5- and 10-day rotationally flooded, and intermittently flooded. Both N sources (sub-plot) were applied at 60 and 120 kg N/ha. Urea was applied in three equal applications (transplanting, active tillering, and primordial initiation growth stages) whereas SCU was applied once at transplanting or in three equal applications. Plots receiving SCU had increased grain yields as compared with grain yields of plots receiving urea at same N rates. These increased grain yields were significant where there was significant interaction between water management regimes and N sources. Plots receiving SCU had increased grain yield per unit N applied values, especially at 60 kg N/ha. A simple economic analysis to determine costs and benefits per ha showed increased SCU benefit, which in one case was greater than the Indonesian mean annual income.

74 Effectiveness of Sulfur-Coated Urea on Lowland Rice in Korea. C. S. Park and K. H. Han (Inst. Agric. Sci., Suweon,

Korea). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*; p.153 (1974). Through a series of field experiments and accompaning laboratory analyses, the use of sulfur-coated urea in growing lowland rice in Korea was found to be very effective in the following ways: the yield of rice and the production of proteins was increased; the efficiency of N uptake was increased; and the hazard from high ammonium ion concentrations in high yielding trials or practices may be prevented compared with ordinary urea in Korea soils having comparatively low cation exchange capacity. Sulfur-coated urea's have a lower dissolution rate in water compared to ordinary urea and the rate of dissolution was correlated with the amount of N uptake by lowland rice and the percent N absorbed from fertilizer N applied. Regression equations and multiple correlation coefficients were determined for: the total amount of N absorbed using various forms of urea; the efficiency of N sources as a % of N absorbed of the total applied; and for yield as a function of the total N absorbed. The respective correlation coefficients were 0.998, 0.998, and 0.997.

75 Nitrogen Management for Rice in Costa Rica. A Cordero *et al* (Ministry Agric., Costa Rica). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*; p. 147 (1974). Urea ammonium sulfate and sulfur-coated urea (SCU) were applied to upland rice (CICA-4) in split applications and only at planting at N levels of 60, 120, 180, and 240 kg/ha at three locations in 1973 in Costa Rica. Nitrogen applied at planting was incorporated by discing prior to planting and later applications were topdressed. Soil samples were taken at 0-20 and 20-40 cm depths at the 120 kg/ha N rate three times during the experiment. Rice grain yields were significantly increased up to the 180 kg/ha N rate at Esquemeka which had a low initial inorganic N level (41 ppm). With initial inorganic N levels of 65 and 55 ppm at Palmar Sur and Cascante, a grain response to 60 kg N/ha and a negative response to [illegible] were obtained, respectively. At Esquemeka, N response patterns were similar using urea and ammonium sulfate as N sources and split N applications were superior to applying N only at planting. In general split applications of urea and ammonium sulfate produced rice yields comparable to those obtained with SCU applications.

76 Relative Efficiency of Nitrogen Management and Weed Control Under Two Systems of Rice Cultivation. M. S. Soundara Rajan and I. C. Mahapatra (S. V. Agric. Coll., Tirupati, Andhra Pradesh, India). *Oryza 16* (2), 137-9 (1979). A study was conducted to determine efficiency of nitrogen fertilizers and relative efficiency of weeding in transplanted and direct seeded rice nitrogen was applied at 100 kg/ha in split (20-40-20-20 kg) applied basal, early-late tillering and panicle primordial initiation stages; or 100 kg N/ha applied as basal through sulfur coated urea. With the same weeding practice, the split application of N yielded 4350 kg/ha of rice compared to 4075 kg/ha of rice for sulfur coated urea. These results were on the transplanted rice.

77 Relative Efficiency of Slow-Release and Split Application of Nitrogenous Fertilizers and Weed Control Methods on Yield of Direct Seeded Upland Rice. M. S. Soundara Rajan and I. C. Mahapatra (Indian Agric. Res. Inst., New Delhi, India). *Oryza 15* (2), 117-23 (1978). In direct seeded upland rice on sandy loam soils of Delhi (India) application of a given qualtity of N (100 kg/ha) in four splits (25-0-25-25-25) synchronizing with four physiological stages of crop, that is, at basal, late tillering, panicle primordial initiation, and booting stages increased the grain yield significantly over sulfur coated urea or nitrification inhibitor treated fertilizer or neem cake mixed urea. Repeated hand weeding (thrice) was very effective to control the weeds and increase the grain yield. Best results were obtained with four split applications of N provided weeds were effectively controlled with repeated hand weeding.

78 Efficiency of Urea and Sulfur Coated Urea on Irrigated Rice Yield. C. P. Machado and A. F. Magalhaes. *Agron. Sulriograndense 9* (2), 195-203 (1973) (Port). A field experiment was conducted to determine the effect of fertilizer N source on rice yield. Three N-sources urea, sulfur-coated urea-1 (30.2% N and 29.6% S), and sulfur-coated urea-2 (34.6% N and 20.0% S) were applied to Vacacai silt loam at rates of 0, and 60 kg N/ha. The slow release fertilizers (SCUs) were not superior to standard urea. Sulfur-coated urea-2 was more efficient than SCU-1. A single application of SCU-2 was equivalent to split application of urea.

79 Use of Sulfur-Coated Urea a Slow Release Fertilizer as a Source of Nitrogen for Rice. D. G. Westfall. *Tex. Agric. Exp. Stn. Prog. Rep.* 3092-3105; pp. 8-10 (1972). Sulfur-coated urea (SCU) was evaluated as a source of N for rice during two growing seasons. The use of SCU materials as a N source did not result in increased rice production or higher N efficiencies in comparison with split application of regular fertilizer grade urea. Smaller yield responses to N were obtained from SCU material with slower dissolutation rates as compared to a SCU material with a more rapid dissolution rate. Based on 2 yr results, and considering an estimated 20% increased production cost of SCU, it appears that the use of SCU as a source of N under the highly refined cultural practices used in Texas is of no benefit to the rice producer.

80 Release of Nitrogen from Sulfur-Coated Urea in Flooded Soil. P. M. Giordano and J. J. Mortvedt (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Agron. J. 62* (5), 612-14 (Sept.-Oct. 1970). Laboratory and greenhouse tests were conducted to investigate the release of N in Mountview sil from S-coated urea (SCU) and the subsequent uptake of N by rice (*Oryza sativa* L. variety 'Nato'). The rate of N release was much greater in moist than in flooded soil. Granules of SCU became coated with FeS after two weeks in flooded soil. When the flooded soil was dried to about field capacity, oxidation of the FeS coatings appeared to seal the granules so that very little N was released. In general, the release of N was slightly greater from SCU applied to limed soils fertilized with P. Dry matter production and uptake of N by rice from SCU was similar to that from uncoated urea when both N sources were incubated in moist soil for at least two weeks prior to planting and flooding. Urea applied to the soil immediately before flooding was also effective, but SCU was not.

81 Hydrolysis of Urea and Performance of Some Slow Release Urea Fertilizers in Flooded Rice. Carmelita Magnaye (Univ. Philippines, Manila). *Thesis*, 85 pp. (Feb. 1971). Two Philippine soils, Maahas clay and Pila clay loam, were used in a laboratory study of urea hydrolysis. The soils were flooded to a depth of 2 cm; 0, 200, and 400 ppm of urea-N was added to the water surface; and the samples were incubated at 20, 30, or 40° for 0-10 days. Hydrolysis was rapid for the first two

days at 30 and 40° and pH of the soil increased as did the mineral N content. More NH_3 (20% of added N) was volatilized from the slightly calcareous Pila clay loam than from the slightly acidic Maahas clay. In a greenhouse study urea and $(NH_4)_2SO_4$ (AS) were applied at rates of 0, 200, and 400 ppm N to the Maahas and Pila soils either at planting time, as a split between planting time and maximum tillering time, or as a split between maximum tillering and panicle initiation. Planting time application of urea adversely affected growth of IR8 rice, especially at the early stage. Plant height and number of tillers were less for urea than for no N. Grain yields with urea were only 44% of those with AS. In a field study urea, AS, crotonylidene diurea (CDU), isobutylidene diurea, and two S-coated ureas produced by TVA were evaluated. Fertilizers were applied broadcast and harrowed in at rates of 0, 25, 50, 75, and 100 kg N/ha for the first (wet) season; in the second (dry) season rates were 0, 20, 40, 60, and 80 kg N/ha. Yield of IR8 rice increased with rate of N applied from 5.2 ton/ha with no N to about 6.3 ton/ha with 75 and 100 kg N/ha in the wet season. Controlled-release materials, except CDU, were as effective as AS in increasing grain yields the first season. Crotonylidene diurea was effective at the high rates of application in the first season and was comparable to the other materials in the second season.

82 Relative Efficiency of Sulfur-Coated Urea (Slow-Release Nitrogen Fertilizer) and Urea in Rice Soils. S. N. Sharma (Indian Agr. Res. Inst., New Delhi, India). *Indian J. Agron. 18* (3), 399-400 (Sept. 1973). A randomized block design with 10 treatments was used to study the efficiency of S-coated urea (SCU) relative to urea. The test was conducted during *karif* 1971 on transplanted Pusa 2-21, a short-stemmed rice. The SCU was applied at a rate of 100 kg N/ha at transplanting time. Urea was applied at rates of 25, 50, 75, and 100 kg N/ha, either all at transplanting time or in various split combinations to provide a total of 100 kg N/ha. Split applications were at tillering, panicle initiation, and booting stages. Grain yield was significantly higher (15-20%) with SCU than with any treatment with uncoated urea.

83 Conventional and Controlled-Release Nitrogen Sources for Rice. B. R. Wells and P. A. Shockley (Univ. Arkansas Rice Br. Agric. Exp. Stn., Stuttgart). *Soil Sci. Soc. Amer. Proc. 39* (3), 549-51 (May-June 1975). Tests were conducted during 1967-1972 with rice (*Oryza sativa* L., cultivar Starbonnet) to compare various formulations of sulfur-coated urea (SCU) and isobutylidene diurea, (IBDU) with urea and $(NH_4)_2SO_4$ as N sources on both silt loam and clay soils. The N sources were applied either preplant or topdress at rates up to 235 kg/ha to drill-seeded rice which was flooded approximately 2 weeks following seedling emergence. Grain yields, dry wt, and N uptake indicated that the controlled-release N sources could be used to regulate rat f N supply to the plant throughout the growing season. Gr th of direct-seeded rice was slowed considerably during the early part of the growing season due to the slow rate of N release but grain yields were not drastically altered. Grain yields on the silt loam soils following use of the controlled-release N fertilizers were consistently equal to those following use of urea or $(NH_4)_2SO_4$. On the clay soils under intermittent flooding, use of SCU resulted in increased yields as compared to urea applied preplant, and in one yr resulted in increased yields as compared to urea applied in split topdress application. Both SCU and IBDU were suitable N sources for rice growing under the water management systems employed in these studies.

84 Slow Release Nitrogenous Fertilizers on Paddy and Sorghum. K. R. Kulkarni *et al* (Univ. Agric. Sci., Hebbal, Bangalore, India). *Mysore J. Agric. Sci. 9* (2), 258-67 (1975). Experiments were conducted to study the efficiency of slow release N fertilizers and urea treated with nitrification retarders—such as Mahua cake, Karanj cake, and Neem cake—with CSH-1, IR-8, and Jaya paddy in black and laterite soils at Siruguppa and Mangalore. With paddy superiority of S-coated urea (SCU) over ordinary urea at 50 kg N/ha was observed for both grain yield and uptake of N. When one-half of the N was applied in the form of SCU and the remaining as top-dressing in the form of ordinary urea at 50 kg N/ha, yields were on par with ordinary urea at 100 kg N/ha applied in three splits. The SCU did not have a notable residual effect on the succeeding paddy crop, thereby indicating that most of the applied N was released and taken up by the main crop. With CSH-1, the urea treated with 20% by wt with neem cake in one application appeared to be on par or better than ordinary urea applied in two splits at 100 kg N/ha, in respect to both grain yield and uptake of N. Neem cake-treated-urea did not indicate any residual effect on the succeeding crop of wheat, indicating that N was released and taken up by the main crop. These differences were not significant, though consistent.

85 Sulfur-Coated Urea (SCU) Effectiveness on Yield of Lowland Rice Grown Under Several Water Management Regimes. S. Partohardjono and J. B. Fitts [Central Res. Inst. Agric. (CRIA), Bogor, Indonesia]. *Contributions-Central Res. Inst. Agric. (Indonesia)* No. 11; 14 pp. (1974). *Abstr. Trop. Agric. 1*, 5430. Experiments conducted under four water management regimes at four different locations in Java, Indonesia, during the 1973 dry season showed that at three locations, the yields were not significantly different as related to interaction between water regimes and fertilizer applications. The average yields for all N treatments were also not significantly different as related to water management regimes. Averaging plot yields for all four water regimes, however, showed that SCU at a basic application of 120 kg N/ha significantly increased yields as compared to urea applied in three split applications at the same rate.

86 A New Way to Minimize Nitrogen Soil Losses. R. B. Diamond (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Rice Farming 9* (6), 6-8 (June 1975). The key to efficient use of N fertilizer by most flooded rice is to prevent N losses by maintaining the N in the NH_4 form. Careful control of cultural practices helps prevent N losses. Use of S-coated urea (SCU) is about 25-30% more costly than commercial urea but tests with SCU on rice in Arkansas and California showed profitable returns for its use. Similar tests in Louisiana and Texas showed no advantage for SCU over commercial use.

87 Direct, Residual, and Combined Effects of Various Slow Release Nitrogenous Fertilizers in Rice-Rice Rotation. G. K. Patro, B. C. Sahoo, and K. Mohanty (Orissa Univ. Agriculture Tech., Bhubaneswar, India). *Mysore J. Agric. Sci. 9* (4), 523-9 (1975). Among the various slow release materials like S-coated urea, isobutylidene diurea (IBDU), lac-coated urea, AM fertilizer and Karanj cake-blended urea that were tested at 100 kg N/ha, it was observed that the application of lac-coated urea at 100 kg N/ha was the best for the first crop of rice while assessing the direct effects of slow release materials. When indirect effects in the second crop of rice and combined effects (first crop and second crop of rice taken together) were

assessed, it was observed that application of S-coated urea at 100 kg N/ha was the best for obtaining maximum yields. Application of urea as such, even up to 150 kg N/ha, was found to be decidedly inferior to all slow release N fertilizers at 100 kg N/ha when their direct, indirect, and combined effects were examined in rice-rice rotation.

88 Sulfur-Coated Urea and Sulfur-Coated Potassium Chloride for Paddies, Taiwan. N. R. Su (Joint Commission on Rural Reconstruction, Taipei, Taiwan). *Soils Fert. (Taiwan)*; pp. 1-10 (1974), publ. 1976. In trials at 3 sites in 1972, N as S-coated urea or ureaform at 120-130 kg/ha for the first crop and 100-110 kg for the second crop were compared with applications of ammonium sulfate and KCl. In the first crop the highest yield was given by 75% of the N applied as S-coated urea before transplanting and 25% as ammonium sulfate at panicle initiation which gave yields 5-9% higher than four split applications of ammonium sulfate. Yield differences in the second crop were not significant. In a trial at one site in 1972, application of 66 kg K/ha as S-coated KCl increased yields by 11-16% while KCl gave smaller increases. In 1973 at various sites combinations of S-coated urea and S-coated KCl were compared. In the first-crop trials at 28 sites, fewer dressings of S-coated urea and S-coated KCl gave yields 96-115% of those given by more dressings of ammonium sulfate and KCl; in 24 trials with the second crop, yields were 96-117% of those given by ammonium and KCl.

89 An Observation on the Fertilizer Effect of Locally Produced Sulfur-Coated Urea Used for Paddy. C. C. Lee. *Techn. Bull., Taiwan Fertilizer Co.* No. 48 (1973). *Soils Fert. 40*, 5610. On a sandy paddy field the yields of plots fertilized with ordinary urea decreased with decreasing application rate, but with S-coated urea of higher S content the yields remained high even at lower N rates. Compared with the S-coated urea of lower S content, the S-coated urea of higher S content always showed better fertilizer effect. It is estimated that 30% of the N consumption of rice could be saved by using S-coated urea of higher S content instead of ordinary urea.

90 Comparative Study of Different Nitrogenous Fertilizers on Their Mineralization in Submerged Rice Soils. S. Singh and Pati Ram (Banaras Hindu Univ., Varanasi, Uttar Pradesh, India). *J. Indian Soc. Soil Sci. 24* (4), 409-13 (Dec. 1976). Incubation studies on mineralization of slow-release N fertilizers, $(NH_4)_2SO_4$ and urea under waterlogged soil conditions with a red soil of Mirzapur and an alluvial clayey soil (Karail) of Azamgarh districts of Uttar Pradesh. The studies showed that NH_4-N increased during the first 4 weeks of submergence and afterwards it tended to decrease. The magnitude of release was in the order: $(NH_4)_2SO_4$ > urea > lac-coated urea > S-coated urea for both the soils. Less than 50% of the N was released as NH_4-N by the slow release N fertilizers. The decreases were appreciably noted in the case of $(NH_4)_2SO_4$ and urea in comparison to S-coated and lac-coated urea. The content of NO_3-N after submergence decreased, but after 2 weeks it fluctuated during the incubation period. Only a very small amount of added N appeared as NO_3-N.

91 Evaluation of Indigenous Sources of Slow-Release Nitrogen for Flooded Rice Using ^{15}Nitrogen. C.U.M. Rao and J. E. Shinde (Central Rice Res. Inst., Cuttack, India). *J. Nucl. Agric. Biol. 6* (4), 139-41 (Dec. 1977). Among slow-release N sources, S-coated urea produced by TVA, has been most widely tested in flooded rice culture. An attempt was made to prepare slow-release N sources from urea or ammonium sulfate, rice straw, and husk. A mixture of carbonaceous materials and inorganic ^{15}N to give a C:N ratio of 12:1 was kneaded with sufficient water and soil, shaped into a ball form and air-dried. The balls were placed 8 cm depth between rows of flooded rice at time of transplanting. Performance of the indigenous sources was compared with basal application of urea, ammonium sulfate, S-coated urea, and neem extract treated urea. Results of two field experiments showed that the indigenous materials, particularly prepared from urea and rice husk, performed better than S-coated urea and basal applications of both urea and ammonium sulfate.

92 Evaluation of Domestic Sulfur-Coated Urea and Simplified Application of Ammonium Sulfate on Different Paddy Soils. Shen Lian, Jung-Hsien Cheng, and Chun-Tao Su (Taiwan Agric. Res. Inst., Taipei, Taiwan). *T'ai-wan Nung Yeh Chi K'an 13* (2), 135-48 (1977) (Ch). Field experiments were conducted with $(NH_4)_2SO_4$ in the standard method of application (4 rates, 25, 20, 30, and 25% of the total N dressed before transplanting and at three stages of rice growth) and with the simplified method (75% of N applied as a basal dressing and 25% at panicle formation). The experiments were on a variety of soils with textures ranging from relatively coarse to fine. The simplified method was inadequate on course-textured sandy loam soils, equivalent to the standard method on silt loam soils, and superior on the fine-textured clay loam and silty clay loam soils. Sulfur-coated urea (SCU) from Taiwan and TVA were also tested and it was concluded that the rate of N release was too fast with both sources, even though the wax coating on the Taiwan SCU was thicker. Sulfur-coated urea gave a higher rice yield than with $(NH_4)_2SO_4$ simplified application on sandy loam soils but a lower yield than $(NH_4)_2SO_4$ applied in four rates.

93 Fertilizers for Deep Placement and Slow Release of Nitrogen for Rice. E. T. Craswell and P.L.G. Vlek (Int. Fert. Development Center, Muscle Shoals, Alabama). *Inter. Rice Res. Newsletter 3* (4), 2[illegible] 1 (Aug. 1978). Rice commonly uses only 30 to 40% of applied fertilizer nitrogen. Three major approaches that have been developed to increase N efficiency are split application, deep placement, and controlled release. The latter two approaches-as mudballs or urea supergranules and sulfur-coated urea, respectively-have frequently proven superior to split application of urea. A fourth approach combining deep placement and slow-release was developed by IFDC in the form of sulfur-coated urea supergranules. Preliminary results in a greenhouse study suggest that a combination of deep placement and slow release shows considerable promise for improving fertilizer N efficiency. The sulfur-coated urea supergranules urea are being tested at IRRI in 1978 as part of a joint IRRI-IFDC project to improve N efficiency for rice.

94 Evaluation of Sulfur-Coated and Uncoated Ureas as a Source of Nitrogen for Flooded Rice. Mohamad Sudjadi (North Dakota State Univ., Fargo). *Diss. Abstr. Int. B39* (10), 4685 (Apr. 1979). Greenhouse experiments were conducted using a Glyndon silt loam from Minnesota, a Krawang silty clay and a Paron silt loam both from Java, and a Lampung clay from Sumatra to compare three types of S coated urea (SCU) and conventional urea as sources of N for flooded rice (*Oryza sativa* L.). A laboratory incubation study was also conducted with the Glyndon soil to study the mineralization of two types of S coated and conventional urea used in the experiment.

Evidence obtained in these experiments showed that conventional urea gave higher grain yield increases than S coated urea on all soils except on the Glyndon soil. Grain yields on the Glyndon soil were very low, apparently because of the cool night temperatures during the fruit set. Seedling toxicity was found on the Glyndon and Lampung soils as a result of the application of conventional urea at the rate of 1.5 and 2.5 g N/pot. Apparently type of fertilizer and method of placement rather than soil properties were the casual factors. Sulfur coated urea mineralized much slower than conventional urea in the Glyndon soil. Higher amounts of NH_4-N and NO_3-N remained in this soil at harvest on pots that received S coated urea. Nitrogen contained in the straw of the second rice crop on the Glyndon soil was significantly higher than that from conventional urea at the rates of 1.5 and 2.5 g N/pot as SCU.

95 Slow Release Fertilizers and Nitrification Retarders for Increasing Productivity of Rice, Maize, and Wheat Under Fertilizer Constraints at Pantnagar. K. C. Sharma (Govind Ballabh Pant, Univ. of Agric. and Technology, Nainital, U.P., India). In *Proc First Review Meeting I.N.P.U.T.S. Project (Increasing Productivity Under Tight Supplies)* (held Honolulu, Hawaii, June 7-18, 1976). Editors S. Ahmed *et al. Honolulu, Hawaii: Food Institute*; pp. 223-35 (1976). *Rice Abstr. 2*, 576. In field trials during the 1975 wet season and in winter 1975-76 at Pantnagar, Uttar Pradesh rice cultivar Jaya and wheat cultivar Sonalike were grown with different sources of N and different methods of N application. Data on yield, yield components, and growth characteristics are presented. For rice neither isobutylidene diurea (IBDU) and S-coated urea (SCU) nor methods of N application (mudball, point placement, and banding) gave significantly higher grain yields than urea applied in the normal way. In wheat earlier tillers with more grains/ear were produced with urea than with SCU. None of the methods of fertilizer application had any significant effect on grain yields. Other trials on rice and maize did not show any superiority of IBDU, coated fertilizers, or nitrification inhibitors over urea.

96 The Fertilizer Value of the Sulfur-Coated Urea and Isobutylidene Diurea as Nitrogen Carriers for Paddy. M. R. Hamissa (Soil Res. Inst., Ministry of Agric., Cairo, Egypt). In *Proc. First Review Meeting I.N.P.U.T.S. Project (Increasing Productivity Under Tight Supplies)* (held Honolulu, Hawaii, June 7-18, 1976). S. Ahmed, M. Sadiq, and L. Kobayashi, Editors. *Honolulu, Hawaii: Food Institute*; pp. 147-57 (1976). In field trials in 1975 at Sackha Experimental Station, Egypt, the effect of four forms of N, different methods of N placement, and time of N application on grain yields of rice cultivar Giza 170 was examined. The untreated control gave grain yields of 6.47 tons/ha compared with 7.30, 7.51, and 7.72 tons/ha for 29, 58, and 96 kg N/ha, respectively (30, 60, and 100% of recommended rate), 7.18, 7.15, 6.79, and 7.52 tons/ha for sulfur coated urea, isobutylidene, $(NH_4)_2SO_4$ and urea, respectively, and 7.51, 7.40, 7.23, 7.65, and 6.79 tons/ha for N applied by surface broadcast, mudball, point placement, shallow banding and broadcasting, and incorporation, respectively.

97 An Analysis of Nitrogen Nutrition on Yield and Yield Components for the Improvement of Rice Fertilization in Korea. P.L.G. Vlek, C. W. Hong, and L. J. Youngdahl (Int. Fert. Development Center, Muscle Shoals, Alabama). *Agron. J. 71* (5), 829-33 (Sept.-Oct. 1979). Experiments were conducted in Korea over a period of 2 yr using two varieties of rice (*Oryza sativa* L., variety Tongil and Jinheung), two water management regimes (continuous and intermittent flooding), and three fertilizer sources (regular urea and two sulfur-coated ureas) applied at four or five different levels of N. Continuously flooded experiments were conducted on an Aquic-Fluventic Eutrochrept and the intermittently flooded on an Aquic-udipsamment. Yield response to N and apparent fertilizer N recovery varied with N source, rate, and variety, but in an inconsistent pattern. Close examination of yield component development as a function of N uptake revealed that variations in yield were mainly determined by panicle density and number of spikelets/panicle; the product of these components can serve as a potential yield index (PYI). The PYI is, to a large extent fixed by heading time and is closely related to the amount of N taken up between transplanting and heading. Path coefficient analysis was used to ascertain the N uptake during the period between 2 weeks after transplanting to maximum tillering most critically influenced PYI.

98 Utilization of Sulfur-Coated Urea in Paddy Fields and Production of Toxic Sulfides. V. A. Jacq (Lab. Microbio. Sol, ORSTOM, Dakar, Senegal). *Cah. ORSTOM, Ser. Biol. 13* (2), 133-6 (1978) (Fr). *Abstr. Trop. Agric. 5*, 27186. Microplot experiments on rice soils showed that the use of SCU instead of urea may increase sulfide accumulation in waterlogged soils. When this fertilizer was applied to the soil just before sowing, high toxic levels of sulfides were reached, resulting in considerable mortality of seeds and seedlings. When incorporated into the upper 10 cm of soil during tillage no effect was noticed on the seeds.

99 Denitrification in Paddy Soils: Effect of the Form and Method of Application of Nitrogen Fertilizers. J. L. Garcia (Lab. Microbiol. Sol. ORSTOM, Dakar, Senegal). *Cah. ORSTOM Biol. 12* (2), 83-7 (1977) (Fr). *Field Crop Abstr. 32*, 6833. Rice cultivar IR8 was grown in pots fertilized with urea applied (a) after submersion to the soil surface or (b) injected deeper into the soil (200 kg N/ha at tillering and 100 kg at booting), or with 200 kg N/ha as (c) S-coated urea or (d) N-lignin, both applied to the surface before submersion. Little or no N loss occurred in (b); significant losses occurred in (a) and (d) and slightly lower losses in (c). Grain yields were 102.7, 149.3, 83.0, and 43.6 g/10 plants for (a), (b), (c), and (d), respectively, compared with 46.7 g in the control (22 ref).

100 Relative Efficiency of Slow Release and Split Application of Nitrogenous Fertilizers and Weed Control Methods on Yield of Direct Seeded Upland Rice. M.S.S. Rajan and I. G. Mahapatra (Indian Agric. Res. Inst., New Delhi, India). *Oryza 15* (2), 117-23 (Apr. 1979). In direct seeded upland rice on sandy loam soils of Delhi, application of a given quantity of N (100 kg/ha) in four splits (25-25-25-25) synchronizing with four physiological stages of crop, at basal, late tillering, panicle primordial initiation, and booting stages increased the grain yield significantly over SCU or nitrification inhibitor treated fertilizer or neem cake mixed urea. Repeated hand weeding (thrice) was very effective to control the weeds and increase the grain yield. Best results were obtained with four split applications of N provided weeds were effectively controlled with repeat hand weeding (14 ref).

101 Effect of Source and Methods of Nitrogen Application on Yield of Sorghum and Rice Grown on Irrigated Uplands in Bangladesh, India, and West Samoa. H.P.M.Gunasena and

Saleem Ahmed (Resource Systems Inst., East-West Center, Honolulu, Hawaii). *Indian J. Agric. Sci. 49* (10), 790-6 (Oct. 1979). In field studies conducted on irrigated uplands in Bangladesh, India, and West Samoa, urea proved to be significantly superior to S-coated urea for fodder sorghum [Sorghum bicolor (Linn.) Moench] at both 50 and 100% of the N levels recommended for these regions. Broadcast application of S-coated urea was inferior to banding as well as broadcasting and incorporating methods. Nitrogen application increased the yields of upland rice (*Oryza sativa* Linn.) in some experiments, while a high coefficient of variation appeared to mask treatment effects in others (19 ref).

102 Comparison Between Slow-Release Nitrogen Fertilizers and Sulfate of Ammonia for Use in Rain-Fed Rice Cultivation in Northern Ghana. A. G. Carson and J. E. Quansah (Crops Res. Inst., Nyankpala/Tamale, Ghana). *Ghana J. Agric. Sci. 10* (Part 1), 33-7 (Apr. 1977). The efficiency of slow-release N fertilizers applied once at planting was compared with the standard practice of applying $(NH_4)_2SO_4$ split at planting and at maximum tillering stage in field trials from 1973 to 1975. Split application of $(NH_4)_2SO_4$ gave higher yields than either the sulfur-coated urea (SCU) or the isobutyliden diurea (IBDU) fertilizer under nonpermanent flooded conditions, although differences were not significant. However, SCU was more efficient under permanent flooded conditions than under nonpermanent flooded conditions. There were also no significant differences in the response to the rice cultivars to the various N sources. The trend was for SCU to provide optimum grain yields when applied at time of planting.

103 The Response of Some Improved Food Crop Varieties to Fertilizers in the Forest Zone of Western Nigeria. A. A. Agboola and G. O. Obigbesan. In *Seminar on Fertilizer Use Development in Nigeria* (held Rome, Italy, 1974), pp. 63-77 (1976). *Abstr. Cassava 5*, 0066-11207. Experiments with improved varieties of maize, rice, and cassava in the forest zone of W. Nigeria showed that N was the most important nutrient limiting the yield of the first two crops. Improved cassava cultivar 60506 responded better (64.1 tons at 90 kg N at 15 months) to N fertilizer than the standard local 53101, which had a lower yield ceiling (55.7 tons at 60 kg N at 15 months). Potassium increased the dry matter and starch content and total root yield of the improved cultivar. Ammonium sulfate seemed to be superior to S-coated urea or urea.

104 Nitrogen Fertilizer Efficiency. In *Annual Report for 1978. Manila, Philippines: The International Rice Research Institute*; pp. 250-64 (1979). Research on ways of increasing the efficiency of N fertilizers for rice was intensified during 1978 through a collaborative project with the International Fertilizer Development Center, Muscle Shoals, Alabama. Two general approaches—deep placement and slow release—are being tested. Among the experimental fertilizers being considered, two—sulfur coated supergranules and forestry-grade sulfur-coated urea (SCU)—were developed especially for rice and were first tested in the field in 1978. The forestry-grade SCU granules are approximately 10 times larger than regular SCU granules and are easier to incorporate into puddled soil. The second trial of the International Network on Fertilizer Efficiency in Rice was continued at IRRI (Alfisol) and in two farmers' fields (Ultisol and Vertisol) with early maturing variety IR36 and the medium-maturing IR42. Point placement (10-cm depth) of mudballs or urea briquets was compared with band placement (15-20 cm) of prilled urea by the plow sole applicator. Another treatment was regular SCU broadcast and incorporated at final harrowing. These fertilizer treatments were compared with split application, which is the best method presently available. The first 52 kg N increased yields of both varieties by more than two tons/ha. Except for SCU, higher rates of N did not further increase the yield of IR36. However, IR42 at IRRI gave significantly higher yields with 82 kg N/ha from methods other than split application. In fact, its highest yield from split application was obtained at 120 kg N/ha. Yield response to SCU at 82 kg N/ha was consistently higher than that to split application. With SCU at that rate, IR42 gave a particularly high yield of 7.7 tons/ha, suggesting that in the dry season, when demand for N is high, slow-release fertilizers may be especially effective with medium-to-late-maturing rice varieties.

105 Response of Rice (*Oryza sativa*) to the Source, the Rate, and the Time of Applying Nitrogen Under Flooded Conditions. Rajinder Singh, Jagrup Singh, and D. S. Bains (Punjab Agric. Univ., Ludhiana, Punjab, India). *J. Res. Punjab Agric. Univ. 15* (1), 8-14 (1978). *Biol. Abstr. 69*, 68845. The application of 100 kg N/ha one-half as a basal rate as S-coated urea (SCU) and one-half in two equal splits, each at tillering and panicle initiation as urea, gave the highest yield of rough paddy (75 q/ha) in a field trial conducted on *O. sativa* L. cultivar Jaya in Ludhiana (India) for 2 yr in the kharif of 1973 and 1974. The SCU produced 9% more rough paddy rice (504 kg/ha) than was produced with urea. The application of N greatly increased grain yield. At 100 kg N/ha grain yield increased by 13.2% over that with 50 kg N/ha. Three splits of N; one-half at planting, one-fourth at tillering, and one-fourth at panicle initiation, were more beneficial than a single application at transplanting.

106 Soil Fertility and Fertilizer Management. *Manila, Philippines: The International Rice Research Institute Annual Report for 1977*; pp. 270-1 (1978). The magnitude of direct volatilization losses during rice fertilization was determined in field and greenhouse experiments. Maximum NH_3 volatilization losses amounted to 18% of the urea N and to 15% of the $(NH_4)_2SO_4$-N when both fertilizers were entirely broadcast during the period of high sunlight and active algae growth. Even when surface applied, slow-release fertilizers, particularly IBDU, substantially minimized NH_3 volatilization losses. *In situ* release patterns of N from placement sites of prilled urea, supergranule urea, sulfur-coated urea (SCU), and urea in mudballs were compared in field studies. The rate of N release was considerably slower in the placement site of SCU than in that of prilled urea, supergranule urea, or mudball urea.

107 The Promise and Problems of Supergranules for Rice Fertilization. B. H. Byrnes, P.L.G. Vlek, and E. T. Craswell (Int. Fert. Development Center, Muscle Shoals, Alabama). In *Proc. Final Inputs Review Meeting* (held Honolulu, Hawaii, Aug. 20-24, 1979). *Honolulu, Hawaii: East-West Resource Systems, Inst.*; pp. 75-83 (1979). Uncoated supergranules of urea were shown to be suceptible to leaching losses at percolation rates of from 5 to 20 mm/day under simulated paddy conditions while S-coated supergranules (SCSG) were not. Under nonleached conditions, the S-coated supergranules gave higher plant recoveries (80-85%) than the uncoated supergranules (60-70%). Basal applications of urea, however,

gave recoveries of 21% to 25%. The results indicate that NH_3 volatilizaiton is probably the major loss mechanism responsible for the poor performance of basal urea applications when compared to deep placement of urea and $(NH_4)_2SO_4$. Direct measurement of volatilization showed that approximately 42% of the urea fertilizer-N is lost by this mechanism on a silt loam soil when the urea is applied at a rate of 100 kg/ha (16 ref).

108 Movement and Distribution of Ammonium-Nitrogen Following Deep Placement of Urea in a Wetland Rice Soil. N. K. Savant and S. K. De Datta (Int. Rice Res. Inst., Los Banos, Laguna, Philippines). *Soil Sci. Soc. Am. J. 44* (3), 559-65 (May-June 1980). Vertical distribution of NH_4^+-N following subsurface placement of different forms of urea was studied in incubated, undisturbed wetland soil cores. For prilled urea, supergranule urea, and prilled urea in mudballs placed at the 10-cm depth, peak concentration of NH_4^+-N was near the placement site and decreased with time, whereas after placement of sulfur-coated urea (SCU-21) at the same depth, peak concentration of NH_4^+ increased over a period of 4 weeks. With time, the NH_4^+-N tended to move downward more than upward from the placement sites, probably because of the mass flow of percolating water. Movement and spatial distribution of NH_4^+-N were studied following application of 2-g supergranules of urea (SGU) and sulfur-coated granules of urea (SC-SGU) at a depth of 10 cm in transplanted and cultivated wetland fallow plots. After 2 weeks, NH_4^+-N concentration gradient for SGU was 1850 to 32 μg N/cm^3 wet soil, over a distance of 10-12 cm from the placement site. The corresponding gradient for SC-SGU was 287 to 32 μg N/cm^3 wet soil, over a distance of 5-7 cm from its placement site. For SGU in transplanted plots, the concentration gradient decreased steadily through 8 weeks, whereas for SC-SGU it increased during the first 4 weeks and then decreased. The disappearance of NH_4^+-N with time and distance from the site of application is attributed to diffusive transport or convective transport, or both, and root-sink effect. The general movement of NH_4^+-N was downward > lateral > upward.

109 Recent Developments in Research on Nitrogen Fertilizers for Rice. E. T. Craswell and S. K. De Datta (Int. Fert. Development Center, Muscle Shoals, Alabama). *IRRI Res. Paper Series* No. 49; 11 pp. (1980). The stable isotope ^{15}N is used in studies to determine the role of N losses in the low efficiency of N utilization by rice. Two basic concepts deep placement and slow release have been evaluated as methods to increase N fertilizer efficiency for rice. Data from 117 trials in countries cooperating in the International Network on Soil Fertility and Fertilizer Evaluation for Rice (INSFFER) program show that deep placement of urea briquets or supergranules and the use of sulfur-coated urea (SCU) are both effective in increasing rice yields compared with the traditional split application techniques. Broadcast application of urea causes losses of up to 50% whereas point placement of urea supergranules 10 cm deep in the soil may result in negligible loss. Ammonia volatilization appears to be the major mechanism of N loss although recent measurements of N_2O fluxes from wetland soils provide conclusive evidence that nitrification-denitrification does occur. Other research has examined the effect of urea supergranule placement on root growth patterns and on NH_4 distribution in the soil. Supergranule placement provides a bonus of N to the soil-plant system by not disturbing the algal N fixation in the same way that broadcast N fertilizers do (17 ref).

110 Methods, Sources, and Time of Nitrogen Application for Upland Rice. A. Thasanasongchan, B. B. Mabbayad, and S. K. De Datta. *Philipp. J. Crop Sci. 1* (4), 179-85 (1976). Field experiments were conducted at IRRI and at Cuenca, Batangas, Philippines, to determine the effects of method, source, time, and N uptake of C22 and IR1529-430-3 rices grown under rainfed upland culture. In both locations, IR1529-430-3, a semi-dwarf selection, produced higher grain yield, more panicles and less percentage of unfilled grains than C22, a tall recommended rice variety for rainfed upland rice. Slow-release S-coated urea (SCU) was a better source of N than prilled urea and $(NH_4)_2SO_4$ when applied at planting, either broadcast and incorporated or placed in band. Split application was better than single application at planting, particularly in light textured soil, when urea and $(NH_4)_2SO_4$ were the N sources. Urea and $(NH_4)_2SO_4$ applied in 2 split rates at 30 days after emergence (DAE) and at panicle initiation or in 3 split rates at 10 DAE, 30 DAE, and panicle initiation were as effective as SCU applied singly at planting in increasing panicle number and grain yield of both varieties.

111 Effect of Rates of Nitrogen and Relative Efficiency of Sulfur-Coated Urea and Nitrapyrin-Treated Urea in Dry Matter Production and Nitrogen Uptake by Rice. S. N. Sharma and Rajendra Prasad (Indian Agric. Res. Inst., New Delhi, India). *Plant Soil 55* (3), 389-96 (1980). A field experiment conducted for two rainy seasons (1974 and 1975) on a sandy clay loam soil at the Indian Agricultural Research Institute, New Delhi showed that at 100 kg N/ha the apparent recovery of urea N by the rice crop was only 28%, which was raised to 41.7% by treating urea with Nitrapyrin and to 47.4% by coating urea with neem (*Azadirachta indica* Juss) cake. The recovery with S-coated urea was 37.7%. Dry matter production, N concentration in plant, and uptake by rice were increased as the rate of N was increased from 0 to 150 kg N/ha. Advantage of treating urea with Nitrapyrin or coating with neem cake was seen more in grain than straw yield (14 ref).

112 Effect of Slow-Release Nitrogenous Sources on Growth and Yield of Rice, Variety: Jaya. M. Oommen, *et al* (College of Agric., Vellayani, Kerala, India). *Agric. Res. J. Kerala 15* (1), 24-8 (1977). *Soils Fert. 43*, 2592. In field plots at Karamana during the second crop season, 1975-76, sulfur-coated urea, shellac-coated urea, IBDU, neem cake-blended urea, and AM-treated urea were all superior to urea in terms of yield components and grain yield.

113 Greenhouse Evaluation of Nitrogen Fertilizers for Rice. E. T. Craswell and P.L.G. Vlek (Int. Fert. Development Center, Muscle Shoals, Alabama). *Soil Sci. Soc. Am. J. 43* (6), 1184-8 (1979). A number of modified urea products were evaluated in a greenhouse experiment. Fertilizers were applied to rice grown in two soils subjected to continuous or intermittent flooding. The results demonstrate the advantages of split application, deep placement, and controlled release in increasing fertilizer efficiency. However, the major finding was that a combination of deep placement and controlled release results in a substantial increase in fertilizer N recovery by the plant. This combination, in the form of sulfur-coated supergranules of urea, gave a mean apparent recovery of fertilizer N by rice of approximately 84% compared with only 28% for urea applied in a single application at transplanting. By using ^{15}N-labeling, losses of applied N were measured for selected treatments. Extensive losses (> 30% for Decatur soil, > 50%

for Crowley soil) were measured for urea applied at transplanting. Much less (≃ 6% and 14-24%, respectively) was lost of ammonium sulfate applied similarly. Point application of the urea as a supergranule at the 8-cm depth reduced losses to < 4%. The intermittent flooding did not promote losses. Losses of broadcast fertilizers were greater from the Crowley soil (pH 6.2) than from the Decatur soil (pH 5.0).

114 Response of Rice to Sulfur-Coated Urea. E. C. Doll (Int. Fert. Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1975 Annual Meetings* (held Knoxville, Tennessee, Aug. 24-30, 1975). *Madison, Wisconsin: Am. Soc. Agron.;* p. 173 (1975). Sulfur-coated urea has been most effective as a source of N for rice grown under conditions conducive to denitrification or severe leaching. This would be under water regimes leading to intermittent flooding and/or alternate wetting and drying, or heavy flooding. It has not been superior to soluble N sources when rice is grown under continuous flooding. When rice is grown under water management conditions favorable to heavy losses of N, basal applications of N as SCU have consistently produced from 15 to 30% more rice than that produced with basal applications of soluble N fertilizers, and from 10 to 15% more than split applications of soluble N materials. It has been estimated that about 75% of the rice grown in Asia, and at least 50% of that grown in the world is grown under water management regimes where SCU would be expected to be a superior source of N as compared to the completely soluble forms.

115 Researches on Sulfur-Coated Urea with Rice in Korea. C. W. Hong (Inst. of Agric. Sci., Office of Rural Dev., Suweon, South Korea). In *Proc. First Review Meeting I.N.P.U.T.S. Project (Increasing Productivity Under Tight Supplies)* (held Honolulu, Hawaii, June 7-18, 1976). S. Ahmed, M. Sadiq, and L. Kobayashi, Editors. *Honolulu, Hawaii: Food Institute*; pp. 158-70 (1976). Sulfur-coated urea (SCU) was shown to increase rice grain yield by 5% or more and there were different responses to varying types of SCU between rice cultivars. The recovery rate of applied N by the rice plant increased up to 50% or higher with SCU. There were some indications that the use of SCU may improve rice quality by increasing the protein content of certain rice cultivar.

116 Rice Research in Sierra Leone. R.A.D. Jones, I. C. Mahapatra, and S. A. Raymundo (Rice Res. Sta., Rokupr, Sierra Leone). In *Rice in Africa.* Editors, I. W. Buddenhagen and G. J. Persley. *London, England: Academic Press*; pp. 223-30 (1978). *Field Crop Abstr. 33.* 10731. Agronomy trials conducted in 1975-1976 to assess the effects of soil and water conservation methods on rice grain yields on sloping terrain; N, P, and K application; sources and levels of P and N; trace element application; and weed control on grain yields are presented. Grain yield data are tabulated. Upland rice cultivar ROK 1 gave 280% increase in grain yields with soil and water conservation when grown on sloping land. Liming improved yields, and NPK application + lime gave the best response. In a pot trial, waterlogging reduced yields markedly on soils with Fe toxicity, with or without added P. Optimum P level was 25 kg P_2O_5/ha and all P sources gave similar results. Due to its soil amelioration properties, basic slag and/or rock phosphate is suggested instead of the current application of single superphosphate. Of N sources, S-coated urea (SCU) gave the highest yields of 2.64 tons of grain/ha. On the boli lands, SCU at 67 kg N/ha gave the highest yields. This slow-release S-coated urea appeared to be promising on swampy land. In upland culture, SCU was not as effective as ammonium sulfate or urea. Zinc deficiency on an upland site was relieved within 1 week by application of 5 kg Zn/ha. Weed control was important both to establishment and growth of rice seedling in mangrove swamps. The test cultivars were salt-resistant (BD2, ROK4, and ROK7) (13 ref).

117 Crop Responses and Related Beenfits from Sulfur-Coated Urea (SCU). R. B. Diamond and F. J. Myers (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Sulphur Inst. J. 8* (4), 9-11 (1972). Sulfur-coated urea was tested as a N-source for several crops under different soil and climatic conditions. It was found that SCU gives a higher yield of rice, bermudagrass, and Hawaiian sugarcane than uncoated urea. In all the tests, it was also found that to get a high yield fewer applications of SCU than of uncoated urea are needed.

118 Tailoring of Fertilizers for Rice. O. P. Engelstad, J. G. Getsinger, and P. J. Stangel (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Muscle Shoals, Alabama: TVA, National Fertilizer Development Center,* Bull. Y-52; 56 pp. (Dec. 1972). Emphasis in this project, sponsored by the Agency for International Development, was placed on improving the efficiency of N fertilizers; determining suitable P sources for rice grown on acid soils; and determining suitable Zn sources, carriers, and methods of application. Thirty-two greenhouse tests and a large number of engineering tests were conducted at TVA. Field trials were conducted in India, The Philippines, Thailand, Ceylon, Peru, Brazil, and Colombia. Nitrification inhibitors were found to have little potential for reducing N losses from flooded soils whereas coated, soluble N sources have a real potential where flooding is delayed or intermittent. Basal applications of sulfur-coated urea (SCU) showed consistent yield increases over uncoated urea under such water management conditions. Basal applications of SCU frequently were better than topdressed urea. The rate of N release from SCU within the range tested, had no consistent effect on yield. Economic calculations showed SCU to compete favorably where there were yield advantages. Rock phosphates of different geographic and geological origins vary in agronomic effectiveness. Effectiveness is correlated with citrate solubility and some rocks approach triple superphosphate in effectiveness. Relative agronomic effectiveness and price ratios of competing P sources can be used in determining which source should be used on the acid soils in the rice-growing regions of Southeast Asia. Initial soil pH is most important in determining the effectiveness of rock. Most of the commonly known Zn sources are satisfactory for flooded rice. Early application and placement are most important. Marked varietal differences were found in relation to response to Zn.

119 Studies on Nitrogen Efficiency Improvement Under Flooded Conditions: I: Effect of Different Methods of Nitrogen Application on the Grain Yield of Rice. T. Marumoto and T. Higashi. *Bull. Fac. Agric. Yamaguti Univ.* No. 27; 67-78 (1976). The broadcast application of fertilizer N failed to increase the productivity of rice because of the loss of N under flooded conditions. The application point placement of N fertilizer, especially mudballs, and the use of slow-release N fertilizers such as S-coated urea (SCU) or isobutylidenediurea (IBDU) reduced N loss. However, the grain yield in these treatments were not always higher due to low N absorption during the reproductive stage of rice. The application of N fertilizer at a rate corresponding to the mineralization of

decomposable soil organic N ensures the efficient use of N fertilizer.

120 Studies on Nitrogen Efficiency Improvement Under Flooded Conditions. Part II: Effects of Point Placement and Timings of Nitrogen Application on the Yield of Rice. T. Marumoto and T. Higashi. *Bull. Fac. Agric. Yamaguti Univ.* No. 29; 1-10 (1978). The point placement of N as basal application under flooded paddy conditions was effective in stimulating rice growth. Growth was better in point placement (PP) as basal application with peat ball (PB) and urea supergranule (USG) than application as broadcast and incorporation (B + 1) with slow-release N fertilizers such as isobutylidene diurea (IB) and S-coated urea (SCU). Growth in the treatment with PB was superior to that with USG. The rice yield in T-10 (local practice: urea, 120 kg N/ha. B&I and split application) was the highest of all treatments. In the group of the application amount of 90-92 kg N/ha, the yields were about the same level (brown rice: about 4.5 tons/ha) although the yield in T-4 (urea, 90 kg N/ha, PP) was rather low (brown rice: 4.2 tons/ha). The yields in the group were about 95.7% of T-10, and were not markedly reduced in spite of the application rate of about 75% N of T-10. In the group of 60 kg N/ha, the yield in T-5 (urea, pp and split application, brown rice: 4.4 tons/ha) of the point placement with additional application of 30 kg N/ha for the reproductive growth stage was the highest of the group. The yield was higher in T-12 (PB, brown rice: 4.3 tons/ha) than in T-11 (USG, brown rice: 4.1 tons/ha). The yield in T-2 (urea, 30 kg/ha, PP) was brown rice: 3.7 tons/ha. The absorbed amounts of N during the former growth stage in the treatments of only point placement as basal application were comparatively higher than those during the latter growth stage of rice. The absorbtion pattern of N by rice in T-4 was unsuitable for the high yield of rice because of the lower absorbed amount of N during the latter growth stage. The patterns in the treatments of only basal application of 92 kg N/ha (T-13 to T-16) were not so unsuitable as T-4 because of the characteristics of slow-release N fertilizer such as PB, IB, and SCU and of the lower solubility of USG than urea. The utilization coefficient of fertilizer N by rice was considerably higher in the group of PP than in B&I as basal application.

121 Efficiency of Slow Release Nitrogen Fertilizers for Rice in Black Soils. G. Ramasubbareddy *et al* (Agric. Res. Inst., Rajendranagar, Hyderabad, India). *Indian J. Agron. 25* (1), 129-31 (1980). Application of 80 kg N/ha as S-coated urea to rice grown in the rabi (winter) seasons of 1976-1977 gave paddy yields similar to those obtained with 100 kg N/ha as urea applied in three split dressings; application of 80 kg N/ha as neem (*Azadirachta indica*) cake-coated urea or as IBDU gave lower yields.

122 Nitrogen Efficiency Under Upland Conditions—A Review of INPUTS II Trial. M. Sadiq *et al* (Pakistan Fertilizer Co. Ltd., Karachi, Pakistan). In *Proc. First Review Meeting I.N.P.U.T.S. Project (Increasing Productivity Under Tight Supplies)* (held Honolulu, Hawaii, June 7-18, 1976). Editors S. Ahmed *et al. Honolulu, Hawaii: Food Institute;* pp. 173-90 (1976). *Field Crop Abstr. 32*, 2016. In field trials in upland areas of Bangladesh, India, Iran, Pakistan, and Western Samoa, N as S-coated urea or urea was applied at 0, 50, or 100% of recommended rates by banding or broadcast with or without incorporation to determine the most efficient way of supplying N to sugar beet, rice, maize, and sorghum. Data of sugar beet root, maize and rice grain, sorghum fodder yields, sugar beet plant height, and agronomic characteristics of rice are presented. Nitrogen banding gave greater yields than the other two methods of N application. There were no significant yield differences between the two N forms.

123 Influence of Applied Nitrogen on Grain Yield, Protein Content, and Milling Outturn in Transplanted Rice. P. W. Pisharody, R. R. Nair, and R. Gopalakrishnan (Rice Res. Sta., Pattambi, Kerala, India). *Agric. Res. J. Kerala 14* (2), 109-12 (1976). *Soils Fert. 41*, 7186. In field trials at Pattambi, India with rice cultivar Thriveni, N was applied at 100 kg N/ha either as urea (single rate or split application) or as S-coated urea. Application of part of the N as a top-dressing at the panicle-initiation and booting stages increased grain yield, grain crude protein content, and head rice recovery compared with application of N as a single rate rate at sowing. The highest average paddy yield of 3.3 tons/ha was obtained with 100 kg N/ha as S-coated urea, but this yield was not significantly higher than those obtained with split applications of urea; the unfertilized control gave a yield of 1.8 tons/ha. Sulfur-coated urea also gave a high grain crude protein content (9.33% compared with 6.92% for the control) and a high level of recovery of head rice (69.3% compared with 61.7%).

124 Performance of Sulfur-Coated Urea Under Intermittently Flooded Rice Culture in Peru. P. A. Sanchez *et al* (North Carolina State Univ., Raleigh). *Soil Sci. Soc. Amer. Proc. 37* (5), 789-92 (Sept.-Oct. 1973). Short-statured, high yielding rice (*Oryza sativa* L.) varieties grown extensively in northern Peru require extremely high rates of conventional N sources to achieve maximum yields. The recovery of applied N is extremely low due to the use of intermittent flooding. This water management system results in heavy N losses even with properly timed split applications. In search of simpler and more efficient methods of N management, eight field experiments were conducted in the region to evaluate sulfur-coated urea (SCU), an experimental, slow-release N source supplied by the Tennessee Valley Authority. Rice yields were increased an average of 59% more by pretransplant-incorporated SCU than by urea or ammonium sulfate applied in the same manner. Sulfur-coated urea produced an average of 20% higher grain yield response than topdressed applications of urea or ammonium sulfate. Sulfur-coated urea applications increased panicle production, N uptake at harvest, and the apparent recovery of added N. Beneficial effects of SCU were more pronounced in sites where check yields were low, especially less than about 4.8 tons/ha. In sites with high N supplying capacity, SCU produced excessive vegetative growth which resulted in yield reductions at high N rates. Regardless of an assumed 48%-higher unit N cost in SCU, the overall benefits of pretransplant-incorporated applications of SCU were favorable since there was a decrease of 40% in the optimum rate of N and the need for precise timing of application was eliminated.

125 Nitrogen Release Patterns from Deep Placement Sites of Urea in a Wetland Rice Soil. N. K. Savant and S. K. De Datta (International Rice Res. Inst., Los Banos, Laguna, Philippines). *Soil Sci. Soc. Am. J. 43* (1), 131-4 (1979). Release patterns of N from deep placement sites of prilled urea (PU), supergranule urea (SGU), sulfur-coated urea (SCU), and urea in mudball (MBU) were studied in *in situ* wetland Maahas clay at the International Rice Research Institute. Nitrogen release from PU and SGU was rapid during the first day after placement and decreased thereafter. Nitrogen release from urea in a mudball was slower than that from PU or SGU. Deep placed

SCU released N at a markedly slower rate than MBU throughout 45 days after placement. Nitrogen release from deep placement sites of the different forms of urea appeared to be a diffusion-controlled process.

126 Effect of Nitrogen Source and Management on Ammonia Volatilization Losses from Flooded Rice-Soil Systems. P.L.G. Vlek and E. T. Craswell (Inter. Fert. Development Center, Muscle Shoals, Alabama). *Soil Sci. Soc. Am. J. 43* (2), 352-8 (1979). Ammonia volatilization was studied by equipping capped greenhouse pots with a forced-draft system with external acid trap or by placement of open pots in a closed gas-lysimeter (allowing plant growth) with internal acid traps. In both systems air turbulence was optimized to simulate undisturbed open systems. Flooded soils were fertilized with approximately 50 or 100 kg N/ha of granular urea (GU), ammonium sulfate (AS), and two modified urea products—sulfur-coated urea (SCU) and urea supergranule (USG). The first three materials were broadcast and incorporated, whereas the last was placed at a depth of 8 cm. Ammonia volatilization from urea proceeded rapidly following hydrolysis of urea in the floodwater, leading to losses of up to 50% of the applied urea within 2 to 3 weeks. Ammonia loss from $(NH_4)_2SO_4$ occurred to a lesser extent due to a lack of alkalinity and occurred at a nearly constant rate, accumulating to 15% loss in 3 weeks. Ammonia losses from the modified urea materials were negligible. Soil pH had little effect on the pH of the floodwater and, thus, on the ammonia volatilization process. However, ammonia volatilization losses were generally reduced by factors that reduced the level of ammoniacal N in the floodwater, such as increasing soil CEC and reduced N application. Daily ammonia volatilization losses correlated well ($r = 0.92$) with the NH_3 (aqua) concentration of the floodwater sampled between 1000 and 1100 hr each day. This observation holds promise for the development of a simple technique for assessing ammonia volatilization losses from flooded soils based on simple physical and chemical parameters of the floodwater.

127 A Comparison of Sulfur-Coated Urea and Urea on Corn Yields and Soil Profile Nitrate–Nitrogen Content after Three Years of Application. D. H. Sander and W. J. Moline (Univ. Nebraska, Lincoln). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 154 (1974). Several rates of sulfur coated urea and urea were studied on a sandy soil with a water table at 1.5 m and a deep loess soil in eastern Nebraska under irrigated corn production from 1970 through 1972. Soil profile samples were taken after 3 yr of application of N rates up to 36 kg/ha. Yield was characterized by dry matter production, grain yield, grain to forage ratio, and N uptake. Most applied N was leached from the sandy soil while the loess soil retained substantial amounts of nitrate-N in the soil profile. Little difference was found between the effectiveness of the two forms of N on either yield performance or nitrate-N leaching potential.

128 Nitrogen Sources for Corn Grown on a Gravelly Loam Soil. W. D. Laws, L. R. Robison, and S. D. Nelson (Brigham Young Univ., Provo, Utah). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 151 (1974). In attempts to produce maximum yields of corn silage on Bingham gravelly loam, application rates of N up to 450 kg/ha had been used. Even at this high rate, the corn developed N-deficiency symptoms late in the growing season. This was thought to be due to leaching of N under the irrigation regime used. Sulfur-coated urea, a slow release N source, was compared with ammonium sulfate alone and in combination with ammonium sulfate. There were nine treatments, six consisting of all or part of the N applied by SCU. All plots receiving SCU yielded higher than the check or plots receiving only ammonium sulfate. At 448 kg/ha of N, SCU plots yielded 44.4 tons/ha and the ammonium sulfate 37.6 tons/ha. At the 224 kg/ha the respective yields were 37.9 and 37.7 tons/ha. When the N was supplied as two parts from ammonium sulfate and one part SCU, the mean yield of both rates was 20.9 tons/ha, and when the ratio of N from each source was 1:1, the mean yield was 42.0 tons/ha. The control yielded 33.9 tons/ha. All yields are silage at 70% moisture content.

129 The Effect of Sulfur Coated Urea, Urea, Ammonium Nitrate, and Ammonium Sulfate on the Yield of Corn. R. H. Follett (Kansas State University, Manhattan). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 149 (1974). A nitrogen source and rate study with corn (*Zea mays*) was conducted for 3 yr (1971-73) on a Crosby silt loam at Columbus, Ohio. The N sources used in this study were sulfur-coated urea, urea, ammonium nitrate, and ammonium sulfate. Nitrogen rates were 0, 90, 180, and 270 kg/ha. The N treatments were broadcast and disked in just prior to planting. Uniform P and K treatments were applied as a row fertilizer at planting time. Tissue samples were taken at silking time for plant analysis. The 3 yr data indicated that there was not a significant difference between N source on the yield of corn. The amount and distribution of rainfall during the growing season influenced the yield of corn almost as much as N rate. A large amount of rainfall during the early part of the 1973 growing season resulted in N deficient corn for all N rates and sources used in this study. There was a significant increase in the amount of S found in the plant tissue for sulfur-coated urea and ammonium sulfate after the 2nd yr.

130 Comparison of Urea and Sulfur-Coated Urea as Nitrogen Sources for Corn. C. S. Baldwin and C. K. Stevenson (Ridgetown College Agric. Tech. Ridgetown, Ontario, Canada). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 146 (1974). Field experiments were conducted on eight clay and clay loam soils to compare the yield response of corn (*Zea mays L.*) to urea and sulfur-coated urea (SCU) applied the previous fall, and in the spring before planting. Nitrogen was applied at 56, 112, 168, and 224 kg/ha of additional N over and above a uniform application of N, P, and K banded at planting time. Additional treatments included in these experiments were a check plot with no additional N, and an anhydrous ammonia sidedressed application. In one trial urea gave significantly higher yields than SCU, both in the fall and in the spring (364 and 910 kg/ha, respectively). In three trials there was very little or no difference between the two materials applied in the fall, however, urea gave slightly higher yields than SCU when applied in the spring. In four trials SCU gave slightly higher yields than urea when applied in the fall, however, there was very little or no difference between the two materials when applied in the spring.

131 Efficient Use of Nitrogen by Corn. D. F. Baker and James

Shuford (Pennsylvania State Univ., University Park). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.:* p. 146 (1974). The objective of the study was to develop a system of chemical monitoring of soil and N fertilization of continuous corn. For Hagerstown silt loam it was assumed that nitrate-N more than 4 ft within the profile would not be recovered. Rates of N were 84, 140, 197, and 253 kg/ha applied as urea (45% N), papermill sludge (5% N), and sulfur coated urea (36.8% N with 12% dissolution in 7 days) plowed down in the spring prior to planting; other plots received poultry manure (5% N) and urea (45% N) side-dressed 5 weeks after planting. All plots received 20 kg/ha with the corn in 30-in. rows. The experimental design was a factorial with three replications. Grain yields averaged 9715 and 9778 kg/ha in 1972 and 1973, respectively. Over all methods of application, grain yields were not significantly different over rates of N in 1972 or 1973. Only in 1972 corn yields were significantly lower on plots treated with papermill sludge. Sulfur coated urea was not different from uncoated urea with respect to corn yields, leaf N, or movement of nitrate-N within the soil profile. The lack of response to higher rates of N were attributed to high initial levels of nitrate-N within the soil and lower rates of leaching than expected.

132 Effects of Manures Ammonium Nitrate and Sulfur-Coated Urea on Yield and Uptake of Nitrogen by Corn and on Subsequent Inorganic Nitrogen Levels in Soils in Southern Quebec Canada. P. L. Miller and A. F. Mackenzie (McGill Univ., Canada). *Can. J. Soil Sci. 58* (2), 153-8 (1978). Effects of added N in the form of ammonium nitrate, S-coated urea, solid cow manure, liquid hog manure and liquid hog manure plus straw on yield, and N uptake of corn (*Zea mays* L.) were determined in 1971. Residual effects of the fertilizers were measured in 1972. Levels of added N were 150 kg/ha, on three soils varying in texture. In 1971, highest yield and N uptake was found using NH_4NO_3, followed by S-coated urea. The manures were not different than the control, and the average values with liquid manure plus straw were generally lowest. Ammonium nitrate treatments had the lowest mineral N levels in the soil profile in September. Ammonium nitrate was considered to have the lowest pollution potential, assuming that fall-accumulated inorganic soil N was a hazard for pollution of groundwater.

133 Efficiency of Nitrogen Recovery from Controlled-Release Urea Under Conditions of Heavy Leaching. J. J. Oertli (Univ. California, Riverside). *Agrochimica 19* (3-4), 326-35 (1975). Single applications of slow-release N fertilizers (S-coated urea) from 7.5 to nearly 30 g N/pot (10 kg sand) supplied sufficient N for one or two crops of corn plants in sequence under severe leaching conditions. Subsequent crops of sunflowers or tomatoes became increasingly N-deficient because of exhaustion of the N supply. In spite of heavy periodic leaching, around half of the applied slow-release fertilizer was recovered by plants. In contrast, recovery from conventional urea under comparable conditions was only 14%. These experiments demonstrate that plants can be grown successfully with S-coated urea as the sole source of N and, under very extreme leaching conditions, the efficiency of N recovery is increased from 10 to 50 fold through the use of slow-release fertilizers.

134 Nutrient Effectiveness in Relation to Rates Applied for Pot Experiments: I. Nitrogen and Potassium. G. L. Terman and J. J. Mortvedt (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Soil Sci. Soc. Am. J. 42* (2), 297-302 (1978). An N source experiment was conducted on infertile Mountview soil (Typic Paledult) to evaluate four N sources at multiple rates of applied N and P. Granular ammonium nitrate (AN), sulfur-coated urea (SCU), oxamide (Ox), and isobutylidene diurea (IBDU) were evaluated for corn (*Zea mays* L.) at N rates of 0, 400, 800, and 1200 mg/pot (5 g of soil), each at P rates of 0, 60, 120, 480, and 960 mg/pot. Yield response to applied N was in the order AN $\gg$ SCU > Ox > IBDU at the higher rates of applied P. At 60 and 120 mg of applied P, P was too deficient for satisfactory evaluation of the N sources. In an experiment with flooded rice (*Oryza sativa*), P limited yields less than did N. In other N-P and P-K factorial experiments, rates of other nutrients and length of growth period also greatly affected crop response to applied N and K. Satisfactory evaluations of N or K sources are therefore possible only at adequate rates of nontest nutrients. Nutrient rates adequate for small greenhouse pots are much higher than rates equivalent to normal rates recommended for crops grown under field conditions. Length of growth period and other growth-limiting factors are equally important.

135 Modified Sulfur Coated Granular Urea for Controlled Nutrient Release. O. R. Lunt (Univ. California, Los Angeles). *Trans. 9th Intern. Congr. Soil Sci. 3;* pp. 377-83 (1968). Field tests were conducted with urea coated with S and a plasticizing agent and sealed with a soft wax. Yields and N recovery by corn were as good from a single application of coated fertilizer as from three applications of regular urea when irrigation practices were carefully managed to avoid large leaching losses. Under high leaching conditions, yield and N recovery from comparable applications of coated urea were superior to uncoated urea. The coated materials show substantial release at slow rates for 80-100 days.

136 Comparative Efficiency of Soluble and Controlled-Release Sulfur-Coated Urea Nitrogen for Corn in Tropics. R. C. Dalal (Univ. West Indies, St. Augustine, Trinidad). *Soil Sci. Soc. Amer. Proc. 38* (6), 970-4 (Nov.-Dec. 1974). The efficiency of the soluble-N sources, ammonium sulfate (AS), urea-ammonium phosphate (UAP) and urea and controlled-release-N sources, S-coated urea (SCU-8.9, SCU-1.1, and SCU-0.9) of differing N-release rates (applied at 50, 100, and 200 kg N/ha to an acidic soil) were compared in terms of N uptake and grain yield of corn (*Zea mays* L.). The apparent N recovery of added N, calculated by uptake differences from the control plots, was evaluated from N uptake by the two successive crops, one in the wet season and the other in the following dry season. In general, N uptake, grain yield, and apparant N recovery were increased by added N in the order: SCU-0.9 = SCU-1.1 > SCU-8.9 = Urea > UAP = AS; which was opposite to the nitrification of these N sources except that the performance of urea was better than the other soluble-N sources, primarily because it had a smaller effect on soil pH and exchangeable Al. The inclusion of microbicide in the S-coatings of SCU had no influence on N efficiency or grain yield. More N was recovered from SCU with slower N-release characteristics irrespective of coating wt. Apparent recovery of added N was almost complete from urea, SCU-8.9, SCU-1.1, and SCU-0.9 when applied at the rate of 50 kg N/ha, although the recovery at 200 kg N/ha was about 50%. The "priming effect" of soluble-N sources on soil N was observed. It appeared that release of fixed NH_4^+-N was primarily responsible for the priming effect on soil N.

137 Effects of Nitrogen Source and Rate and Use of Plastic Covers on Yield and Nutrient Status of Corn. M. C. Lutrick and W. K. Robertson (Univ. Florida, Gainesville). *Soil Crop Sci. Soc. Fla. Proc. 32;* pp. 87-9 (1973). Sulfur-coated urea (SCU) designed for slow release of N, was compared to NH_4NO_3 in corn production on a Triton fine sandy loam (Plinthic Normuldult). A basic application of 54-70-134 kg/ha of N-P-K was applied just prior to planting. Additional N at 81 or 216 kg/ha from each source was banded with and without a 25 cm strip of black polyethylene cover. There was no yield respor for rates or source of N but a significant yield inc: was obtained when the plastic strip was used. When the corn was in the early dough stage the soil N content was significantly less than all other treatments where 81 kg/ha of NH_4NO_3 was added and significantly higher than all other treatments where the 216 kg/ha SCU was added. The soil N content was the same for the 216 kg/ha NH_4NO_3 and the 81 kg/ha SCU treatments.

138 Use of Urea and Sulfur-Coated Urea for Corn Production in a Tropical Soil. R. C. Dalal (Univ. West Indies, St. Augustine, Trinidad). *Soil Sci. Soc. Amer. Proc. 39* (5), 1004-5 (Sept.-Oct. 1975). Placements of applied N at surface and at the 5-cm depth at the rates of 50, 100, and 200 kg/ha of urea and S-coated urea (SCU) were used to measure changes in grain yield and N uptake by corn (*Zea mays* L.) grown during the wet season in Trinidad. Sulfur-coated urea performed better than urea. Surface applied SCU was more efficient than when placed at 5 cm depth. Urea placed at 5 cm depth was more efficient in corn production than when applied on the surface.

139 Effect of Sulfur-Coated Urea on Nutrient Uptake by Maize (*Zea mays* L.). R. C. Dalal (Univ. West Indies, St. Augustine, Trinidad). *Trop. Agric. 54* (1), 47-52 (Jan. 1977). The effects of soluble sources of N, $(NH_4)_2SO_4$ (AS), urea ammonium phosphate (UAP), and urea, and controlled release N sources, S-coated urea (SCU-8.9, SCU-1.1, and SCU-0.9) of differing N release rates, applied at 0, 50, 100, and 200 kg/ha on an acidic soil, were compared in terms of P, K, Ca, and Mg uptake. Phosphorus uptake usually increased with increasing N rate and SCU-1.1 and SCU-0.9 gave larger uptakes of N and P than the soluble N sources. When the N rate of AS was increased from 100 to 200 kg/ha, P uptake was not increased, possibly because of the adverse effect of increasing exchangeable Al. The same change in N rate of AS and UAP tended to depress K, Ca, and Mg uptakes. On increasing the N rate from 100 to 200 kg/ha, SCU-1.1 and SCU-0.9 increased K, Ca, and Mg uptake. The factors responsible for the differences in nutrient uptake due to N sources were probably the differences in nitrification rates and consequent changes in soil pH and exchangeable Al, soil NH_4-N:NO_4-N ratio, and the maintenance of soil NO_3-N levels during crop growth.

140 Fall-Versus Spring-Applied Sulfur-Coated Urea, Uncoated Urea, and Sodium Nitrate for Corn. W. W. Frye (Tennessee Technol. Univ., Cookeville). *Agron. J. 69* (2), 278-82 (Mar.-Apr. 1977). The practice of applying fertilizer in the fall for crops grown the next summer is advantageous to the fertilizer manufacturing and marketing sector as well as saving time for farmers in the spring planting season. Sulfur-coated urea (SCU), $NaNO_3$, and uncoated urea were applied in field experiments during 1972-74 to compare their efficiency in fall application with spring application for the production of corn (*Zea mays* L.) grain on a Mountview silt loam soil (typic Paleudult, fine silty, siliceous, thermic) at Cookeville, Tennessee. Two dissolution grades of SCU were compared with $NaNO_3$ and uncoated urea, at rates of 112 and 224 kg N/ha in 1972-73 and 168 and 224 kg N/ha in 1974. Grain yields were measured and relative efficiency of fall application and response to rates, sources, and dates of application were calculated. Soil concentrations of NH_4- and NO_3-N were measured on some treatments. Soil temperature at 10 cm depth was recorded during the winter and early spring of 2 yr. There were little or no differences in corn grain yields between fall and spring applications of N at the 224 kg/ha rate. At the lower N rates, spring-applied N increased yields compared to fall-applied N. The relative efficiency of fall compared to spring application of the materials, averaged for 3 yr, was 0.52 and 0.86 for $NaNO_3$ at 112 and 224 kg N/ha, respectively, 0.49 and 0.95 for uncoated urea, 0.80 and 1.10 for SCU-1, and 0.72 and 1.03 for SCU-2. Nitrates leached to a depth of 45 cm or more during the winter and early spring in plots treated with $NaNO_3$ and uncoated urea. Conditions were probably favorable for a slow but significant dentrification rate at times during the winter and early spring, leading to the belief that dentrification may have caused some of the decreased efficiency of fall-applied N. Although SCU was more effective than $NaNO_3$ or uncoated urea, fall-applied N from any fertilizer source would be less effective on subsequent spring and summer growth than spring-applied N under similar soil and climate conditions.

141 Slow-Release Nitrogen Fertilizers Applied in Fall for Corn. E. G. Beauchamp (Univ. Guelph, Guelph, Ontario, Canada). *Can. J. Soil Sci. 57* (4), 487-96 (Nov. 1977). Slow-release N fertilizers were considered as efficient sources of N for fall application to corn (*Zea mays* L.). Accordingly, S-coated urea (SCU) and crotonylidene di-urea (CDU) were compared with urea in several field experiments. Neither SCU nor CDU were shown to be advantageous over urea in terms of grain yield. Similarly, the N content of the leaf opposite and below the ear did not show a greater availability of N from SCU and CDU than from urea applied in the fall. Response to residual N from previous applications of urea, SCU, and CDU was obtained for 2 yr after application. There was a tendency for a greater response to residual SCU. The concentration of NO_3^- in the 0- to 18- and 18- to 36-cm soil layers was usually less with slow-release N fertilizers than urea at early May sampling times. By mid-June, the NO_3^- concentration had increased substantially with both urea and the slow-release N fertilizers. In 2 yr when urea was applied in the spring, the NO_3^- concentration with spring-applied urea was higher than with fall-applied urea. This reflects the greater loss of N during the winter months with fall-applied urea. After growth terminated in the fall, NO_3^- apparently continued to be released from urea and slow release N fertilizers at similar rates. Thus slow release N fertilizers also have potential to contribute significantly to the NO_3^- concentration in drainage and groundwaters. In general, there was no noteworthy difference between SCU and CDU in this study. Also, slow-release N fertilizers did not show any agronomic advantage over urea when applied in the fall.

142 A Comparison of Terrazole- and N-Serve-Coated Urea with Conventional Urea, Anhydrous Ammonia, and Sulfur-Coated Urea as a Fall and Spring Application of Nitrogen to Corn. A. G. Taylor (Southern Illinois Univ., Carbondale). *Thesis;* 54 pp. (Aug. 1976). Field studies were conducted to

determine the effects of nitrificide-coated ureas and S-coated urea as fall and spring fertilizers on corn yield and soil mineral N status. Yields were not affected by use of N-serve, Terrazole, or S-coated urea. Mineralization of N in the early spring compensated for any over-winter losses of fall-applied fertilizers, and conditions favoring denitrification did not prevail following spring fertilizer applications. Both N-serve and Terrazole were partially effective in suppressing nitrification of urea N from time of fall application to time of planting. The 1.0% N-serve and 1.5% Terrazole were the most effective rates tested in retarding nitrification of fall applied fertilizers. N-serve at 1.0% with spring applied urea was the only inhibitor treatment effective in suppressing nitrification for 30 days following the planting date. Had conditions been more favorable for denitrification or leaching during this time, serious losses of N could have occurred.

143 Effect of Urea, N-Serve, and Sulfur-Coated Urea on Growth, Nutrient Uptake, and Yield of Corn (*Zea mays* L.). A.M.O. El Wali, F. Le Grand, and G. J. Gascho (Univ. Florida, Gainesville). *Soil Crop Sci. Soc. Fla. Proc. 38;* pp. 1-3 (1979). Excessive leaching of applied N is often a cause of low yields for corn (*Zea mays* L.) grown on sandy soils in Florida. In this study three SCU products were compared with equal rates of N from urea with and without N-Serve or S applications. N-Serve at rates of 0.28 and 0.56 kg/ha was mixed with urea just before the fertilizer was applied to the field. Sulfur was added in powdered form to the urea at rates equivalent to the amount of S in each of the three SCU products. The fertilizers were applied in furrows at the equivalent rate of 135 kg/ha of N. Subsoil placement of urea with and without N-Serve of S significantly reduced seed germination and plant vigor until the twelfth week when compared with SCU products. Urea with and wthout N-Serve or S significantly increased the percent N in leaf during the first 8 weeks when compared with SCU products. Differences between treatments were not significant for N content of the leaves during the rest of the growing season and for grain yield. Analysis of soil samples taken at the end of the experiment revealed significantly higher N content in plots fertilized with SCU products than in those which received the other treatments (15 ref).

144 Nitrogen Fertilization of Maize on an Oxisol of the Cerrado of Brazil. T. L. Grove, K. D. Ritchey, and G. C. Naderman, Jr. (Cornell Univ., Ithaca New York). *Agron J. 72* (2), 261-5 (Mar.-Apr. 1980). Six crops of 'Cargill 111' maize (*Zea mays* L.) were planted on an Oxisol of the Cerrado of Brazil to define the N fertilizer response curve, estimate increase in N content of aboveground dry matter/unit fertilizer, estimate soil N supply, determine the effects of timing of application on yield and N recovery, and compare conventional and S-coated urea. Yield increased significantly with N fertilization. Average maximum grain yield of 6.1 mt/ha resulted from application of 203 kg N/ha. Recovery of fertilizer N varied with application rate from 60% at 60 kg/ha to 35% at 220 kg/ha. A single application of fertilizer 30 days after planting produced the same yield and N recovery as split applications at 20 and 60 days. Neither S-coated urea nor lime-coated NH_4NO_3 produced greater yield or N recovery than conventional urea. Average N content of above-ground dry matter at maximum yield was 1.18%. Average uptake of soil N was 70 kg/ha/crop. There appears to be no fundamental difference in response of maize to N fertilizer between Oxisols and soils of the temperate regions (21 ref).

145 Sulfur-Coated Urea and Urea Compared as Nitrogen Sources for Irrigated Corn. D. H. Sander and W. J. Moline (Univ. Nebraska, Lincoln). *Soil Sci. Soc. Am. J. 44* (4), 777-82 (July-Aug. 1980). Sulfur-coated (SCU) was compared to urea to determine their value as N fertilizers for irrigated corn from 1970 through 1972, on a Cass sandy loam and Holder silty clay loam. Results indicated little difference between the performance of the two N fertilizers in terms of grain, forage yields, or in N uptake although N from SCU tended to be less available than from urea. After 3 yr of application, more NO_3-N was found in the root zone with SCU than urea. This was especially apparent on the fine-textured Holder soil and to a lesser extent on the sandy Cass soil. While the increased NO_3-N found after 3 yr in the root zone did not affect fertilizer N need, data does suggest that SCU has potential for increased N efficiency by reducing leaching under moderate leaching situations. The data emphasizes the need for more accurate N recommendations that will access NO_3-N in the root zone, N mineralization potential of the soil, and N in the irrigation water. It was possible to grow 92 to 94% of maximum corn yields without losses of N to the groundwater (21 ref).

146 A Comparison of Sulfur-Coated Urea and Other Nitrogen Sources on Corn and Small Grains. C. E. Rivard (Univ. Maryland, College Park). *Diss. Abstr. Int. B 38* (10), 4580 (1978). Sulfur-coated urea (SCU), NH_4NO_3 (AN), $NaNO_3$, and urea were compared in five field experiments in Maryland on four soils for winter wheat, barley, and spring oats. Rates of N of 0, 67, 134, 269, or 538 kg/ha from each source were broadcast for corn and either plowed under or disked in before planting. Corn grain yields in 1971 were not increased beyond the first increment of N; yields and uptake of N, P, and K were similar among N sources. Residual effects on corn yields in 1972 were higher with SCU than with urea or nitrate sources. Wheat grain yields were significantly lower with topdressed SCU than with urea or AN. For topdressing small grains in fall, SCU, AN, and urea had similar effects on yields. Highest yields resulted with soluble N applied in February or early March.

147 Effect of Urea and Sulfur-Coated Urea on Wheat and Maize Yield in Afghanistan. A. Q. Samin (Univ. Kabul, Afghanistan). *Agrokemia es Talajtan 24* (1-2), 17-22 (1975) (Hung). In a field experiment, application of 100 kg N/ha appeared to give highest yields of wheat and maize. Split application of urea (one-half at sowing and one-half as topdressing) had about the same effect as SCU, and at 150 kg N/ha was not much more effective than a single application at sowing time. Potassium did not increase yields of wheat or maize.

148 Nitrogen Fertilization of Corn and Sorghum Grown in Oxisols and Ultisols in Puerto-Rico. R. H. Fox, H. Talleyrand, and D. R. Bouldin. *Agron J. 66* (4), 534-40 (1974). Three rates and two times of application of fertilizer N were applied to 15 corn (*Zea mays* L.) and three sorghum (*Sorghum bicolor* Moench) crops on two Ultisols and three Oxisols during five successive growing seasons in Puerto Rico to determine the most effective means of applying fertilizer N to these crops. Additional objectives were to determine the apparent recovery of fertilizer N by the crops; the interrelationships between crop yield, N fertilization and soil inorganic N content; and the effectiveness of slow-release sulfur-coated urea. Soils had been under cultivation for at least 50 yr and received

relatively high rates of fertilizer for the last 20 yr. The results indicated that: (1) postplant sidedress applications of fertilizer N resulted on the average in higher yields and plant recovery of fertilizer N than preplant applications; (2) when there were no limiting factors of climate or disease, and there was a response to N, the recovery of postplant applied N was comparable to that observed in temperate areas; (3) maximum corn grain yields were approximately 6.3 mt/ha; (4) near-maximum corn grain yields were obtained with 67 kg/ha of postplant-applied N; (5) preplant-applied sulfur-coated urea was no more effective than preplant urea in increasing yields or N recovery; (6) soil inorganic N content was generally not a good index of soil N supplying power in these soils; (7) drought and disease frequently reduced yields; (8) there was very little residual effect of the fertilizer N applied in this experiment; and (9) the clayey Oxisols and Ultisols in Puerto Rico had a relatively high N-supplying power.

149 Timing the Application of Nitrogen to Maize in Sierra-Leone. I. Haque (Univ. Coll. Swaziland, Luyengo, Swaziland, Africa). *Exp. Agric. 15* (3), 247-52 (1979). Application of all the N (urea) at planting or thinning gave lower leaf N values and relatively poor yields compared to split applications. Lower grain yields in the minor season might have been due to poor and inadequate rainfall. Basal application of SCU (S-coated urea) did not seem to release enough N for maximum grain yield of maize. Total N (urea) in the major and minor seasons may be phased in 2 splits, one-half N 30 DAP (days after planting) + one-half N 50 DAP or one-third N at planting + two-thirds N 25 DAP, respectively.

150 Performance of Sulfur-Coated Urea as a Nitrogen Source for Irrigated Corn, Grain Sorghum, and Dryland Wheat. L. S. Murphy *et al* (Kansas State Univ., Manhattan). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 152 (1974). Sulfur-coated urea (SCU-30) has been evaluated along with anhydrous ammonia, urea, ammonium nitrate, and nitrogen solution (UAN) as a source of N on sandy, irrigated soils in central and western Kansas. The slow release N product SCU-30 has shown little, if any, advantage as a N source for row crops where leaching of preplant N can occur. Plant composition studies did not indicate higher concentrations of N resulting from the use of SCU-30. Studies of fall and spring applied N for winter wheat under dryland conditions have shown no advantage for SCU-30. Locations in south central Kansas in 1973 and 1974 were subjected to extremely heavy rainfall and leaching in the fall of 1972 and 1973 after preplant N applications for wheat. Sulfur-coated urea-30 performed at a level equal or inferior to both urea and ammonium nitrate. Plant composition data indicate no advantage in N uptake resulting from the slow release material. Notable delays in N response were noted from the use of SCU-30 in the spring of 1974.

151 A Comparison of Sulfur-Coated Urea and Several Other Nitrogen Sources for Fertilizing Corn and Small Grains. C. E. Rivard and V. A. Bandel (Univ. Maryland, College Park). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 154 (1974). A comparison was made of 4 nitrogen sources on soil nitrate level, concentration in the soil profile as a function of time, and N response of corn and small grains. Included were ammonium nitrate, urea, nitrate of soda, and sulfur-coated urea (SCU). Sulfur-coated urea on small grains resulted in lower yields than in the other sources. Maximum grain yields resulted after a soluble N source was applied in late March. Corn grain and silage yields following 0 to 537 kg/ha of N-plowed down indicated that these N sources were generally comparable. Residual soil N in 1972 following a 1971 application of 537 kg/ha of N resulted in grain yields on the SCU plots nearly double that obtained from the other N sources. Nitrate N concentrations in the soil profile were extremely variable. Soil nitrate levels from SCU were generally much lower immediately after application than from the other sources. By October, high nitrate concentrations still occurred under the SCU plots regardless of soil texture or rainfall. Soil nitrate concentrations ranged from very high to very low for the soluble sources depending upon soil texture and rainfall.

152 Response of Irrigated Corn and Potatoes to Sulfur-Coated Urea. L. M. Walsh and E. A. Liegel (Univ. Wisconsin, Madison). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 156 (1974). Potatoes (Russet Burbank, *Solanum tuberosum*) and corn (Trojan TXS-102, *Zea mays*) were grown on irrigated Plainfield sand (Typic Udipsamment) 3 consecutive yr. A single application of urea, a split application of urea, and a single application of sulfur-coated urea were used as N carriers. Nitrogen rates used were 67, 134, 201, and 268 kg/ha. The N was broadcast as supplemental N. Under severe leaching conditions, a single application of sulfur-coated urea was markedly more effective as a N carrier for potatoes than a single application of urea over all rates of N. The split application of urea produced potato yields similar to those from sulfur-coated urea. However, single and split applications of urea produced equal or better yields of potatoes than sulfur-coated urea when very little leaching occurred. On corn all carriers of N were equally effective, regardless of the leaching conditions. Apparently the deeper rooting of corn as compared to potatoes markedly reduced the amount of NO_3-N lost by leaching, even under severe leaching conditions.

153 Influence of Irrigation Systems on Movement of Nitrogen Released from Sulfur-Coated Urea. A. B. Onken *et al* (Texas A&M Univ. Agric. Res. Extension Center, Lubbock). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* pp. 152-3 (1974). Sweet corn was grown on a Miles lfs soil fertilized with sulfur coated urea mixed with NaBr at an N rate of 115 kg/ha. Irrigation water was applied to separate plots using sprinkler, furrow, and subirrigation systems. Soil samples were taken five times during the growing season at six locations laterally across the beds to depths of 240 cm. The soil samples were dried, ground, extracted and analyzed NO_3^-, NH_4^+, and Br^-. The NO_3^-, Br^-, and NH_4^+ were retained in the top 30 cm of soil in the subirrigated plot and moved to greater depths in the furrow plot than in the sprinkler plot. The continued release of N throughout the growing season in all plots was evidenced by the continued measurement of NH_4^+-N, with amounts of as high as 45 ppm measured at the last sampling date. In general, Br^- peaks coincided with those of higher concentrations of NO_3^-. This and other evidence indicate that Br^- is a reasonably good tracer for NO_3^--N movement.

154 Relative Efficiency of Sulfur-Coated Urea, Urea, and Ammonium Sulfate in a Calcareous Soil. R. C. Dalal, R. F. Dattoo, and T. Indalsingh (Univ. West Indies, St. Augustine, Trinidad). *Trop. Agr. 51* (4), 515-22 (Oct. 1974). The effi-

ciencies of S-coated urea (SCU), urea, and $(NH_4)_2SO_4$ as N sources for maize and Sudangrass in a calcareous soil were compared. The apparent N recoveries by the maize crop in 80 days from SCU, urea, and $(NH_4)_2SO_4$ were 69.4, 36.5, and 50.4%, respectively. Similar trends in N recovery using Sudangrass as a test crop were observed, although recovery was lower. Sudangrass absorbed significantly larger amounts of K and Mg when SCU was used as the N source, especially at higher rates, as compared to urea. With $(NH_4)_2SO_4$ and SCU as sources of N, uptakes of Ca and Mg by Sudangrass were similar.

155 Sulfur-Coated Urea Versus Urea and Ammonium Nitrate as a Nitrogen Source for Grain Sorghum. G. M. Prine (Univ. Florida, Gainesville). *Soil Crop Sci. Soc. Fla. Proc. 35;* pp. 38-42 (1976). Sulfur-coated urea (SCU), a slow release N source developed by TVA, was compared with NH_4NO_3 and urea as N sources for grain sorghum (*Sorghum bicolor* L. Moench.) on Kanapaha fine sand for three seasons at Gainesville, Florida. Nitrogen rates of 0, 78, 157, and 313 kg/ha were supplied by each carrier, and a 470 kg N/ha rate was tested for SCU only. Part of the treatments received all the N at planting and part received 39 kg N/ha at planting and the remainder as sidedressing. An unfertilized winter crop of rye (*Scale cereale* L.) or ryegrass (*Lolium multiflorium* Lam.) was used to measure residual N each season. No difference was found between the three N carriers in production of sorghum grain or silage. Time of application of N to sorghum did not affect yields. The sorghum gave no yield response above 157 kg N/ha. Rye and ryegrass yields and N content were slightly increased by the 313 and 470 kg N/ha. The 470 kg N/ha rate was toxic to sorghum seedlings. At the end of the third season, the pH and the Ca, Mg, and K contents of the top 15 cm of soil were greatly reduced for the treatment receiving 470 kg N/ha from SCU.

156 The Comparison of Sulfur-Coated Urea, Urea, and Ammonium Nitrate on Grain Sorghum Production. J. A. Roth and T. E. Fisher (Univ. Missouri Delta Center, Columbia). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 154 (1974). The application of N on delta soils of southeast Missouri prior to planting has been of considerable interest to assure an ample supply and reduce the work load during the planting and growing season. Sulfur-coated urea, urea, and ammonium nitrate were compared in the production of grain sorghum on Tiptonville silt loam and Portageville clay soils. Varying rates and times of application were included in the experiments. The fall applied sulfur coated urea was superior to ammonium nitrate and urea applied at the same time on clay soil, however the results were reversed on silt loam soil. The results indicated that sulfur coating of urea reduced denitrification on clay soil. Preplant or sidedressing of ammonium nitrate or urea produced higher yields on clay soil, whereas fall or preplant applications were maximum on silt loam soil. On clay soil, 168 kg of N/ha produced highest yield. On silt loam 112 kg of N/ha were sufficient.

157 The Effects of Rates of Application and Sources of Nitrogen on Nitrate Concentration in Oat Forage. B. S. Joshi and R. Prasad (Indian Agric. Res. Inst., New Delhi). *J. Br. Grassl. Soc. 32* (4), 213-16 (1977). A field experiment was conducted during the winter seasons of 1972-73 and 1973-74 to study the effects of application rates (0, 100, 200 kg/ha) and sources of N $(NH_4)_2SO_4$, calcium ammonium nitrate, urea, S-coated urea, and sulfathiazole-treated urea on nitrate-N concentration in oat (*Avena sativa* L.) forage. Nitrogen application increased the nitrate-N concentration, the effects being more marked when the rate was increased from 100 to 200 kg/ha than when it was raised from 0 to 100 kg/ha. The highest nitrate-N concentration in the dry matter ($> 0.16\%$) was obtained when calcium ammonium nitrate was applied at 200 kg N/ha. Sulfur-coated urea gave the lowest nitrate-N concentration. In 1 yr treatment of urea with sulfathiazole reduced nitrate-N concentration in oat forage.

158 Effect of Rates and Sources of Nitrogen Including Sulfur Coated Urea and Sulfathiazole Treated Urea on Yield and Quality of Oat Forage. B. S. Joshi and Rajendra Prasad (Indian Agric. Res. Inst., New Delhi, India). *Indian J. Agron. 24* (3), 301-6 (Sept. 1979). Results from a field experiment conducted during 1972-74 showed that in terms of green forage yield, oat gave a linear response up to 200 kg N/ha. Application of N increased crude protein, mineral matter, and ether extract but decreased crude fiber content in oat forage. For green forage production $(NH_4)_2SO_4$, calcium ammonium nitrate, and urea were equally effective. Sulfur-coated urea was least effective and produced least green forage containing significantly less crude protein and mineral matter. Treatment of urea with a nitrification inhibitor sulfathiazole offered no advantage. Crude fiber content was highest with calcium ammonium nitrate (12 ref).

159 Response of Wheat to Fall Applications of Sulfur-Coated Urea. Tom McCutchen *et al* (Milam Field Stn., Milam, Tennessee). *Tenn. Farm Home Sci.* No. 94; 9 (Apr.-June 1975). In 1971 tests were started to study the response of wheat to S-coated urea (SCU) when all N was applied in the fall. The tests were conducted for 1 yr at the Ames Plantation and for 3 yr on the Milam Field Station in Tennessee. Arthur and Arthur 71 wheat varieties were used. Treatments were 30, 60, and 90 lb N/acre as SCU and 0, 30, and 90 lb/acre as NH_4SO_3 in addition to a base application of 10-20-20 at 300 lb/acre. The check plot (30 lb N/acre as 10-20-20) received a spring topdressing of an additional 30 lb N/acre as NH_4NO_3. Significant responses to N treatments were obtained only in 1971-72 when the check treatment and the 90-lb N/acre as SCU gave the highest yields.

160 Effectiveness of Sulfur Coated Urea in the Cultivation of Wheat. A. F. Magalhaes. *Agron. Sulriograndense 12* (2), 133-40 (1976) (Port). A field trial was set up to evaluate the effectiveness of the sulfur coated urea as a source of N for wheat. Five levels of N (0, 30, 60, 90, 120 kg/ha) were applied to the soil prior to planting as urea and two types of sulfur coated urea. There was no significant difference among the N sources.

161 Response of White Winter Wheat in the Pacific Northwest to Nitrogen Applied as Sulfur-Coated Urea and Other Sources. C. F. Engle and E. T. Field (Washington State Univ., Pullman). In *Agronomy Abstracts 1974 Annual Meeting* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 148 (1974). Sulfur-coated urea is not used as a source of N and/or S for growing white winter wheat in Washington. Several N release rates of sulfur-coated urea (SCU) were compared with ammonium nitrate sulfate (ANS) for growing white winter wheat on several soil types, at rates of N from 0 to 160 lb/acre, and under a range of eastern

Washington climatic conditions. Sulfur-coated urea was surface applied in the fall and compared to ANS surface applied in the fall, spring, and fall-spring. In 1973, a very dry yr, SCU-30 (SCU with fastest release of N used) produced the highest yields of wheat with least damage from shriveling when rates of N exceeded 80 lb/acre. Spring application of ANS at 80 lb/acre was equal to or better than the same rate of ANS fall applied. Pre-harvest observations of trials in 1974 show SCU-40 (SCU with fastest release of N of any available from TVA) at 160 lb/acre to be looking very good.

162 Transformations of Soil and Fertilizer Nitrogen, and Possibilities of their Inhibition. J. Jung and J. Dressel (Landwirtschaftliche Versuchsstation der BASF Aktiengesellschaft, German Federal Republic). *Landwirtschaftliche Forschung, Sonderheft 34* (2), 74-89 (1978) (Ger). *Soils Fert. 42*, 1656. Incubation model and field studies with nitrate, ammonium and sulfur-coated urea fertilizers were conducted using five soils of varying texture. Mineralization potential ranged from 1.3 to 7.4% of organic-bound N; meteorological conditions had a marked influence on mineralization. Nitrification of ammonium-N varied among the soils. The effects of a number of nitrification inhibitors on the movement of N in soil, denitrification, N utilization by ryegrass and nitrate content of spinach are presented. Placement of fertilizer N in deep layers reduced wheat yield.

163 Effects of Nitrogen Rates and Sources on Agronomic Performance of Spring Triticale *Triticosecale*. U. R. Bishnoi and L. M. Mugwira (Alabama A&M Univ., Normal, Alabama). *Commun. Soil Sci. Plant Anal. 11* (9), 873-80 (1980). The N requirements for triticale (*X Triticosecale*, Wittmack) have not been determined for Alabama soils. To determine the effects of N sources and N rates on the agronomic performance of spring triticale, 'Beagle' and 'Drira' were grown on Norfolk loamy sand (Thermic Typic Paleudult) during two cropping seasons. The N treatment were 50, 100, and 200 kg N/ha applied as NH_4NO_3 or sulfur-coated urea (SCU). Increasing N rate increased plant height, grain yields, and, in the case of SCU, grain protein, but did not affect the number of spikes/plant and test weights. There was a high correlation between the grain yields and grain protein of 'Drira' grown with SCU fertilizer but not with NH_4NO_3.

164 Sulfur-Coated Urea as a Source of Nitrogen for Sugarcane. David Eastwood (Sugar Ind. Res. Inst., Jamaica). *Proc. Meet. West Indies Sugar Technol.*; pp. 60-8 (1976). Sulfur-coated urea (20.2% dissolution rate in 7 days in water), $(NH_4)_2SO_4$, and urea were tested as N sources for sugarcane. Rates of 60 and 120 lb/N/acre were surface applied as a single application. Yield responses were obtained with both rates irrespective of N sources in both plant and ratoon cane. At the same N rate, the sources were ranked as $(NH_4)_2SO_4$ = SCU > urea, irrespective of cane class and urea. On coarse-textured sands and loams, urea was less efficient in relation to $(NH_4)_2SO_4$ and SCU than on fine-textured clays. The levels of total and available S in the experiment soils made it unlikely that the superiority of $(NH_4)_2SO_4$ and SCU over urea derived from the S contributed to the soil by $(NH_4)_2SO_4$ and SCU. If the unit price of N in SCU is comparable with that of $(NH_4)_2SO_4$, this controlled-release fertilizer would offer an attractive alternative to straight N fertilizer for sugarcane.

165 Sulfur-Coated Fertilizers for Sugarcane: 1. Plant Response to Sulfur-Coated Urea. G. J. Gascho and G. H. Snyder (Agric. Res. Educ. Center, Univ. Florida, Belle Glade). *Soil Sci. Soc. Am. J. 40* (1), 119-22 (Jan.-Feb. 1976). Crop growth and yield on sand soils is often limited by low N availability due to leaching losses from the soil. This study was initiated to determine if S-coated urea (SCU) could supply adequate N nutrition and eliminate the need for repeated N applications for sugarcane (*Saccharum* spp.) grown on previously uncropped Immokalee fine sand in southern Florida. Single applications of two SCU's were compared with split application of $(NH_4)_2SO_4$ (AS), each at three N rates, 56, 112, and 168 kg/ha. Application of SCU at planting in November resulted in excellent growth and high leaf N concentrations in the spring but did not provide optimum N throughout the growing season. Leaf N concentrations in late summer and tonnages of sugarcane and sugar for SCU plots approached, but did not equal, those attained with four applications of AS. Higher tonnages were recorded for the slower releasing SCU than for the faster releasing source but both SCU sources released large amounts of N before the warm summer months when N is required in the highest quantities. The data indicate that SCU's which release N more slowly and/or a later application date should provide better N nutrition and eliminate the need for several split applications of soluble sources.

166 Sulfur-Coated Fertilizers for Sugarcane: 11. Release Characteristics of Sulfur-Coated Urea and Potassium Chloride. G. H. Snyder and G. J. Gascho (Agric. Res. Educ. Center, Univ. Florida, Belle Glade). *Soil Sci. Soc. Am. J. 40* (1), 122-6 (Jan.-Feb. 1976). Nitrogen release from S-coated urea and K release from S-coated KCl were examined by several techniques under field conditions in three south Florida sand soils in order to assist in the interpretation of plant response data and to provide insight into the use of three slow-release fertilizer materials. Decreased thickness of S coating, higher temperatures, and higher moisture generally favored nutrient release. However, considering the range of field conditions involved in the studies, variation, in N and K release were comparatively small. Release was rapid during the first 6 months, averaging 70-80% of that applied, but was much slower thereafter.

167 Slow-Release Fertilizer-Experimental Results R. S. Uchida, J. B. Thomson, and C. J. Young. *Hawaii Sugar Technol. Rep.* No. 33, 74-9 (1975). *Abstr. Trop. Agric. 1*, 6124. In experiments conducted in sugarcane fields in Hawaii, slow-release fertilizers showed promising results. The limited number of tests indicated, among other things, that these fertilizers were more efficient than urea and that TVA's sulfur-coated urea showed a trend for increasing sugar yield. The efficiency of fertilizers by reducing leaching and volatilization has been accomplished with the use of slow-release fertilizers.

168 Comparison of Sulfur-Coated Urea and Ammonium Sulfate Amended with N-Serve as Sources of Nitrogen for Sugarcane. R. C. Dalal and M. Prasad (Univ. West Indies, St. Augustine, West Indies). *J. Agric. Sci. 85* (3), 427-33 (Dec. 1975). A comparison of ammonium sulfate (AS) with and without N-Serve and S-coated urea (SCU) for sugarcane, studied in a pot experiment, showed that although the tillering, the leaf N concentration, and cane yield were increased by adding fertilizer N there were no significant differences in sources. However, AS and AS + N-Serve depressed the soil pH, more than SCU. In a field experiment where AS, urea, and

SCU were compared on a calcareous soil, it was observed that urea gave significantly lower cane and sucrose yields than AS and SCU when N was applied on the surface, possibly due to greater volatilization losses from urea. Subsurface application increased the efficiency of urea, although the method of placement had no significant effect on the N efficiency of AS and SCU. Ammonium sulfate was as effective as SCU. Thus the coating of urea by S increased its efficiency for sugarcane only when applied on the surface of a calcareous soil.

169 Progress Report on the Evaluation of Sulfur-Coated Fertilizers. M. Isobe, L. L. Buren, and Y. Yamaski (Hawaii Sugar Plant Assoc., Honolulu). *Hawaii Sugar Technol. Rep. 32*, 85-8 (1974). At 12 months, similar cane tonnages were produced with controlled-release sulfur-coated urea (SCU) fertilizer, applied single application, and with urea in multiple applications. The same results were obtained with SCK and with muriate of K. However, in other comparisons, the K-H_2O index and the K uptake were greater with muriate of K than with SCK without affecting growth adversely. More results will be obtained at harvesting.

170 Efficiency of Urea, Nitrification Inhibitor Treated Urea, and Slow-Release Nitrogen Fertilizers for Sugarcane. K. S. Parashar *et al* (Indian Agric. Res. Inst., New Delhi, India). *Z. Pflanzenernaehr. Bodenkd. 143* (3), 262-7 (June 1980). A field experiment conducted for two crop seasons (1976-77 and 1977-78) showed that the treatment of urea with nitrification inhibitor Nitrapyrin (also called N-serve) or neem cake increased its efficiency by preventing N losses and produced significantly more cane. In one of the yr S-coated urea (Gold N) at lower rate (75 kg N/ha) gave higher sucrose content in juice and significantly more commercial cane sugar (CCS) than uncoated urea. Considering both the cane yield and CCS production mixing or coating of urea with neem cake holds considerable promise and needs wider testing along with and in comparison to nitrification inhibitors and S-coated urea and other slow release fertilizers for increasing the efficiency of N applied to sugarcane (14 ref).

171 Sulfur-Coated Fertilizers for Sugarcane in Hawaii. M. Isobe (Exp. Sta. Hawaiian Sugar Planters' Association, Honolulu, Hawaii). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 150 (1974). Sulfur-coated fertilizers were evaluated cooperatively with sugar plantations and TVA in an attempt to reduce fertilization costs for sugarcane. Results of the first experiment with SCU were encouraging. With less N and fewer split applications, SCU plots yielded as much cane and sugar as those plots fertilized with conventional urea. Subsequent experiments were installed under different climatic and soil conditions to compare single applications of SCU and SCK with 4 to 5 split applications of conventional urea and muriate of potash. Results from cane sampling in the 1st yr of a 2-yr crop showed that SCU was equal to its counterpart and SCK was almost as good. Complete evaluation will be made at final harvest. Field investigations on N release by SCU indicated that a single application feeds sugarcane at a desirable rate. The K release was slightly faster than the N release and possibly not the best for some soil and climatic conditions.

172 Sulfur-Coated Fertilizers for Sugarcane. III. Summary and Economic Interpretation of Research Results. G. J. Gascho and G. H. Snyder (Univ. Florida, Gainesville). In *Agronomy Abstracts 1975 Annual Meetings* (held Knoxville, Tennessee, Aug 24-30, 1975). *Madison, Wisconsin: Am. Soc. Agron.;* p. 173 (1975). Sulfur-coated-urea and -KCl have been investigated for Florida sugarcane on sandy soils. The objectives were to reduce the number of fertilizer applications required, maintain adequate availability to the plant, and increase yields. Release rates, nutrient levels and timing of applications were studied in six experiments. A single application of sulfur-coated urea resulted in yields that were generally equal to three to four applications of the same total amount of soluble N. However, analysis indicated no economic advantage. Likewise no advantage was found for sulfur-coated KCl. The inability of a given grower to obtain timely applications of soluble fertilizer or extreme leaching conditions could turn the economic advantage to sulfur-coated fertilizers due to any increased yields or savings in the amounts of nutrients applied.

173 Nitrogen Leaching from Soil and Uptake by Sugarcane from Various Urea-Based Fertilizers. A.M.O. El Wali, F. Le Grand, and G. J. Gascho (Univ. Florida, Gainesville). *Soil Sci. Soc. Am. J. 44* (1), 119-22 (Jan.-Feb. 1980). Two greenhouse experiments were conducted to determine the relative efficiencies of sulfur-coated urea (SCU) and urea with and without N-Serve or S on growth, uptake, and subsequent losses of N from sugarcane grown on Arrendondo fine sand. Three SCU products, with initial dissolution rates of 32.5, 29.6, and 26.8% of the total N in water during a 7-day period were compared with urea, urea applied in two applications, urea + N-Serve, and urea + powdered S at the equivalent amount of S in SCU. In another experiment SCU-30 was compared with urea, urea applied in two applications, urea + N-Serve, and urea + powdered S at two irrigation regimes (36 and 48 mm/week). Growth and uptake of N were not significantly different among treatments, but there were significant differences in leached and residual N. Nitrogen leaching varied from 6 to 24% of applied N depending on the fertilizer treatment and irrigation level. Leaching of the applied N was mainly in the NO_3 form, but when irrigation took place before the N hydrolyzed from urea was completely nitrified, leaching the NH_4 form was of considerable magnitude. The least N leaching resulted from application of SCU. Inclusion of N-Serve with urea did not improve fertilizer efficiency. In these experiments, SCU was more promising for commerical use than was granular urea mixed with N-Serve. Leaching losses of N from all the sources increased with irrigation but to a varying degree. Eleven to 15% of the applied N was not accounted for by the plant, leachate, or soil (13 ref).

174 Sulfur-Coated Urea as a Nitrogen Source for Cotton. Richard Maples, J. L. Keogh, and W. E. Sabbe (Univ. Arkansas, Fayetteville). *Arkansas Agric. Exp. Stn., Bull.* 807; 23 pp. (1976). The efficiency of S-coated urea (SCU) as a N source for cotton was tested at rates of 0, 50, 100, and 150 lb N/acre on Sharkey clay soils and compared with urea at the same rates. The N increased the cotton yields significantly with no difference between the two fertilizers being found. From plant tissue analyses, it was determined that there was a significant increase in S uptake the 2nd yr. From soil tests, it was observed that a significant lowering of soil pH occurred the 3rd yr. In tests in which SCU was compared with urea and S applied preplant or side dressed, the latter gave significantly greater yields. In tests with SCU and urea applied at 25 lb N/acre to Dubbs and Dundee fine sandy loam, N increased yields significantly, with SCU being superior when band applied and urea superior by broadcast application.

175 Influence of Rates and Sources of Nitrogen on Growth, Nitrogen Uptake, and Yield of Cotton (*G. hirsutum* L.). V. Seshadri and Rajendra Prasad (Indian Agric. Res. Inst., New Delhi, India). *Z. Pflanzenernaehr Bodenkd 142* (5), 731-9 (Oct. 1979). Field experiments were conducted on cotton with different forms of urea applied at rates of 40 and 80 kg N/ha. Nitrogen increased plant height, dry matter accumulation, number of bolls/plant, seed cotton yield, and N uptake. The proportion of dry matter and N in the stem was increased and that in the leaves was reduced by N application. Sulfur coated urea (all applied at sowing) was about the same in effect as N-Serve treated urea and gave significantly more seed cotton yield than untreated urea, neem cake treated urea, and sulfur coated urea (applied in two splits). Nitrogen efficiency was greater with 40 kg N/ha rate than with 80 kg N/ha. Sulfur coated urea (all applied at sowing) gave the highest N efficiency followed by N-serve treated urea (12 ref).

176 Comparative Study of Effects of Urea and Sulfur-Coated Urea on Sugar Beet Crop in Iran. A. F. Mahdavi, G. Bakhtiari, and B. K. Nejad (Soil Inst. of Iran, Tehran, Iran). In *Proc: First Review Meeting I.N.P.U.T.S. Project (Increasing Productivity Under Tight Supplies)* (held Honolulu, Hawaii, June 7-18, 1976). S. Ahmed, M. Sadiq, and L. Kobayashi, Editors. *Honolulu, Hawaii: Food Institute;* pp. 191-8 (1976). *Soils Fert. 42,* 1992. In field trials in (a) East Azarbaijan, (b) Loristan and (c) central provinces, Iran, 90 or 180 kg N as urea or S-coated urea (SCU)/ha was applied by banding and broadcasting with or without incorporation. At (a) 120 kg P_2O_5 + 45 kg K_2O/ha were applied, at (b) 90 kg P_2O_5 + 45 kg K_2O/ha and at (c) 90 kg P_2O_5 + 60 kg K_2O. With urea average root yields of 36.28, 31.0, and 36.28 tons/ha for (a), (b), and (c), respectively were obtained compared with 23.73, 26.93, and 23.73 tons/ha for (a), (b), and (c), respectively with SCU. Method of application of N appeared to have no significant effect on root yields. At (b) root yields were only significantly higher when 180 kg N/ha was applied.

177 Effects of 2-Chloroethylphosphonic Acid and Nitrogen Fertilizer on Flue-Cured Tobacco Growth and Maturity. C. R. Blatt and A. G. Sponagle (Agric. Canada, Kentville, Nova Scotia, Canada). *Can. J. Plant Sci. 57* (4), 1179-83 (1977). The 2-chloroethylphosphonic acid (ethephon) was applied at several concentrations and at various stages of growth to tobacco cultivars Hicks Broadleaf and Delhi 34. Generally, ethephon at 1920 ppm advanced the date of harvesting and increased the early yield of mature leaves (75 days after planting) when compared with the control. Ethephon applications did not affect total fresh wt yields when compared with the controls. Nitrogen (N) sidedressings did not increase early or total yields when compared with the initial planting application of 34 kg N/ha. The source of N (ammonium nitrate, urea, and sulfur-coated urea at 26 and 36% dissolution rates) utilized in the planting fertilizer had little effect on total fresh wt yields. Sulfur-coated urea (13% dissolution rate) utilized in the planting fertilizer decreased total fresh wt yields when compared with ammonium nitrate, urea, and sulfur-coated urea at the 36% dissolution rate.

178 Relative Efficiency of Urea and Sulfur-Coated Urea for Upland Irrigated Rice. K. P. Singh and V. Kumar (Haryana Agric., Haryana, India). *Indian J. Agron. 25* (1), 154-5 (1980). In a trial in the kharif (monsoon) season of 1973 with rice given 50-100 kg N/ha as urea and/or S-coated urea applied in one-three split dressings, application of 50 kg N/ha as S-coated urea at transplanting + 25 kg N/ha as urea at tillering + 25 kg N/ha as urea at panicle initiation or 100 kg N/ha as S-coated urea as in the above three split dressings gave the highest paddy yields of 7.33 and 7.0 tons/ha, respectively, compared with 2.73 tons without N.

GRASSES

179 Evaluations of Sulfur-Coated Urea for Southwestern Rangeland Use. G. B. Donart, R. D. Pieper, and K. O. Fulgham (New Mexico State Univ., Las Cruces). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 148 (1974). Sulfur-coated urea was compared to urea, ammonium nitrate, and ammonium sulfate at rates of 45 kg/ha/yr and 90 kg/ha every other yr. Fertilizer treatments were broadcasted in the spring. Plant production was obtained at the end of the growing season. Production from sulfur-coated urea treatments was comparable to other sources of N for both rates of application. End of season crude protein content of grasses was in excess of 9% when treated with sulfur-coated urea. Precipitation pattern and dissolution rate of fertilizer are primary factors regulating program effectiveness. Sulfur-coated urea with a high dissolution rate is being studied to overcome this problem.

180 Levels and Sources of Nitrogen for Winter Annual Pastures Grazed by Growing Beef Calves. J. E. Bertrand and L. S. Dunavin. *Soil Crop Sci. Soc. Fla. Proc. 35;* pp. 70-3 (1976). Levels and sources of N were compared. Sulfur-coated urea (SCU) has a slower dissolution rate than ammonium nitrate (AN) and could reduce the number of applications of N required in a given period. Two experiments were conducted to evaluate levels of SCU and AN (Exp. 1: 113 and 225 kg/ha N, and Exp. 2: 0, 56, and 113 kg/ha N) for pastures containing a forage mixture of triticale (*Triticale hexaploide* Lart.) or rye (*Secale cereale* L.) ryegrass (*Lolium multiflorum* Lam) and crimson clover (*Trifolium incarnatum* L.). There were no statistical differences in daily gains of calves grazing winter annual pasture forages due to N fertilization. In Exp. 2 particularly, N fertilization did not influence forage quality as much as it influenced quantity. The increased gain/ha by calves grazing the pasture forages receiving two high levels of N was due to higher forage production and concomitantly longer grazing periods. The N from one application of SCU at the beginning of the grazing season was no different from an equal amount of N from three applications of AN during the grazing season.

181 Effect of Sulfur-Coated Urea and Urea on the Productivity and Nitrogen Utilization of *Cynodon IB. 8.* M. A. Mohamed Saleem (Univ. Ibadan, Ibadan, Nigeria). *East Afr. Agric. For. J. 43* (1), 25-30 (July 1977). Use of sulfur-coated urea (SCU) did neither improve productivity nor N utilization as compared to readily soluble urea. This was revealed in a study comparing the two sources of N on the performance of *Cynodon IB. 8.* Growth of the pasture with SCU differed from the established pattern suggesting greater dissolution under conditions where the experiment was sited. Residual effects were very low and did not last for more than one growing season. Data point to the ineffectiveness of SCU and establishes that better results in terms of productivity and yield distribution can be expected from split application of urea (10 ref).

182 Effect of Urea and Sulfur-Coated Urea on the Dry Matter and Protein Production of Gulf Ryegrass. D. G. Westfall, A. W. Smith, and G. E. Evers (Texas A&M Univ., College Station). *Tex. Agr. Exp. Sta. Progr. Rep.* 2906 (April 1971). The influence of N rate and source on the dry matter and protein production of Gulf ryegrass was determined throughout the growing season. The rates of N varied from 0 to 200 lbs/acre in 50 lb increments, and the N sources were urea and two slow release sulfur-coated urea (SCU) fertilizers. One yr results show that forage and protein production from one application of SCU was more evenly distributed throughout the growing season than that from two applications of urea. Immediately following the application of urea, there was a flush of growth followed by declining dry matter and protein production for several weeks. The average total dry matter production from urea was higher than from SCU, but there was no significant difference in the total crude protein production. Controlled release rate N fertilizers can benefit the rancher by offering him two advantages: (1) the application of all the fertilizer at planting and (2) a more uniform distribution of forage production throughout the growing season. The economics involved has not been evaluated on these preliminary results because manufacturing costs of SCU have not been determined.

183 Production of Rye and Ryegrass Forage with Sulfur-Coated Urea and Ammonium Nitrate. L. S. Dunavin (Agric. Res. Center, Jay, Florida). *Agron. J. 67* (3), 415-17 (May-June 1975). The need for fertilizer materials which provide particular elements to plants over a long period of time is well known. This reduces the expense of numerous applications. In the production of forage from grasses, N is an element which needs to be continually available but is one which is normally rather quickly dissipated. Sulfur-coated urea (SCU) has given promise as a slow-release source of N and the need to compare it with other sources of N, such as ammonium nitrate (AN), for various crops has arisen. This investigation was conducted to determine the value of the use of SCU as an alternative to AN in the production of forage from rye (*Secale cereale* L.) and ryegrass (*Lolium multiflorum* Lam.). Sulfur-coated urea compositions having dissolution rates of 10, 20, and 30% (dissolution in water in 7 days) were applied at annual rates of 100, 200, and 400 kg of N/ha. Ammonium nitrate was also used at these same rates of N. Ammonium nitrate was tested at one and three times of application. Data were obtained for two seasons with five monthly harvest dates in each season. For the 2-yr period, the highest yield ($P < .05$) was obtained from AN fertilization at a 400 kg/ha rate of N when three applications were made. The next highest yields were obtained when 400 kg/ha of N was applied as SCU with no difference between the dissolution rates. For the 2-yr period, there was no significant difference in the total recovery of N from forage receiving 400 kg/ha of N from AN and that fertilized with SCU at either the 20 or 30% dissolution rates. Monthly forage yield and N recovery differences among rates and between the fertilizer sources were evident.

184 Comparison of Ammonium Nitrate and Sulfur-Coated Urea on Ryegrass Production in South Central Florida. P. Mislevy and C. L. Dantzman (Agric. Res. Cent., Ona, Florida). *Soil Crop Sci. Soc. Fla. Proc. 33;* pp. 199-201 (1973). The influence of single applications of S-coated urea forms and NH_4NO_3 + S on yields, digestibility, and uptake of N by Gulf ryegrass (*Lolium multiflorum*) was studied. Slow-release S-coated urea (7.2% initial dissolution), medium-release S-coated urea (34.0% initial dissolution), and NH_4NO_3 (each with an equivalent amount of S) were compared at 0, 56, 112, and 168 kg/ha rates. Four harvests of ryegrass were removed over a 4.5 month period. Ryegrass yields increased as N rate increased regardless of N carrier. High rates of the slow-release N in a single application produced the highest dry matter yields. However, lowest dry matter yields were obtained when the slow-release N was applied at low rates (56 and 112 kg/ha). The in vitro organic matter digestion (IVOMD) of ryegrass varied little among rates of N, but in the first harvest the IVOMD was significantly higher for the 168 kg/ha rate than for zero N. Nitrogen uptake and percent N recovery were generally highest in the first harvest. In addition, as N carriers increased in solubility, N uptake and percent N recovery also increased in the first harvest. Thus, high levels ($\geqslant$ 168 kg/ha) of a slow-release, sulfur-coated urea (7.2% initial dissolution) applied in one application may be preferred for south central Florida ryegrass production.

185 Sulfur-Coated Urea Compared With Urea and Ammonium Nitrate as a Source of Nitrogen for Swards of Annual Ryegrass (*Lolium rigidum* Gaud.). D. J. Maschmedt and P. S. Cocks (Dep. Agric. and Fish., Adelaide, Australia). *Agric. Rec. (S. Aust.) 3* (4), 4-7 (1976). *Biol. Abstr. 62,* 40888. Two grades of S-coated urea (36.1% and 38.6% N) were compared with urea and NH_4NO_3 as sources of N in swards of annual ryegrass (*Lolium rigidum* Gaud.). The urea and NH_4NO_3 were applied as single autumn dressings of 250 kg/ha of N, or as five dressings of 50 kg/ha at approximately monthly intervals. The S-coated urea was applied in the autumn as a single dressing. The comparisons were made over one growing season. The S-coated urea resulted in better late winter and early spring growth and more uniform seasonal production than did single dressings of urea or NH_4NO_3. Swards receiving the S-coated urea significantly outyielded the sward receiving the single dressing of uncoated urea, but, over one season and with above average rainfall, yielded the same as that receiving the one dressing of NH_4NO_3. The swards recovered 65% and 78% of the N from the two grades of S-coated urea, and a further 4% and 1%, respectively, remained on the surface of the soil at the end of the experiment. This compared with only 44% recovery of the single dressing of urea, and 88% of the single dressing of NH_4NO_3. Sulfur-coated urea maintained higher levels of mineral N in the top 10 cm of soil than did the other treatments.

186 Forage Grass Responses to Sulfur-Coated Urea. D. A. Mays (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1975 Annual Meetings* (held Knoxville, Tennessee, Aug. 24-30, 1975). *Madison, Wisconsin: Am. Soc. Agron.;* p. 174 (1975). Sulfur-coated urea (SCU) has been evaluated for use in grass production over a wide geographical area with both cool- and warm-season species. It has frequently been compared with ammonium nitrate (AN) and uncoated urea (U). In the majority of cases spring-applied SCU has given yields and forage distribution similar to those from several split applications of AN totaling the same amount of N. Spring-applied SCU has almost always been superior to spring-applied AN and U in terms of seasonal forage distribution and has frequently been superior to spring-applied U in yield. Nitrogen recovery from SCU and AN has often been similar, while recovery from U is usually lower. Since significant amounts of SCU may not dissolve during the first growing season, the most favorable comparisons with soluble N sources have usually been obtained with multiple-yr experiments on the same plot area.

In one or two experiments, where subsurface water samples below grass sods have been obtained for analysis, SCU has resulted in lower NO_3 and total N levels than AN or U.

187 Forage Production From Pearl-Millet Following Rye and Ryegrass Fertilized with Sulfur-Coated Urea. L. S. Dunavin (Inst. Food & Agr. Sci. Agr. Res. Center, Jay, Florida). *Soil Crop Sci. Soc. Fla. Proc. 39:* pp. 92-5 (1980). The use of fertilizer materials with a slow release rate has accentuated the need to determine the value of residuals to succeeding crops. This investigation was conducted over a period of 2 yr to ascertain the value of residuals by determining yield and nitrogen (N) uptake by pearl millet [*Pennisetum americanum* (L.) K. Schum.] when it followed rye (*Secale cereale* L.) and ryegrass (*Lolium multiflorum* Lam.) fertilized with sulfur-coated urea (SCU) and ammonium nitrate (AN). Compositions of SCU having dissolution rates of 10, 20, and 30% (dissolution in water in 7 days) were each applied to the winter crops at annual rates of 100, 200, and 400 kg/ha of N. Ammonium nitrate was applied at the same rates of N in one or three applications. Additional AN was applied to millet at 50, 100, and 200 kg/ha of N on plots which had received 100 kg/ha of N from AN during the rye and ryegrass period. Yields of millet were highest where summer applications of AN were made; however, there was no statistical difference (Tukey's HSD, $P < 0.05$) between these yields and yields from the SCU-20 treatment. Nitrogen uptake was highest where AN was applied to the millet during the summer, but, statistically, this exceeded only the uptake from the treatment consisting of SCU-10 applied to the preceding crop of rye and ryegrass and the uptake when three applications of AN were applied to the preceding crop.

188 Effects of Sulfur-Coated Ureas on Forage Production and Nitrogen Recoveries. J. E. Matocha (Texas A&M Univ. Agric. Extension Center, Overton). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 152 (1974). Laboratory and field experiments were conducted to evaluate sulfur-coated ureas (SCU) and soluble N fertilizers in forage production. Measurements included NH_3-N volatilization, N recovery, and dry matter production. Single applications of SCU's with N release rates of 20 and 10% (SCU-20, SCU-10) were compared with split applications of urea and NH_4NO_3 at three rates of N on Coastal bermudagrass. Sulfur was eliminated as a variable. Coating urea reduced NH_3-N losses to a fraction of those from uncoated urea. Maximum volatilization losses occurred from both coated and uncoated materials when the soil was limed. A coating of S plus wax reduced NH_3-N losses to one-third of those when only S was used. Based on NH_4NO_3 as a standard of comparison, SCU-20 produced 86, 99, and 97% of NH_4NO_3 at 224, 672, and 1120 kg N/ha, respectively, over a 4-yr period. Similar values for SCU-10 were 81, 96, and 99%. Nitrogen efficiencies at the low N rate were in the following order: NH_4NO_3 > Urea > SCU-20 > SCU-10, while at the 672 kg/ha N rate these changed to Urea > SCU-20 > NH_4NO_3 ≥ SCU-10. Relative performance of SCU-10 was inversely linear with rainfall occurring early in the season (April, May). Similar relationships for uncoated urea and NH_4NO_3 had nonsignificant r values.

189 Cool-Season Grass Response to Sulfur-Coated Urea. P. L. Carson *et al* (South Dakota State Univ., Brookings). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* pp. 146-7 (1974). The effect of sulfur-coated ureas with dissolution rates of 10, 20, and 30% were compared with urea and ammonium nitrate on cool-season grasses grown in the Northern Great Plains. Rates of application were 0, 78, and 156 kg/ha of N. A time of application variable (fall versus spring) was included. Yields were taken during the summer following the spring application and again the next summer for carryover. The addition of N increased yield the first yr. The average check yield was 2298 kg compared to 5745 kg/ha where 157 kg of N was applied. Comparison of carriers show that the yields decrease as the supply of readily soluble N in the controlled-release fertilizer decreased. This decrease was as much as 25% of the maximum yield obtained with the more soluble N sources. The time of application (fall versus spring) had very little influence on the yield. The yield increase from spring-applied fertilizers over those applied in the fall was 5% or less. The residual effects on yield the following yr from the various N carriers was varied. The N carriers had no effect on the yield when the 78 kg/ha rate of application was compared. But at one site when the 156 kg/ha rate of application was compared, the 30% sulfur-coated urea produced 673 kg/ha more hay than with ammonium nitrate.

190 Soluble and Slow-Release Nitrogen Fertilizer Effects on Grass Forage, as Influenced by Rate and Placement. S. E. Allen, G. L. Terman, and C. M. Hunt TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *J. Agr. Sci. 77* (3), 397-404 (Dec. 1971). Soluble ammonium nitrate (AN) and urea were compared with slow-release oxamide and sulfur-coated urea (SCU) as N sources for clipped annual ryegrass (*Lolium multiflorum*) or common bermudagrass (*Cynodon dactylon*) in four greenhouse experiments. Mixed and surface applications of a wide range of N rates were evaluated for 9 to 14 cuttings of grass forage. Both granular oxamide and SCU exhibited slow-release N properties, especially when surface-applied. Uptake distribution of N with high application rates of AN and urea tended to resemble that with the slow-release sources. Slow-release properties of oxamide and SCU were accentuated at high application rates. Lower N recovery from surface-applied urea than from AN indicated volatilization loss of urea N. Volatilization loss also occurred with oxamide, but low N recovery from oxamide and SCU resulted largely from incomplete dissolution of the granules during the 18- to 34-week experimental periods. Very low N recovery was obtained from urea formaldehyde having an activity index of 42.

191 Coated and Other Slow-Release Fertilizers for Forages. S. E. Allen and D. A. Mays (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Forage Fertilization. Madison, Wisconsin: Amer. Soc. Agron.;* pp. 559-82 (1974). Performance of S-coated urea (SCU) applied to warm-season and cool-season grasses was similar to that of NH_4NO_3 in four split applications in total forage yield. Sulfur-coated K markedly reduced luxury uptake of K in early growth and S-coated P had the undesirable effect of reducing early seedling response. A good case was seen for the use of SCU on warm-season and on turf grasses, given an economic cost.

192 Effects of Sulfur-Coated Urea on California Annual Grassland Yield and Chemical Composition. C. E. Vaughn, M. B. Jones, and J. E. Ruckman (Univ. California, Hopland).

Agron. J. 71 (2), 297-300 (May.-Apr. 1979). Urea (U), urea with 100-mesh elemental S (U + S), and two formulations of SCU were broadcast on resident annual grassland, dominated by annual bromes (*Bromus* spp.), wild oat (*Avena barbata*), broadleaf filaree (*Erodium botrys*), and clover (*Trifolium* spp.) in a climate with cool, rainy winters and hot, dry summers. Forage yield and N and S uptake were measured seasonally in the 1st yr and annually the following 5 yr. Seasonal growth distribution was similar from all fertilizers in the 1st year. However, U + S was significantly more productive and gave greater herbage S uptake than the SCU's and U throughout the first growing season, and greater N uptake in the first winter. Residual studies suggested the long-term benefit of S fertilization; the U + S and SCU treatments were significantly more productive for the last 5 yr. Residual N uptake responses were similar to the yields. Herbage S uptake was similar in the U and check treatments for the entire study. The more heavily coated SCU formulation gave greater S uptake than both U + S treatments in the 4th and 6th yr after application. It was concluded that the SCU's were of no greater benefit than urea combined with fine S in fertilizing California annual grasslands. The slow release of N from SCU did not give any greater apparent residual N response. There was a long-term response to the larger particles of S in SCU, but it is questionable that this would justify the extra cost of the fertilizer (14 ref).

193 Sulfur-Coated Urea and Uncoated Soluble Nitrogen Fertilizers for Fescue Forage. D. A. Mays and G. L. Terman (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Agron. J. 61* (4), 489-92 (July-Aug. 1969). Field experiments were carried out during 1965-67 to compare rates, sources, and times of N topdressing for 'Kentucky 31' fescue (*Festuca arundinacea*). Uncoated ammonium nitrate (AN), urea, and other readily soluble N fertilizers resulted in higher first-cutting yields, which were higher in content of total N. Sulfur-coated urea (SCU) resulted in lower first-cutting and higher later-cutting yields than did the soluble N sources. Total annual yields were usually similar with all N sources. Mixtures of AN and SCU or split applications of AN resulted in the most uniform seasonal growth and N content. Lower yields and apparent crop recovery of N from uncoated urea and urea ammonium phosphate indicated lower efficiency of these urea-containing N sources for topdressing, particularly at higher N rates. December, January, February, and March topdressing dates had rather similar effects on forage yields and N contents.

194 Sulfur-Coated Urea: A Slow-Release Nitrogen Source for Grass. D. A. Mays (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Proc. Int. Grassland Congr., 11th;* pp. 428-30 (1970). The Tennessee Valley Authority has developed an effective slow-release N fertilizer by coating granular urea with elemental S and microcrystalline wax. Sulfur-coated urea was compared with NH_4NO_3 and uncoated urea for production of tall fescue (*Festuca arundinacea*) and Coastal bermudagrass (*Cynodon dactylon*). When these N sources were compared on tall fescue, spring forage production was less but summer and fall production was higher from S-coated urea than from the soluble N sources. In trials on Coastal bermudagrass, the coated product was superior in total yield and uniformity of seasonal production when all sources were applied in a single spring application, but not with four split applications.

195 Nutrient Uptake by Grass and Leaching Losses from Soluble and Sulfur-Coated Urea and Potassium Chloride. S. E. Allen, G. L. Terman, and H. G. Kennedy (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Agron. J. 70* (2), 264-8 (Mar.-Apr. 1978). This study was conducted to measure crops response to N or K in uncoated urea, ammonium nitrate (AN), S-coated urea (SCU), KCl, and S-coated KCl (SCK) and to relate leaching losses to NO_3-N and cations. In one series, granular N sources to supply 200 or 400 kg of N/ha were mixed with the upper 20 cm of a 1:1 mixture of Norfolk sandy loam and builders sand contained in 15-x 120-cm columns. A second series was similarly fertilized with K sources to supply 100 or 200 kg of K/ha. Soil columns were left fallow or planted to tall fescue (*Festuca arundinacea* Shreb. 'Kentucky 31') which was harvested six times at 4-week intervals. Then stubble and roots were incorporated into the soil along with a second application of N or K and cultures were planted to sorghum-sudangrass [*Sorghum bicolor* (L.) Moench x *Sorghum vulgare sudanese* 'Green M'], which was harvested four times at 4-week intervals. Water was applied as required for crop growth and once during each growth period all columns (including fallow) were heavily watered to collect 2 L (10 cm) of leachate from each. Total recovery of N by both crops was in the order: SCU-12 > split-AN > SCU-20 > urea > AN > no N. With cropping, 0 to 11% of applied N was found in drainage water. Under fallow, losses of N were much higher (29 to 72%) and were in the order: split-AN > SCU-12 = SCU-20 > AN = urea > no N. These results support the premise that slow-release fertilizers supply more N for crop response, but may not reduce leaching losses. Leaching of cations was well correlated with loss of NO_3-N (r = 0.83 to 0.90) under fallow, but was less correlated (r = 0.33 to 0.74) under grass. Recovery of K by both crops was near 100%. Applied K decreased loss of NO_3-N, Ca, and Mg under cropping and increased losses under fallow. Leaching of NO_3-N and cations was highly correlated. Applied N and oxidation of S in S-coated products both contributed to acidification of the soil, which intensified leaching of Ca and Mg.

196 Urea Release from Sulfur-Coated Urea and Nitrogen Utilization by Tall Fescue. G. S. Pettygrove (Oregon State Univ., Corvallis). *Diss. Abstr. Int. B38*, 994. Little is known of the mechanism of urea release from S-coated urea (SCU) and the environmental factors which affect the urea release rate. Objectives of this thesis were: (1) to determine factors which affect the rate of N release from SCU; (2) to compare N utilization by tall fescue (*Festuca arundinacea* Schreb.), fertilized with urea or SCU. The rate of urea release from SCU surface-applied to soil was determined during incubation for periods of up to 5 months under a range of temperatures (5 to 35°) and soil water potentials (-5 to -30 bars). Three SCU fertilizers with different 7-day urea release percentages and sealants were studied: SCU 4 (wax sealant); SCU 25 (polyethylene-oil sealant, 30:70 w/w); and SCU 23 (no sealant). After a lag period of 25 days, wax-sealed SCU applied to nonsterile soil at 25° and -5 bars water potential released urea at a rate of 1.0%/day. In sterile soil, after an initial release of about 10%, no further release occurred. At -15 and -30 bars water potential in nonsterile soil, release took place at 0.5%/day, with a lag period of up to 60 days. SCU sealed with polyethylene-soil released urea at a slightly faster rate at -30 bars than at -5 and -15 bars. Following an initial release of 10%, urea release rates from wax-sealed SCU at 35, 25, 15, and

5% were 1.5, 0.71, 0, and 0%/day, respectively. The urea release pattern from multi-granule samples of SCU 4, 23, and 25 was shown to correspond to the coating thickness distribution. The coating thickness distribution can be rapidly determined and is a better indicator of the long-term urea release pattern than the conventional 7-day release test. In the field experiment, over a 4-yr period, tall fescue fall-fertilized with SCU produced about 20% more dry matter than fescue fall-fertilized with urea, versus 50 mt/ha at the 800-kg N/ha/yr rate. Fall application of SCU and split application of urea resulted in the same dry matter yield. Residual N resulted in higher yields by SCU-fertilized tall fescue during the 2nd, 3rd, and 4th yr. Four-year N recoveries by tall fescue receiving fall applications of 800 kg N/ha/yr as urea, SCU 30, or SCU 4 were 43, 58, and 61% respectively. Over a 2-yr period NO_3-N leaching losses from plots fertilized with urea (400 kg N/ha/yr), SCU 4 (400 or 800 kg N/ha/yr), or urea (800 kg N/ha/yr) were estimated at 65, 20, 19, and 126 kg N/ha, respectively. Nitrate-nitrogen leaching losses were < 10% of the total N applied.

197 How Different Sources and Rates of Nitrogen Fertilizer Affect the Production of Tall Fescue. C. D. Spies, C. B. Southard (Purdue Univ., Lafayette, Indiana), and C. Fanning. In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin; Am. Soc. Agron.*: p. 155 (1974). Tall fescue (*Festuca arundinacea*) was fertilized at the beginning of the growing season in late March. Ammonium nitrate, urea, and two sulfur-coated urea sources were applied at 0, 67, 134, and 201 kg N/ha. Uniform application of P and K was broadcast on all plots. Three harvests were made during the growing season and measurements included percent N, protein, and total dry matter. Ammonium nitrate and urea gave greater total yield at the two lower rates of application but at the high rate (201 kg/ha) all sources gave similar yields. Production was uniformly divided between the three harvests with the sulfur-coated urea sources whereas most of the response from the other two sources was obtained at the first harvest.

198 Sulfur-Coated Urea as a Commercial Nitrogen Source for Established Pastures. B. W. Remick (Missouri Farmers Association, Columbia, Missouri). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*: p. 154 (1974). Sulfur-coated urea at the 20% and 30% dissolution rates was compared with ammonium nitrate and prilled urea at 60 and 120 kg/ha N on established fescue sod. The randomized block technique was used employing three replications. Treatments were applied on March 1 and cutting taken on May 4, June 14, and October 10. Sulfur-coated urea demonstrated the capability to supply N on a season-long basis and to sustain fescue growth into late fall after only one application. Data indicates this to be the direct result of the interaction between increasing N level and decreasing dissolution rate. It was most clearly demonstrated in those plots treated with SCU-20, having the lower dissolution rate of the two sulfur-coated products tested, at 120 kg/ha N. This compared favorably with results from the plots treated with the conventional products which out-yielded sulfur-coated urea at both N rates at the first but sharply declined in yield at the second and third cuttings. Both sulfur-coated ureas outyielded these conventional products for the season at the 120 kg/ha N rate.

199 Effect of Sulfur-Coated Urea and Ammonium Nitrate and Time of Application on Coastal Bermudagrass Yield and Nitrogen Uptake. C. L. Parks and J. R. Woodruff (Clemson Univ., Clemson, South Carolina). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*: p. 153 (1974). Three N sources ammonium nitrate and S-coated urea with two dissolution rates were added to established stands of Coastal Bermudagrass on a Norfolk sandy loam. Each material was added at rates to supply 224 and 448 kg N/ha. Both S-coated ureas were applied the 3rd week in April. A 224 and 448 kg/ha rate of N, as ammonium nitrate, was also applied on this date. The same rates of ammonium nitrate were used in two other treatments, applied in four equal applications (one-fourth in April and one-fourth after the first, second, and third harvest). There were no differences in yield due to source for the 224 kg/ha rate applied in April. Yield and N recovery was highest in the plots receiving ammonium nitrate applied in four equal applications. At the 448 kg/ha rate, plots receiving S-coated urea with the slower dissolution rate yield more dry matter than those receiving S-coated urea with the faster dissolution rate and ammonium nitrate when all of the N was applied in April. Nitrogen recovery was higher in the plots treated with ammonium nitrate for 2 of the 3 yr that the test was conducted.

200 Grass Response to Sulfur-Coated Urea, as Affected by Coating Method. D. A. Mays (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*; p. 152 (1974). Sulfur-coated urea (SCU) lots with S applied using pneumatic or hydraulic nozzles and coated with S only or with S plus wax and conditioner were evaluated as N sources for Coastal bermudagrass (*Cynodon dactylon* L.) and tall fescue (*Festuca arundinacea* L.) cut at the hay stage and for tall fescue and Tifway bermudagrass cut at weekly or biweekly intervals. The effectiveness of spring-applied SCU relative to spring or split applications of ammonium nitrate varied somewhat with coating type and dissolution rate. Preliminary data indicated that both nozzle types were satisfactory. In most comparisons SCU with wax and conditioner was more effective during the first growing season than SCU coated with S only when both materials had similar short-term laboratory dissolution rates. Apparently this was because the S-only materials required a heavier coating to achieve the same short-term dissolution rate. The S-only fertilizers have usually shown more residual effect. Sulfur-coated urea with a 7-day dissolution rate of approximately 25% was generally more effective than less soluble SCU.

201 Effects of Rates of Nitrogen from Sulfur-Coated Urea, Ammonium Nitrate, and Urea on Coastal Bermudagrass Grown on a Coastal Plains Soil. M. M. Eichhorn, Jr. (Louisiana State Univ., Baton Rouge). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*; p. 148 (1974). Coastal bermudagrass (*Cynodon dactylon*) was grown on two soil types with varying rates and sources of N. The rates were 200, 400, and 600 kg/ha. The sources were ammonium nitrate (AN), urea (U), and sulfur-coated urea (SCU) having dissolution rates of 10, 20, and 30%. Phosphorus and potassium were applied uniformly on the different treatments and all materials were applied broadcast on the surface. The average yield of forage was increased 4834, 8498, and 10,708 kg/ha at rates of 200, 400, and 600 kg/ha of N. Ammonium nitrate had the greatest effect on the yield of forage. Average forage yields were

increased 1054 kg/ha. Urea produced average forage yields that were 1067 kg/ha lower than AN and 155 kg/ha higher than SCU. Forage yields were higher when SCU having a 10% dissolution rate were compared with SCU 20 and 30%. Average forage yields of SCU 10% were 750 and 610 kg/ha higher than SCU 20 and 30%. Forage yields were increased 1892 and 954 kg/ha where AN and U had been applied in four as opposed to one increment. The N content of the forage responded to each N addition.

202 Response of Coastal Bermudagrass to Nitrogen in Sulfur-Coated Urea, Urea, and Ammonium Nitrate. D. A. Mays and G. L. Terman (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Sulphur Inst. J. 5* (3), 7-10 (Autumn 1969). Coastal bermudagrass on field plots of Sango silty clay loam was treated with 224 or 448 kg/ha of N in 1, 2, or 4 applications using ammonium nitrate (AN), uncoated urea or sulfur-coated urea (SCU) as N sources. The experiment was conducted from 1966 to 1969 at Muscle Shoals with N applied the first 3 yr only. Sulfur-coated urea contained 40-45% S as elemental S coated on urea granules. Uncoated urea produced significantly less forage than AN or SCU when all were applied as a single spring application. A single spring application of SCU produced four harvests of forage as uniform in yield as four split application of AN. Apparent N recovery was as high for the single application of SCU (66-70% recovery) as for four applications of AN (55-65%).

203 Sulfur-Coated Fertilizers for Controlled Release: Agronomic Evaluation. S. E. Allen and D. A. Mays (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *J. Agr. Food Chem. 19* (5), 809-12 (Sept.-Oct. 1971). Three greenhouse pot tests were run to evaluate long-term crop response to uncoated and S-coated urea (SCU), diammonium phosphate (SCP), and KCl (SCK). With bermudagrass cut eight times at 2-week intervals, SCU gave more uniform uptake of N and yield of forage than did uncoated urea (U). At higher rates of application where luxury uptake of N from U occurred, SCU also gave greater total forage yield. Yield and uptake of K from SCK by three crops of corn, each grown for 6 weeks, resulted in the same patterns of controlled release as for SCU. At limiting rates, the only benefit from SCK over uncoated KCl was more uniform yield of forage; at higher rates, SCK also gave greater total forage yield. With sorghum clipped four times at 4-week intervals, SCP did not supply adequate P for optimum early growth. As a result, total yield of forage was less from SCP than from uncoated $(NH_4)_2HPO_4$ (DAP), although total uptake of P was similar from SCP and DAP.

204 Response of 'Sunturf' Bermudagrass to Slow-Release Nitrogen Sources Under Greenhouse Conditions. A. Boonduang, Y. Kanehiro, and C. L. Murdoch (Univ. Hawaii, Honolulu). *HortScience 11* (4), 379-81 (Aug. 1976). Slow-release N sources [sewage sludge, Agriform, Osmocote, S-coated urea (SCU), and isobutylidene diurea (IBDU)] and a soluble N source $(NH_4)_2SO_4$ were applied to soil at the rates of 224 and 448 kg N/ha before planting bermudagrass (*Cynodon* Magenisii Hurcombe cultivar Sunturf). Yield, % N, and N recovery at three cuttings at 30-day intervals were significantly higher at the 448 kg/ha rate than at the 224 kg/ha rate and were highest in the first of three cuttings and decreased significantly in the second and final cuttings. The slow-release N sources, except Agriform, generally gave higher yield, % N, and N recovery values than $(NH_4)_2SO_4$, especially at the third cutting and at the higher N rate. Osmocote, SCU, and IBDU generally gave higher values than sewage sludge and Agriform.

205 Effect of Sulfur-Coated Urea and other Nitrogen Sources for Fertilizing Subirrigated Hay Meadows. L. A. Daigger and W. J. Moline (University of Nebraska Lincoln). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*; pp. 147-8 (1974). Sulfur-coated urea, urea, and ammonium nitrate broadcast in the spring and fall on subirrigated hay meadows at rates of 0, 34, 68 and 136 kg N/ha during 1971, 1972, and 1973 significantly increased yields at all rates. There were no differences in hay yields among N sources at rates of 34 and 68 kg N/ha. However, at the high N rates ammonium nitrate produced significantly higher yields than sulfur-coated urea and urea. There were no differences in dry matter yields between SCU and urea at all rates. Data on N recovery percentage show that spring applications of SCU were more efficient than were fall applications. This positive response to spring applied SCU was undoubtedly influenced by the composition of the meadow which included warm season grasses that can more effectively use slow release N.

206 Sources, Rates, and Frequencies of Nitrogen Application in Subirrigated Hay Meadows. L. A. Daigger and W. J. Moline. *Agron. J. 69* (4), 644-7 (1977). The effectiveness of three N sources at various rates in alternating sequences of N applied annually, biennially, and triennially for meadow hay production was evaluated. The hay consisted of a complex mixture of Agropyron, Poa, Sorghastrum, and Carex species harvested from a subirrigated meadow of an Aquic Ustifluvent soil. Sulfur-coated urea (SCU), urea, and ammoniun nitrate (AN) were broadcast in the spring on subirrigated hay meadows at rates of 0, 34, 67, and 135 kg N/ha applied during 1971, 1972, and 1973. All N sources and rates increased hay yields. There were no differences in hay yields among N sources at the low rates of 34 and 67 kg N/ha; however, at high N rates AN and SCU produced higher hay yields than urea. Under these meadow conditions, N recovery percentages from SCU were greater than with urea or AN. Total protein production increased with increasing rates of N. Where fertilizers were applied once in 2 yr higher total protein yields were produced with SCU than from urea or AN at 67 kg N/ha. At higher N rates protein differences between SCU and AN were not observed in the 2- and 3-yr intervals of N application. Efficient use of N fertilizer can be attained when applied once in 2 yr for hay production in subirrigated meadows, where transport of fertilizer materials to the field site is difficult.

207 Nitrogen Sources for Hay Production on Flooded Meadows. A. F. Ludwick, C. B. Rumburg, and E. G. Siemer (Ft. Collins, Colorado). *Soil Sci. Soc. Am. J. 42* (3), 509-12 (1978). Three experiments were conducted over a 3 yr period to compare various urea materials and ammonium nitrate as N sources for hay production on flooded meadow sites. Each experiment was a complete factorial combination of fertilizer N sources and rates broadcast once in the spring on established forage prior to flood irrigation. Experiment 1 in Gunnison County, Colorado, consisted of ammonium nitrate (AN), urea (U), S-coated urea (SCU), and urea ammonium polyphosphate (UAPP) broadcast at rates of 0, 67, 134, 202, and 269 kg N/ha. A second season's data was collected to evaluate carryover N. Experiments two and three were conducted in Jackson County for a single season and consisted of AN, U, UAPP, and urea ammonium sulfate (UAS) broadcast at 0, 90, 179, and 269 kg

N/ha. Hay yields and N uptake were significantly increased by N fertilizer at each location. There was no significant response in hay yield or N uptake resulting from residual N in the second season of Experiment 1. Source of N did not influence hay yields nor N uptake. The N content of the hay was significantly influenced by the N fertilizer rate at two locations and the N source at one location. In general, hay yields and N uptake increased with increasing rates of fertilizer N. Fertilizer efficiency was low at all locations, ranging between 8.5-19.6 kg hay/kg N. Fertilizer N recovery was < 30% for all treatments. Both efficiency and recovery of N tended to decrease with increasing N rates.

208 Use of Slow-Release Nitrogen Fertilizers on Native Mixed Prairie. J. F. Power (AR-SEA-USDA, Lincoln, Nebraska). *Agron. J. 71* (3), 446-9 (May-June 1979). A 4-yr field experiment was conducted at Mandan, North Dakota, to compare the effects of S-coated urea and ureaformaldehyde with NH_4NO_3 for production of mixed native prairie vegetation. In general, all fertilizers at all rates of application decreased *Boulettoua gracilis* (blue grama) density, while *Agropyron smithii* (western wheatgrass) density generally increased at rates above 56 kg N/ha annually. Dry matter production from all rates of N application was greatest for NH_4NO_3 and least for ureaformaldehyde, with intermediate production, for the S-coated ureas. Fertilizer N recovery in harvested forage followed this same order. In general, the mixed prairie grasses used N from urea-containing fertilizers less efficiently than that from NH_4NO_3 (14 ref).

209 Effects of Types and Rates of Nitrogen Fertilizer on Range Herbage Production Under Drought Conditions. K. O. Fulgham *et al* (New Mexico State Univ., Las Cruces). *Res. Report, Agric. Exp. Stn., New Mexico State Univ.* No. 343; 6 pp. (1977). Blue grama rangeland herbage production was evaluated with NH_4NO_3, $(NH_4)_2SO_4$, urea, and S-coated urea applied at 40 lb N/acre annually and 80 lb N/acre biennially during 1970 and 1971. Total herbage production was separated into *Artemisia carruthii*, forbs and grasses. *A. carruthii* produced little growth increase due to fertilization. Limited early growth-season precipitation allowed annual forbs to initiate growth and successfully utilize the fertilizer. In 1970, grass responded positively to the application of 80 lb N/acre. In 1971 grass production was higher under the annual application of 40 lb N/acre, except for the higher rate of S-coated urea applied in the yr before. Although production was less on plots where fertilizer was applied each yr, S-coated urea showed some residual effect on grass production. Other vegetation classes showed mixed responses to either application rate or fertilizer form. Ammonium sulfate generally tended to be less effective and urea more effective for increasing herbage production especially in 1970. Precipitation for New Mexico SW rangelands was a more critical factor than fertilizer practices. Fertilization of rangelands under a drought stress condition did not produce the anticipated herbage production improvement (19 ref).

210 Evaluation of Sulfur-Coated Urea and Urea-Ammonium Sulfate as Nitrogen Sources for Cool Season Grasses. R. E. Lamond *et al* (Kansas State Univ., Manhattan). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 151 (1974). Studies were initiated in 1973 at four locations in Kansas to evaluate performance of five carriers as sources of N for smooth brome and tall fescue. Nitrogen carriers were ammonium nitrate, urea, urea-ammonium nitrate solution, sulfur-coated urea (SCU-30), and urea-ammonium sulfate (UAS). Nitrogen rates were 67, 134, and 202 kg N/ha applied in the spring, and a series of spring-summer split applications using the 134 and 202 kg rates. In 1973, N carrier comparisons indicate outstanding performance by UAS: significantly better than all other carriers at two of three bromegrass sites on total yearly yield basis. At the single fescue location, SCU-30 was significantly better than all other carriers for fall and total yearly yields. In 1974, three of four locations indicated no significant differences between N carriers. In 1973 and 1974, yields increased linearly with N, all rates were superior to the control. The 134 kg rate was superior to the 67 kg rate at all locations both years, while the 202 kg rate was superior to the 134 kg rate at one location in 1973 and two locations in 1974. Split applications produced superior yields for fall harvested material. On a total yield basis, two of four times of N application effects were not consistent.

211 Effect of Sulfur-Coated Urea on Yields of Two Warm and Two Cool Season Grasses. E. M. Kroth, R. Mattas, and L. Meinke (Univ. Missouri, Columbia). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 150-1 (1974). Three sulfur-coated ureas, urea, and ammonium nitrate were compared by effects on yields of switchgrass, blue stem, reed canary grass, and tall fescue. The warm season grasses were grown on Crelden silt loam in southwest Missouri, the carriers top dressed at 67 and 134 kg N/ha in mid-May. No yield differences occurred between carriers at either rate. The 134 kg rate tended to increase yields but not significantly. Reed canary grass was grown on Grundy silt loam in North Missouri at 134 kg N/ha for all carriers. No significant differences in forage yields were noted. Carriers were applied to fescue on Mexico silt loam in Central Missouri totaling 180 and 360 kg N/ha. Yield differences between N rates of all carriers were significant. The yield using uncoated urea was significantly lower than the other carriers at the 360 kg rate.

212 The Effect of Source and Rate of Applied Nitrogen on Irrigated Grass. R. L. Croissant, J. O. Reuss, and W. G. Stewart (Colorado State Univ., Fort Collins). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 147 (1974). Comparisons of ammonium nitrate sulfate and sulfur-coated urea on irrigated smooth-bromegrass (*Bromus inermis* Leyss.) and orchardgrass (*Dactylis glomerata* L.) mixtures were made in Eastern Colorado. Sulfur-coated urea treatments were applied in one application and the ANS treatments were split corresponding to harvest periods. Sulfur-coated urea treatments yielded 9720, 9690, 11,670, 11,690, and 15,400 kg/ha of air dry forage at 168, 224, 336, 448, and 672 kg/ha of applied N. Ammonium nitrate sulfate treatments yielded 7010, 10,310, 12,870, 14,560, 14,660, and 16,460 kg/ha of air dry forage at respective N levels. Average nitrate-N concentrations in the forage 7 days after harvest and fertilization with both sources of N across all N rates were .115, .210 and .219%. Seven days after the first harvest, nitrate-N concentrations from SCU treatments with the 336 kg/ha rate were .064% whereas with 336 kg/ha, nitrate-N levels averaged .317% on ANS treatments. Nitrate-N levels, under all treatments, decreased rapidly from a period 7 days after harvest and fertilization until the next fertilization and regrowth period. Nitrate-N levels with both SCU and ANS applied at 672 kg/ha were .3% or higher 55% of the time. The crude

protein level of the forage, tested to 336 kg/ha, increased by each increment of N up to 336 kg/ha and decreased with each successive harvest.

213 Response of Orchardgrass to Sulfur in Sulfur-Coated Urea. G. O. Klock, J. M. Geist, and A. R. Tiedmann (USDA, Pacific Northwest Forest Range Exp. Stn.). *Sulphur Inst. J. 11* (3-4), 4-8 (Fall-Winter 1975). The availability of S in S-coated urea (SCU) for plant growth on S-deficient forest and range soils was tested under greenhouse conditions on three regionally important soils. Although the degree of plant yield response varied among the three soils, it appeared that S in SCU was available in sufficient amounts to be of acceptable fertilizer value, depending on fertilization objectives. Not all differences in fertilizer treatment effects were reflected by soil chemical analyses. It was found that soils with similar N:S values apparently had widely different rates of S oxidation, hence different S availability. This seemed to apply to native S as well as certain elemental S sources. The control of N solution by the S-coating property appeared to have no depressing effect on plant yield for any of the three soils tested. With the advantages accrued to a slow-release N fertilizer plus the added benefit of S, SCU shows promise as an acceptable fertilizer on certain forest and range soils of eastern Oregon and Washington.

214 Effects of Nitrogen Carriers, Nitrogen Rates, and Maturity on Composition of Smooth Bromegrass. C. L. Harms *et al* (Kansas State Univ., Manhattan). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*: p. 149 (1974). Increasing incidences of the grass tetany syndrome of beef cattle related to low forage Mg concentrations have been suggested to be a result of increased usage of nitrogen fertilizers on grass pastures. Rates of 67, 134, and 202 kg N/ha from ammonium nitrate, urea, urea-ammonium nitrate solution, sulfur-coated urea, and urea-ammonium sulfate were applied to smooth bromegrass in late winter. Magnesium concentrations in the plant tissue were unaffected by N carrier or rate and remained constant until rapid growth began in mid-May after which they declined until early June harvest. Highest seasonal concentrations of Mg were found in the fall growth. Calcium concentrations were unaffected by N carrier or rate and declined from the initial sampling date to summer harvest. Highest Ca concentrations were found in the fall growth. Potassium, P, and N concentrations were highest at early stages of growth and declined with increasing maturity in both spring and fall. Forage yields were doubled with the use of 67 kg N/ha and tripled by application of 202 kg N/ha. Significant yield differences were evident among the different N carriers.

215 Comparative Performance of Nitrogen Sources on Smooth Bromegrass and Tall Fescue. R. E. Lamond *et al* (Kansas Agric. Exp. Stn., Manhattan). *Soil Sci. Soc. Am. J. 43* (3), 610-12 (1979). Studies were initiated in 1973 at two locations in eastern Kansas to evaluate the performance of five N carriers as sources of N for bromegrass (*Bromus inermis*) and tall fescue (*Festuca arundinacea*). Late winter applications of ammonium nitrate, urea, urea-ammonium nitrate solution (UAN), sulfur-coated urea (SCU), and urea-ammonium sulfate (UAS) were compared at rates of 67, 134, and 201 kg N/ha. Excellent visual responses to applied N were evident in both years. Total yields of forage generally increased with N applications up to 201 kg N/ha. The response to N decreased as the rate was raised from 134 to 201 kg N/ha. Maximum economic return from the application of N occurred at a level of about 134 kg N/ha. No clear-cut superiority was established for any N carrier. Sulfur-coated urea performed well on tall fescue but less effectively on bromegrass. Although there was evidence of delayed release N from SCU, its efficiency as measured by total yield was similar to conventional N sources. The effectiveness of a carrier was influenced by location, environmental conditions, and grass species.

216 Response of Permanent Grass at Cockle Park to Ammonium Nitrate, Isobutylidene Di-Urea, and Sulfur-Coated Urea. D. Joshy and F. Hunter (Univ. Newcastle upon Tyne, England). *J. Sci. Food Agric. 26* (9), 1428 (Sept. 1975). On a typical southeastern Northumbrian boulder clay soil [pH (H_2O) 6.5] with a sward derived from Cockle Park seeds mixture NH_4NO_3 was compared with isobutylidene diurea (IBDU) and (SCU). In 1973 four cuts were taken. Against a control yield of 8080 kg/ha dry matter (DM), four split dressings each of 125 kg/ha as NH_4NO_3 gave 13,510 kg/ha DM, a single dressing IBDU at 625 kg N/ha, 12,810 kg/ha DM, and of SCU also at 625 kg N/ha 12,980 kg/ha DM [LSD 650 ($P = 0.05$)]. Nitrogen recoveries were 61% for NH_4NO_3, 44% for IBDU, and 54% for SCU. Controlled-release materials from one single spring application can give broadly similar production and efficiency to a series of split dressings of NH_4NO_3. When NH_4NO_3 dressings were doubled at 250 kg N/ha per application DM production fell by 13% whereas with massive single dressings of 1250 kg N/ha IBDU gave 8% more and SCU 16% more DM than the 625 kg N/ha level. The risk of scorch at normal rates of usage of either of these last two materials is therefore minimal. The most interesting feature of this study was the ability of controlled-release materials from a single spring dressing to provide N in a pattern over the season correlated with the requirements of many seed-sown crops. Both Hamamoto with IBDU and Jung with crotonylidene diurea have reported similar results. An intriguing aspect of the results was that in the dry July-August growth period there was greater N uptake from the single spring dressing of IBDU than from the split NH_4NO_3 treatments. Growth room trials at controlled moisture tensions with the polyethylene glycol technique confirmed the ability of IBDU in particular to release available N in dry conditions.

217 Comparison of Sulfur-Coated Urea and Ammonium Nitrate as Fertilizers for Pensacola Bahiagrass on a Spodosol. W. G. Blue (Florida Agric. Exp. Stn., Gainesville). *Soil Sci. Soc. Am. J. 41* (6), 1191-3 (Nov.-Dec. 1977). Two slowly available TVA experimental sulfur-coated ureas (SCU) were compared with ammonium nitrate (AN) as N sources for 'Pensacola' bahiagrass on Myakka fine sand. One SCU contained 35.4% N with a S coating of 23%; the other contained 40.2% N with a 12.6% coating which included S plus 2% diatomaceous earth and 0.25% coal tar. Four levels of N (0, 112, 224, and 336 kg/ha) were applied annually for 3 yr to an established grass sod which had not been fertilized with N during the previous 2 yr. Ammonium nitrate was applied in single and split applications, and SCU as a single annual application in late March of each yr. Split AN was applied half in late March and near July 1. Forage growth increased with each level of N from all sources. Recovery of N in forage roots and stolons was higher (67%) from the 224- and 336-kg/ha N rates than from the 112-kg/ha rate (57%). Forage yield increase from the SCU (35.4% N) was relatively poor in the 1st yr; pellets of this material were found consistently in the

grass thatch at the soil surface 1 yr after application. However, forage yields and N contents for each N rate over the 3-yr comparison period were not affected by N source or number of applications. The residual effect of SCU during the 4th yr as measured by N content of forage ranged from 2 to 7% of the total N applied. These quantities of N were generally less than the decline in N content of the stolon-root system. Forage production and N content distribution with time were similar with these slow release SCU's and AN.

218 Effect of Nitrogen Source on Seasonal Yield Distribution and Nitrogen Recovery by Stargrass. J. R. Thomas and G. Oerther (USDA Agric. Res. Service, Weslaco, Texas). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*; p. 156 (1974). Irrigated pastures in the Lower Rio Grande Valley of Texas need N fertilization 5 to 7 times throughout the growing season to insure uniform production of high quality forage and to minimize N leaching losses. Since most ranchers have not adopted this practice, studies compared the effects of total and seasonal production of grass dry matter and the crop's N recovery from single and split applications of NH_4NO_3, urea, and a slow release N source--sulfur coated urea (SCU). Ammonium nitrate applied 5 times during the growing season at rates of 320 and 470 lbs N/acre, yearly to an established stand of stargrass (*Cynodon plectostachyus*) was compared to a single application of SCU at rates of 470 and 670 lbs N/acre. Single and split applications of urea and SCU at rates of 450 lbs N/acre, yearly were compared. A single application of SCU produced the same total hay tonnage as the same amount of N applied in 5 dressings as NH_4NO_3. Single applications of SCU gave slightly better seasonal distribution of dry matter and protein concentration than corresponding additions of urea. Approximately 15% of the SCU and less than 1% of the urea was in the surface 122 cm of the soil profile at the end of the growing season.

219 Efficiency of Sulfur-Coated Urea and Potassium Chloride Compounds Applied to Stargrass Growing on an Ultisol Under Humid Tropical Conditions. Fernando Abruna, Jacinto Figarella, and Ruben Caro-Costas (Univ. Puerto Rico, Rio Piedras). *J. Agric. Univ. P.R. 60* (3), 310-15 (July 1976). The efficiency of various S-coated urea and KCl compounds applied to stargrass growing on an Ultisol under humid tropical conditions was determined. Applying N as urea in six applications yearly or in one application of S-coated urea compounds TVA 1415 and 1255 resulted in higher recovery of fertilizer N compared to urea in one application. Applying K as KCl in six applications yearly resulted in higher recovery of fertilizer K in the forage than when applied in one application. The various S-coated KCl compounds did not result in higher recovery of fertilizer K than did KCl in one application.

220 Nitrogen Effects on Mobility and Plant Uptake of Heavy Metals in Sewage Sludge Applied to Soil Columns. P. M. Giordano and J. J. Mortvedt (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *J. Environ. Qual. 5* (2), 165-8 (Apr.-June 1976). Cation movement in soil under leaching conditions has been associated with N fertilization. Therefore, a study was conducted to determine whether the mobility of some heavy metals applied in the inorganic form or in sewage sludge is enhanced in the presence of urea or sulfur-coated urea sources of N. Columns of heavy metal-amended soil in plastic well casings were cropped with tall fescue (*Festuca arundinacea* Schreb.) and leached three times with deionized H_2O. Heavy metal concentrations above check values were not detected in leachates from any column. Mobility of the heavy metals from the inorganic sources was slightly greater than that from the sewage sludge. Nitrogen fertilization did not affect the downward movement of Zn, Cd, Cr, Pb, or Ni in soil but enhanced uptake of these metals by fescue because of increased growth. These results suggest that heavy metal contamination of ground water is not likely in heavy textured soils when sewage sludge applications are accompanied by N fertilization, at least for short periods of time.

221 Two Grass Field Trials with a Sulfur-Coated Urea to Examine its Potential as a Slow Release Nitrogen Fertilizer in the United Kingdom. L. H. Davies (Imperial Chem. Ind. Ltd., Jealott's Hill Res. Sta., Bracknell, Berkshire, England). *J. Sci. Food Agr. 24* (1), 63-7 (Jan. 1973). In two trials conducted during 1971 the effects on total and seasonal production of grass dry matter and the crops' N recovery from a single spring application of a S-coated urea or urea formaldehyde were compared with an equal amount of N applied in five dressings of urea or ammonium nitrate. Ammonium nitrate gave higher dry matter yields and N recovery than urea. Sulfur-coated urea as a single application gave results similar or superior to split applications of ammonium nitrate, but seasonal distribution of these were slightly different. Urea formaldehyde proved inferior, in the parameters measured, to the other fertilizers.

222 Evaluation of Isobutylidenediurea and Sulfur-Coated Urea for Grass and Lettuce. Munoo Prasad (Agr. Inst., Dublin, Ireland). *J. Agr. Food Chem. 21* (5), 919-22 (Sept.-Oct. 1973). Isobutylidenediurea (IBDU), sulfur-coated urea (SCU), and calcium ammonium nitrate (CAN) were compared at three rates for their effect on two contrasting crops, lettuce and grass, and in two contrasting soil types, organic and mineral, in a greenhouse experiment. Five cuts of grass and three harvests of lettuce were taken over a period of 5 months. In peat with grass and in soil with lettuce, the cumulative yields from the N fertilizers were of the order IBDU > SCU > CAN, in peat with lettuce it was IBDU = SCU ≫ CAN, and in soil with grass there were only slight differences. In contrast to CAN, but IBDU and SCU gave sustained response, although early response to SCU was slow. For the first month the only substantial losses of N through leaching were from CAN; some leaching losses also occurred from IBDU with lettuce.

FRUITS AND VEGETABLES

223 Vegetable Utilization of Nitrogen from Controlled-Release Fertilizers. R. P. Wiedenfeld (Texas Agric. Exp. Stn., Weslaco). *College Stn., Texas: Texas Agric. Exp. Stn.* Pr-3589; 10 pp. (Nov. 1979). Field studies to evaluate slow release N fertilizers (sulfur-coated urea and methylene urea) were established with cantaloupes and bell peppers in the Rio Grande valley of Texas in 1978. Slow-release N materials applied preplant appeared to be superior to soluble fertilizers applied preplant, and equivalent to split soluble fertilizer treatments in providing N to the plant. Soil N in the top 6 in. using slow-release N fertilizers preplant was comparable to split applications of conventional soluble fertilizers. Only in petiole N content did split soluble fertilizer treatments show an advantage over some preplant slow release treatments. Results thus far indicate that where the savings resulting from a reduction in required field operations offset the higher cost of a slow release N fertilizer, the fertilizer's use is justified. A

material with an even slower release pattern than those tested may be more suited to the Lower Rio Grande area as conditions there encourage abundant microbial activity. Application of any N fertilizer could probably be delayed until plant thinning because of the adequate soil N initially available regardless of treatment.

224 Crop Yield-Nitrate-Nitrogen, Total Nitrogen, and Total Potassium Relationships: Leafy Vegetables. G. L. Terman and S. E. Allen (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Commun. Soil Sci. Plant Anal. 9* (9), 813-25 (1978). Pot experiments were conducted to determine effects of applied N on nitrate-N and total N concentrations in Swiss chard (*Beta vulgaris* variety cicla) and of applied N, P, and K on Bloomsdale spinach (*Spinacia oleracea*) and on curly mustard (*Brassica pervirdis*). Ammonium nitrate produced greater increases in nitrate and total N concentrations in chard than did sulfur-coated urea at the same N rates. Both N and K increased yields and nitrate accumulation in spinach and mustard; responses to applied P resulted only in decreased nitrate. Both total and nitrate-N concentrations decreased with dilution and/or assimilation associated with time of growth and higher yields. An examination of published results with several spinach cultivars indicates that differences in nitrate-N accumulation attributed to leaf type can also be explained by the higher yields of the low nitrate accumulators. The same is true for differences in nitrate accumulation attributed to light and temperature effects.

225 Some Responses of Lettuce Grown in Beds of Peat to Nitrogen Potassium Magnesium and Molybdenum. P. Adams, C. J. Graves, and G. W. Winsor (Glasshouse Crops Res. Inst., W. Sussex, England). *J. Hortic. Sci. 53* (4), 275-82 (1978). The effects of 96 combinations of N, K, and Mg were studied in three crops of lettuce grown in peat; there were two sources of N, Nitrochalk (26% N) and S-coated urea (32% N) and Mo was included as an extra factor in one crop. The yield and proportion of hearted lettuce increased with applied N until the peat contained 60 mg N/L. In two crops higher N concentrations were unfavorable, due to increased acidity of the peat which resulted in greater uptake of Mn by the plants. The yield and the proportions of both hearted and of marketable lettuce declined as the Mn content of the leaves increased. In the third crop, which was not affected by Mn toxicity, there was little response to N over the range 60-250 mg N/L. The yield and quality of the produce improved with increasing K until the peat contained 200 mg K/L, but concentrations of up to 600 mg K/L had little further effect. The N and K contents of the leaves corresponding to maximum yield were 5% N and 8% K. There was no response to added Mg. The yield and proportion of hearted lettuce were increased by addition of Mo in plots receiving the heaviest dressing of Nitrochalk. The increase in the proportion of hearted lettuce was greatest in plots also receiving S-coated urea. The water-soluble phosphate content of the peat increased from 19 mg P/L to > 50 mg P/L as the pH of the peat declined from 6.7 to 5.5 in response to increasing N application rates.

226 Slow Release Fertilizers and Nitrification Suppressants as Nitrogen Management Tools for Lettuce. F. D. Moore III and P. N. Soltanpour (Colorado State Univ., Fort Collins). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 152 (1974). Three coated N fertilizers, simultaneous injection of NH_3 + nitrapyrin, $(NH_4)_2SO_4$ + nitrapyrin, and $(NH_4)_2SO_4$ + KN_3 were tested on furrow irrigated crisphead lettuce (*Lactuca sativa* L.) growing on a well-drained calcareous sandy loam soil (pH 7.9-8.2). The slow release N fertilizers and nitrification suppressing systems as single preplant or at planting applications were compared with NH_3 (single application) and three applications of $(NH_4)_2SO_4$ (control). All treatments were compared at equivalent N application rates. In most instances, the slow release fertilizers and those to which nitrapyrin was added, resulted in yields equivalent to the control. In one experiment, however, the $(NH_4)_2SO_4$ + KN_3 reduced head wt and the $(NH_4)_2SO_4$ + nitrapyrin increased head wt as compared with the control. Ammonia + nitrapyrin increased NH_4^+, decreased NO_3^- and had no influence on NO_2^- in the soil when compared with NH_3. In most instances, single N applications lowered dry tissue NO_3-N relative to the control treatment. None of the N sources affected market quality of heads according to evaluations made after an 11-day simulated transit period.

227 Use of Sulfur-Coated Urea for Season Nitrogen Supply to Trellised Tomatoes. J. E. Shelton (Mt. Hort. Crops Res. Sta., Fletcher, North Carolina). *HortScience 8* (3, Sec. 2), 233 (June 1973). Sulfur-coated urea, applied preplant on trellised tomatoes produced equivalent or higher marketable yields when compared to ammonium nitrate applied preplant or split into five or six topdressing applications. In 1971 389 kg/ha of N from S-coated urea, having a release rate of 10% over a 7-day period, produced significantly greater marketable yields than the same rate of N from NH_4NO_3. Sulfur-coated urea having release rates of 20 or 30% over a 7-day period, resulted in yields only slightly lower than split applications of NH_4NO_3. Similar trends were obtained in 1972. Yields from N rates of 556 or 722 kg/ha were not different than the 389 kg/ha rate from either S-coated urea or NH_4NO_3.

228 Sulfur-Coated Urea Casein and Other Slow Release Nitrogen Fertilizers for Tomato Production. M. Prasad and P. A. Gallagher. *Acta Hortic. 26;* pp. 165-73 (1972). The feasibility of using sulfur-coated urea (SCU), casein and other slow release N-fertilizer was examined. Experiments which included various methods of application were conducted for tomato production in moss peat in a glasshouse. In incubation studies in peat SCU (dissolution rate 1% a day) released about 45% of the total N applied in about 14 weeks and showed increasing release in the latter half of this period. Initially most of the N was in the NH_4 form, while after the 5th week all the N was in the NO_3 form. With tomato as a test crop SCU with different methods of application and in combination with calcium ammonium nitrate (CAN) gave yields in all the three experiments which were lower than the standard treatment. The standard treatment consisted of half the N as CAN and half as ureaformaldehyde (UF) with liquid feed. Nitrogen content of the foliage was lower in the SCU treatment (except in combination with CAN) than the standard, early in the season, but gave highest N-content at the end of the growing period. Casein which was tested in two experiments gave the highest yields and the N content was higher than the standard treatment at all sampling dates. Isobutylidenediurea which was tried in one experiment only, gave high N-content, but yields were lower than the standard, probably due to severe scorching of the foliage. Ureaformaldehyde gave low yields and the N-content was also low.

229 Evaluation of Sulfur-Coated Urea as a Preplant Total Season Nitrogen Supply for Trellised Tomatoes. J. E. Shelton

(North Carolina State Univ., Raleigh). *Soil Sci. Soc. Am. J. 40* (1), 126-9 (Jan.-Feb. 1976). The use of a controlled release N source for the production of trellised tomatoes (*Lycopersicon esculentum*) which require frequent topdressings would be desirable. Three S-coated urea (SCU) materials having release rates of 11.4, 21.5, and 29.3% over a 7-day period were compared to NH_4NO_3 applied preplant or as multiple applications. Nitrogen rates were 392, 560, and 729 kg N/ha. Marketable yields from an application of $SCU_{11.4}$ at 392 or 560 kg N/ha were greater than with the same rate of N as NH_4NO_3 either as preplant or split applications. When $SCU_{21.5}$ or $SCU_{29.3}$ was used, the yields were comparable to a single application of NH_4NO_3. Differences in fruit number per plot were not significantly related to treatments. However, there was a significant difference in average fruit wt which was correlated with total yield. Tissue N content was highest at first sampling from a single application of NH_4NO_3 and lowest from $SCU_{11.4}$. However, at later sampling periods the N content was maintained at a higher level with $SCU_{11.4}$. Although 729 kg N/ha as a single application of NH_4NO_3 detrimentally affected plant growth and production, this effect was not noted with the SCU materials.

230 Leaching Resistance of Sulfur-Coated Nitrogen and Potassium Fertilizer. P. G. Orth (Univ. Florida, Agric. Res. Education Center, Homestead). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 153 (1974). Leaching of conventional and slow release fertilizer was compared by measuring growth of and nutrient uptake by tomato seedlings. The soil was shallow (15 cm) and rocky. Rain supplied 22 cm of water between planting and the first sampling 23 days later. Irrigation supplied an additional 11½ cm to a second set of plots. Sulfur-coated urea and KCl at 6 g N and 5 g K/m of row were compared with NH_4NO_3 and K_2SO_4 at 8 g N and 6.8 g K/m. At moderate leaching, plant wt was 30% less with conventional fertilizer than with sulfur-coated fertilizer at the first sampling and 50% less at the second sampling. Heavy leaching reduced plant wt 25% for both fertilizers at the first sampling. However, at the second sampling 8 days later this reduction was only 4% for sulfur-coated fertilizer and still 25% for conventional fertilizer indicating the release of additional nutrients by the former. Leaching of residual N and K in the soil was more noticeable when P starter fertilizer was applied in the seed furrow. Plastic-coated slow release N and K applied as starter supplied as much N and K to the seedlings as the conventional fertilizer which was applied at eight times the rate.

231 Effect of Sulfur-Coated Urea on Yield, Nitrogen Uptake, and Nitrate Content in Turnip Greens, Cabbage, and Tomato. G. C. Sharma, A. J. Patel (Alabama A&M Univ., Norman), and D. A. Mays. *J. Am. Soc. Hortic. Sci. 101* (2), 142-5 (Mar. 1976). In a 3-yr study S-coated urea (SCU) resulted in differences in crop response which were related to the different N release rates. On Decatur silty clay loam at Normal, Alabama, SCU with relatively high N-dissolution rates performed best in terms of yield and N uptake for turnip greens, *Brassica campestris* L. (Rapifera group) while SCU with a slower dissolution rate performed better on Morrison sandy loam at Tuskegee, Alabama. On cabbage, *Brassica oleracea* L. (Capitata group), SCUs performed similar to NH_4NO_3 (AN) and uncoated urea (UCU). With tomato, *Lycopersicon esuletum* Mill., Spring-applied SCU with the highest dissolution rate, performed as well as split applications of AN, indicating the possibility for labor saving with SCU through reduced number of applications. Effect of SCU on NO_3 accumulation was minimal. At harvest in the top 15 cm soil the total N content was highest in tomato plots treated with split AN, followed by SCU-A, SCU-C, and AN, respectively.

232 Effect of Controlled-Release Nitrogen Fertilizers on Yield and Nitrogen Absorption by Potatoes, Cantaloupes, and Tomatoes. O. A. Lorenz, B. L. Weir, and J. C. Bishop (Univ. California, Davis). *J. Amer. Soc. Hort. Sci. 97* (3), 334-7 (May 1972). In field studies with potatoes, cantaloupes, and tomatoes, using N sources banded in the soil, highest yields were obtained with $(NH_4)_2SO_4$. Yields with urea-formaldehyde and S-coated urea were similar to each other, and less than those from urea. Nitrogen absorption, as determined by NO_3-concentration in the petiolar tissue or total N absorption by the entire plant, was in the same sequence as yields. Controlled-release fertilizers did not increase N absorption during late growth. About 90% of the N from $(NH_4)_2SO_4$ and urea had nitrified and leached from the fertilizer band within 40 days after application. In contrast, about half of the N from urea-formaldehyde remained in the fertilizer band 120 days after application.

233 Evaluation of Sulfur-Coated Urea for Bell Pepper. S. J. Locascio and J.G.A. Fiskell (Univ. Florida, Gainesville). *HortScience 8* (3, Sec. 2), 232 (June 1973). Four formulations of S-coated urea applied broadcast were compared at three N rates with urea. Urea treatments were applied banded, banded with a strip mulch, broadcast, or broadcast with polyethylene or paper mulches in a single application. During a season of relatively high rainfall, N rate and urea treatments interacted in their effect on fruit yield. Yields increased linearly with rates of N from 56 to 224 kg/ha. At all N rates, maximum yields were produced with mulch treatments and urea applied in a split application. At the low N rate, yields with the S-coated urea sources were relatively low due to the inadequate release of N. At the highest N rate, yields with the S-coated urea formulations were similar to those produced with the mulch treatments. Differences in production were attributed to soil soluble salts and N levels throughout the season.

234 Nitrogen Source and Rate Effects on Nitrate Levels in Soils and Selected Vegetable Crops. D. L. Coffey, G. M. Lessman, and J. F. Brown (Univ. Tennessee, Knoxville). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 147 (1974). Experiments were conducted with spinach, *Spinacia oleracea* L., comparing four N sources, $Ca(NO_3)_2$, NH_4NO_3, $(NH_4)_2SO_4$, and sulfur-coated urea, SCU at two N rates (112 and 224 kg N/acre) as they affected yield and NO_3-N content of leaf tissue. Soil samples were also collected at two depths, 0-4 and 4-8 in. and analyzed for NO_3-N levels. Both soil and plant samples were collected for analysis at selected intervals throughout the growing season. Yields obtained from the 112 kg rate of both NH_4NO_3 and $Ca(NO_3)_2$ were the largest of any source or rate investigated. Plant NO_3-N levels were the highest when $(NH_4)_2SO_4$ was the N source. This effect can be described by the sequence $(NH_4)_2SO_4 > Ca(NO_3)_2 = NH_4NO_3 >$ SCU. Soil NO_3-N levels were found to be in the order $Ca(NO_3)_2 = NH_4NO_3 > (NH_4)_2SO_4 >$ SCU at the two depths measured. Similar experiments were conducted with bell peppers, *Capsicum frutesens* variety *grossum*. No yield differences were obtained

with any N source tested. Other plant and soil parameters were similar to those found with spinach.

235 Pepper *Capsicum-Annuum* Response to Sulfur-Coated Urea Mulch and Nitrogen Rate. S. J. Locascio and J.G.A. Fiskell (Univ. Florida, Gainesville). *Proc. Fla. State Hortic. Soc.* No. 92; pp. 112-15 (1979). Bell pepper (*C. annum* L.) response to broadcast applications of various S-coated urea (SCU) formulations, urea-formaldehyde (UFA), and isobutylidene diurea (IBDU) were compared with urea applied broadcast, banded, banded with strip-mulch or broadcast under paper or polyethylene mulch. All treatments were applied at 50, 125, and 200 lb N/acre. Significant effects of N source treatments were obtained in both yr of the study. Highest pepper yields were produced with the more rapid release formulations of SCU, urea applied broadcast in 3 applications, and urea applied under paper or polyethylene mulches. Yields were lowest with urea banded, urea applied with strip-mulch, and with urea-formaldehyde. Maximum yields were obtained with most treatments with the application of 200 lb N/acre. Plant and soil-N levels were also significantly influenced by treatment.

236 Effects of Fertilizer Nitrogen Sources, Rates, and Placement on Soil Test Values for Bedded Peppers With and Without Mulch. J.G.A. Fiskell *et al* (Univ. Florida, Gainesville). *Proc. Soil and Crop Sci. Soc. Fla. 37;* pp. 183-8 (1978). The purpose of this study was to determine the soil test values for peppers. Fertilizer treatments were 56, 140, and 224 kg N/ha as urea, ammonium nitrate (AN), ammonium sulfate (AS), isobutylidene diurea (IBDU), or one of three sulfur-coated urea (SCU) formulations and with a uniform supply of P, K, and micronutrients. Beds that received all the fertilizers preplant were covered with polyethylene mulch while plots without mulch received one-half the fertilizer preplant and two equal top-dressings at 1 and 2 months after planting. At the 140 kg N/ha rate, the above sources were also placed in three bands on the bed and were mulched. Soil samples were taken each month during the growing season. These were extracted with water, 1*N* KCl, 0.05*N* HCl in 0.025*N* H_2SO_4 (double-acid), and 0.7*N* NH_4OAc at pH 4.8. Soil test values for Ca, Mg, and K declined slightly over the 4-month span. There was little effect of N sources or N rates on these values except that K values were lowest for the AS source and declined sharply by 4 months. Mean NH_4^+-N values showed small differences between N sources and for mulching. Soil test values for NO_3^--N, Cl^-, K^+, and NH_4^+-N values were much higher for the 0 to 15-cm depth than 15 to 30-cm depth in the beds but this effect was not found for Ca and Mg. At the 0 to 15-cm depth, water-extractable Ca, Mg, K, and NH_4^+-N values were 14, 26, 44, and 47% respectively, of those obtained by double-acid extractant. At the 15 to 30-cm depth respective values were 7, 16, 34, and 34% for water extractable compared to double-acid soil test values. These studies indicated that soluble salt composition from a 1:1 soil to water extract can supplement soil test data obtained by the double-acid method, particularly for K and NH_4^+-N analysis.

237 Sulfur-Coated Urea as a Slow-Release Nitrogen-Source for Pepper and Watermelon. S. J. Locascio and J.G.A. Fiskell (Univ. Florida, Gainesville). *Proc. Tropical Region, Am. Soc. Horticultural Science 19;* pp. 171-80 (1975). In studies with the watermelon cultivar Charleston Gray and *capsicum* cultivar Yolo Wonder L., sulfur coated urea (SCU) was applied at 56, 140, and 224 kg N/ha plus a basal dressing of P_2O_5 and K_2O at 84:35 kg N/ha. This was compared with plots receiving non-coated urea. Productivity of both crops was considerably higher on plots receiving SCU, indicating the beneficial effect of slow-release N source in areas with high rainfall. Watermelon yields were highest (43.7 tons/ha) on plots receiving SCU at 140 kg/ha and *capsicum* yields (over 22 tons/ha) on plots receiving SCU at 224 kg/ha.

238 Comparison of Sulfur-Coated and Uncoated Urea for Watermelons. S. J. Locascio, J.G.A. Fiskell, and G. W. Elmstrom (Univ. Florida, Gainesville). *Soil Crop Sci. Soc. Fla. Proc. 37;* pp. 197-200 (1978). Sulfur-coated urea (SCU) (10-60% initial dissolution) and uncoated urea were evaluated in field studies as N sources for watermelons (*Citrullus lanatus*) at six sites. At four sites, yields were higher with SCU than with urea applied in one application. However, yield differences among sources were significant only during one very wet season. Yields with SCU were equal to urea applied in two or three split applications in all experiments. Response to N rate was independent of N source. Maximum yields were generally produced with application of 140 kg/ha N. Available N declined rapidly in yr with rainfall sufficient for leaching from the beds. Differences in available soil N due to N source were generally smallest after 1 and 3 months and greatest 2 months after fertilizer application.

239 Evaluation of Sulfur-Coated Ureas in Laboratory and Field Studies. S. J. Locascio, J.G.A. Fiskell, and F. G. Martin (Univ. Florida, Gainesville). *Soil Crop Sci. Soc. Fla. Proc. 33;* pp. 191-6 (1974). Sulfur-coated urea (SCU) sources with 7-day dissolution rates from 9.5 to 59.5% in water were found to retain 76 to 21% of the applied N, respectively, in pellets resistant to release either by submerged leaching or intermittent leaching over a 6-week period. In laboratory studies, N release from the various sources was related to TVA rated dissolution rates but was considerably slower. Field studies with watermelons [*Citrullus lanatus* (Thunberg) Matsumura and Nakai] were conducted during three seasons. Urea, NH_4, and NO_3 levels in soil were monitored each month of the growing season to evaluate the effects of various N sources, placements, and mulch treatments at N rates of 56, 140, and 224 kg/ha. Soil urea values with SCU sources and with urea protected with polyethylene or paper mulch were higher early in the season than those with urea. Two to three months after fertilizer application, differences in urea level between N sources were not significant. Ammonium and NO_3 levels were maintained higher with mulched than unmulched treatments. There was no significant effect of SCU on soil pH during the experiments. It was concluded that SCU sources, regardless of dissolution rating, were somewhat better than urea or other soluble N sources in sustaining available N but were inferior to mulched protection of applied N.

240 Watermelon Response to Sulfur-Coated Urea, Mulches, and Nitrogen Rates. S. J. Locascio, J.G.A. Fiskell, and H. W. Lundy (Univ. Florida, Gainesville). *Proc. Fla. State Hortic. Soc. 86;* pp. 201-4 (1973). Watermelon response to various formulations of S-coated urea applied broadcast were compared with noncoated urea either broadcast, banded, banded with a strip mulch, or broadcast under paper or polyethylene mulches. Significant effects of N source treatment were obtained in two of the three seasons evaluated. Fruit yields with S-coated urea with 30 and 40% dissolution rates and with isobutylidenediurea as the N source were similar to either treatments with urea applied broadcast under polyethylene or

paper mulch, under strip mulch, or when urea or NH_4NO_3 was applied in three applications. In 1 of the 2 yr, lowest yields were produced by urea applied either broadcast or banded without mulch. Significant quadratic yield responses to N rate occurred in two of the three seasons. Fruit production increased with an increase in N rate from 50 to 125 lb/acre. A further increase of N to 200 lb/acre depressed yields slightly. Tissue N reflected rate and N source effect.

241 Effects of Sulfur-Coated Urea and Potassium Chloride on Watermelon Production and Soluble Salts. S. J. Locascio and J.G.A. Fiskell (Vegetable Crops Dep., IFAS, Gainesville, Florida). *Soil Crop Sci. Soc. Fla. Proc. 30;* pp. 113-22 (1970). Experiments with sulfur-coated urea and KCl in Florida with watermelon as the test plant showed that higher levels of NO_3 and K were maintained in the soil with this source than when uncoated fertilizers were used. In the first month after application the S-coated urea decreased soil pH from 5.81 to 5.26. Yield and mean wt of marketable fruit were significantly higher with S-coated urea as compared with uncoated urea applied in a single application.

242 Sulfur Coated Fertilizers in Watermelon Production. S. J. Locascio and J.G.A. Fiskell (Univ. Florida, Gainesville). *Sulphur Inst. J.* 7 (1), 7-10 (Spring 1971). Laboratory and field tests were conducted with S-coated urea and S-coated KCl prepared by TVA. The S-coated urea contained 34.8% N, 19.5% S, wax sealant, and microbicide. The S-coated KCl contained 41.6% K_2O, 26.1% S, wax sealant, and microbicide. In the laboratory study, release of N and K over a 90-day period was greater to Leon fine sand than to deionized water. In the field study with Charleston Gray watermelons on a Leon fine sand, treatments were 500, 1000, and 2500 lb/acre of 6-8-8 fertilizer formulated with S-coated and uncoated urea and KCl. All fertilizer was applied broadcast and rototilled into the soil before planting except in one treatment in which uncoated fertilizer was applied one-third at planting, one-third at thinning, and one-third at lay-by. Sulfur coating was effective in reducing the soluble salts in the soil for the first 4 months after application. Soil pH decreased linearly with rate of S-coated urea application but was not affected by uncoated urea and S-coated KCl. Yields were higher with S-coated urea than with uncoated urea; KCl source had no effect on yield. Sulfur-coated urea reduced % Mg in plant tissue at 12 and 20 days after emergence but not at 30 days. Sulfur-coated KCl increased the % Ca at 12 and 30 days and % Mg at 30 days.

243 Slow Release Fertilizers for a Uniform Supply of Nitrogen and Potassium to Watermelon. G. W. Elmstrom, J.G.A. Fiskell, and F. G. Martin. *Soil Crop Sci. Soc. Fla. Proc. 34;* pp. 88-91 (1975). Split applications of conventional sources of fertilizer N were more effective in maintaining soil N than single applications. There was no evident benefit from splitting the application of conventional sources of fertilizer K. Resin-coated N (Osmocote), sulfur-coated urea (SCU), and sulfur-coated KCl (SCK) were effective in maintaining soil nutrient levels during the growing season, although release of N and K from Osmocote was probably too slow for complete utilization of the nutrients by watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]. To maintain the same levels of soil N and K, about 50% more fertilizer N and K were needed when conventional materials were used than when Osmocote, SCU, and SCK were used. Soil N levels were low throughout the season in areas treated with urea formaldehyde, indicating that this material was not suitable as a sole source of N for watermelon.

244 Comparison of Sulfur-Coated and Uncoated Urea. II. Changes in Available Nitrogen in Sandy Soils. J.G.A. Fiskell, S. L. Locascio, and G. W. Elmstrom (Univ. Florida, Gainesville). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* pp. 148-9 (1974). Sulfur-coated urea (SCU) formulated for 7-day dissolution rates ranging from 9.5 to 59.5% of total N was compared with uncoated urea in 6 field experiments with watermelons grown on sandy soils; N rates were 56, 140, and 224 kg/ha at four sites and 135 kg/ha at two sites as preplant broadcast applications. Soil from the fertilized beds was sampled monthly during the growing season and analyzed for urea-N, NH_4-N, NO_3-N, Cl, pH, and exchangeable cations. Significant rate and source x rate differences were noted for the first 2 months. Soil urea from SCU sources was quite low the second month and negligible by the third; available N followed a similar pattern. Differences in extracted soil N between SCU sources of various dissolutions were rarely significant; since SCU did not cause a drop in soil pH, S oxidation of the coating was probably minimal in 3 months. Changes in soil available N were compared with rate of urea released from SCU sources for laboratory water-extraction losses during 3 months. It was concluded that S-coated urea decreased early season leaching losses of N and had a small but significant effect on available soil N supply as the crop neared maturity.

245 Comparison of Sulfur-Coated and Uncoated Urea. I. Watermelon Response in Field Experiments. S. J. Locascio, G. W. Elmstrom, and J.G.A. Fiskell (Univ. Florida, Gainesville). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 151 (1974). Sulfur-coated urea (SCU) and uncoated urea were evaluated in field studies as nitrogen sources for watermelons [*Citrullus lanatus* (Thunberg) Matsumura and Nakai]. Nitrogen sources were applied at rates of 56, 140, and 224 kg/ha. Experiments were conducted at three locations to evaluate SCU of various dissolution rates (9.5% to 59.5% dissolution rate in a 7-day period). Yields were consistently increased with SCU as compared with urea applied in one application. Production was equal to urea applied in three split applications. Response to N rate was independent of N source. Maximum yields were generally produced with the application of 140 kg N/ha. The response to SCU was obtained although foliage N content taken at two or three growth stages was not consistently affected by N source.

246 Muskmelon Response to Rates and Sources of Nitrogen. G. E. Wilcox (Purdue Univ., West Lafayette, Indiana). *Agron. J.* 65 (5), 694-7 (Sept.-Oct. 1973). The method and rate of N fertilization of muskmelons (*Cucumis melo*) on sandy soils is of concern because of the leaching potential of N. The relative availability of N from ammonium nitrate, urea-formaldehyde, and S-coated urea (SCU) was studied in the field with regard to influence on growth, leaf and petiole composition, and fruit yield of muskmelon. The field studies compared various N materials in different timing and rate schedules. The fertilizers were used at 0, 33, 66, 99, 132, and 264 kg N/ha in single (preplant) and split (preplant + sidedressing) applications. Data were collected for four seasons. In each yr N application increased vine growth and intensity of the green color of the leaves. The N concentration of the recently mature melon leaves was increased more by NH_4NO_3 than by urea-for-

maldehyde or SCU. The relationship of N rate was linear with N composition but parabolic with yield. Optimum plant growth and fruit yields were obtained with a preplant application of 80 to 90 kg/ha. The same total N rate as a split application or as a less available N source was not as effective for fruit yield production. The increased yield from N treatment was due to increased vine size and increased numbers of fruit. Optimum fruit yields were produced at leaf composition of total N over 4.5% or petiole content of NO_3-N over 15,000 ppm during vegetative and fruit initiation stages. Sulfur-coated urea with 37% dissolution rate produced NO_3-N and total N concentrations of petioles about equal to the same N rate as NH_4NO_3; SCU with 12% dissolution rate resulted in NO_3 concentrations equal to one-quarter the N rate as NH_4NO_3 at the runner stage and equal to one-half the N rate as NH_4NO_3 just prior to harvest. Ammonium nitrate applied preplant at 80 to 90 kg N/ha was the most effective treatment and resulted in optimum muskmelon fruit yields on sandy soils of southwestern Indiana in each yr of the study.

247 Sulfur-Coated Urea as a Fertilizer for Potatoes. David Cox and T. M. Addiscott (Rothamsted Exp. Stn., Harpenden, Hertfordshire, England). *J. Sci. Food Agric. 27* (11), 1015-20 (Nov. 1976). In a field experiment comparing S-coated urea (SCU) and "Nitro-Chalk" at rates up to 400 kg N/ha, potato tuber yields were greater with "Nitro-Chalk" at rates up to 200 kg N/ha, but there was no consistent difference between forms of N at larger rates. The crop recovered more N from "Nitro-Chalk" at all rates except 350 kg N/ha. The largest measured yield was at 200 kg N/ha with "Nitro-Chalk" and 250 kg N/ha with SCU, and the optimum N rate inferred from split-line regressions of yield on N rate was also at a lower N rate with "Nitro-Chalk." Yields of winter wheat following the potatoes increased significantly with the N rates given to the potatoes and, at rates above 200 kg N/ha, were larger where SCU had been used. Residues from SCU also lessened the response of the wheat to a spring top-dressing of new N slightly more than those of "Nitro-Chalk." The sum of the apparent recoveries by the two crops of N given to the potatoes was greater from "Nitro-Chalk" at rates up to 200 kg N/ha. In the glasshouse, potato plants grown in 3 kg soil took 71 days to initiate tubers when given 2 g N as NH_4NO_3 but this time was much decreased as increasing proportions of SCU were used. When 1 g N was given, the time was only 47 days with NH_4NO_3 and the proportion of SCU had little effect. In the field, the number of tubers/plant by mid-June decreased with increasing N rate with "Nitro-Chalk" but not with SCU.

248 Evaluation of Sulfur-Coated Urea (SCU) Applied to Irrigated Potatoes and Corn. E. A. Liegel and L. M. Walsh (Univ. Wisconsin, Madison). *Agron. J. 68* (3), 457-63 (May-June 1976). Excessive rates of soluble N fertilizers are sometimes used on irrigated sands in Central Wisconsin to compensate for loss by leaching of some of the applied N. Use of a slow-release form of N or several small applications of a soluble N fertilizer may eliminate some leaching and subsequent loss of NO_3-N. This study was designed to evaluate these methods of reducing N losses by measuring yield and recovery of applied N by potato and corn. Nitrogen treatments applied each yr for 3 yr were: (1) urea in a single or split application, (2) SCU impregnated with a wax coating, and (3) SCU with only a S coating. Recovery of applied N by tubers from a single urea application was extremely low in 1972 due to severe leaching induced by abnormally high precipitation. Slow-release SCU carriers produced higher yields and N recovery that yr because their slow dissolution reduced leaching losses of N. However tuber yields and recovery of N from urea treatments were greater than from SCU treatments in 1973 and 1974 because of reduced leaching those years. In addition, the supplemental N (urea or SCU) for all potato treatments was protected from leaching in 1973 and 1974 by placement of the N into a relatively dry zone of the potato hill. Corn yields and grain N recovery were similar among carriers of N in 1972 and higher from urea than SCU in 1973 and 1974. The greater recovery of N from urea by corn grain as compared to potato tubers in 1972 apparently was due to the deeper rooting of corn. Furthermore the potatoes received twice as much water by irrigation as compared to the corn. Oat (*Avena sativa* L.) forage yields from both trials in 1975 indicated there was greater residual N in SCU plots than urea plots due to incomplete release of urea-N from SCU. Adequate dissolution of SCU-N within a single growing season occurred only under severe N-leaching conditions.

249 Use of Slow-Acting Nitrogen Fertilizers in Agriculture. Possibility of Increasing Potato Yields With Sulfur-Coated Urea. S. De Haan (Instituut voor Bodemvruchtbaarheid, Oosterweg, Haren, Groningen, Netherlands). *Bedrijfsontwikkeling 6* (5), 435-8 (1975) (Dutch). *Soils Fert. 38*, 6364. In a trial in the northeast polder potato yields were higher with S-coated urea than with $Ca(NO_3)_2$, but the difference was not sufficiently great to make it more economic. In a trial in North-Groningen the yield response to S-coated urea was no greater than to calcium ammonium nitrate. However, S-coated urea gave higher dry matter contents and lower N contents of the tubers than did the Ca fertilizers.

250 Comparison of Sulfate of Ammonia and Sulfur-Coated Urea for Red McClure Potatoes in the San Luis Valley. P. N. Soltanpour. *Colo. Agr. Exp. Sta. Progr. Rep. Pr.* 70-48; 2 pp. (Dec. 1970). Use of sulfur-coated urea (SCU) to provide 100 lbs N/acre resulted in chlorotic potato plants and lower U. S. No. 1 yields compared to the use of ammonium sulfate to provide the same amount of N. U. S. No. 1 yield with sulfur-coated urea was 77% of the yield with ammonium sulfate with 100 lb of N/acre. No advantage was observed in mixing SCU and AS compared to the use of AS alone. One application of N at planting was adequate for the high yields obtained. At 70 days after planting, petiole NO_3-N contents of 3358 and 21,476 ppm were deficient and adequate, respectively, for the maximum yield obtained. Application of Zn to the soil did not increase the yield of potatoes in this soil of 0.61 ppm DTPA-extractable Zn.

251 Effect of Slow-Release Nitrogen Compounds on the Yield and Quality of Russet Burbank Potatoes in Washington. R. Kunkel, B. L. McNeal, and C. B. Kresge (Washington State Univ., Pullman). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*; p. 151 (1974). It seems desirable to supply the plant with small uniform amounts of N during the season thereby maintaining a relatively constant size plant that produces tubers instead of excessive vines. This is especially important in the irrigated Columbia Basin of Washington where potatoes are harvested 100 to 180 days after planting. Also, leaching of nitrates and sulfates could be minimized. Ureaformaldehyde (UF) and sulfur-coated urea (SCU) were compared to readily available N sources during 1971, 1972, and 1973. In 1971, reducing the amount of readily available N early in the season by substituting UF or

SCU decreased yields. Sulfur-coated urea materials of higher dissolution rates were used in 1972 and 1973 and yields were comparable to those with ammonium nitrate, ammonium sulfate, and urea. Ureaformaldehyde produced lower yields. Total N and nitrate concentrations in the petioles tended to be lower with SCU than with readily available N sources, particularly at higher N rates. Soil nitrates in the 0 to 61 cm depth early in the growing season under fertilization with SCU was about one-half that found in plots fertilized with a readily available N source. At season's end, soil solution N with SCU generally was the same or slightly higher.

252 Effect of Five Levels and Three Sources of Nitrogen on Sweet Potato Yields on an Ultisol. H. Talleyrand and M. A. Lugo-Lopez (Univ. Puerto Rico, Rio Piedras). *J. Agric. Univ. P. R. 60* (1), 9-14 (1976). The soil was situated in the central, hilly, interior of Puerto Rico at about 450 m above mean sea level. Treatment differentials were: Broadcast, preplant applications of 0, 10, 20, 40, and 50 kg N/ha from urea and 40 kg N/ha from two sulfur-coated urea compounds (slow-releasing N sources) containing 39.6 and 37% N in each case. The soil had a pH of 4.7 in the top 25 cm of the profile but it apparently supplied enough Ca for a sweet potato crop. There was no evidence of Al injury to the crop even though exchangeable Al levels were high, more than 50% of the sum of cations were in the 25-50 cm layer. Maximum marketable yields were 14.6 tons/ha, which were obtained with the application of 40 kg/ha of N as ordinary urea. Evidently there was no advantage in using slow-releasing N sources. In fact, a slight yield depression was observed. The Capo fertilizer-yield equation was applied to the mean yield data obtained from the urea treatments, and a coefficient of determination of 0.99 was obtained. This equation appeared to be useful in predicting sweet potato yields in terms of the N fertilizer applied in this experiment.

253 Problems of Nitrogen Nutrition of Mature Apple Trees on M-9 Rootstock. D. C. Ferree and G. A. Cahoon. *Ohio Agric. Res. Dev. Cent. Res. Circ.* No. 239; 9-12 (1978). The increasing use of trees on clonal size controlling rootstock, particularly in the most dwarfing M 9, has created a need for more precise information on the proper fertilization of these trees. Although various investigations have found some differences in nutrient uptake of dwarf versus standard sized trees, it is generally agreed that alteration of nutrient uptake is not the mechanism causing dwarfing. Most current fertilizer applications are based on recommendations of foliar analysis and tree age. Such recommendations make no adjustment for tree size as influenced by rootstock. The amount of N fertilizer required to maintain adequate leaf N levels and sustain optimum shoot and fruit growth in mature dwarf trees has not been determined.

254 Effects of Fertilization, Herbicides, Growth Regulators, Planting Material, and Breeding on Malanga (*Xanthosoma* spp.) Production in Southern Florida. A. J. Beale (Univ. Florida, Gainesville). *Diss. Abstr. B40* (8), 3523-4 (Feb. 1980). A series of seven trials and 17 experiments were established to develop preliminary technological practices for growing malanga (*Xanthosoma* spp.) efficiently under the climatic and edaphic conditions of southern Florida. Sulfur-coated urea tended to produce more foliage, higher yield, and higher average wt/main and secondary corms than NH_4, NO_3, or organic N under irrigation when applied to 420 kg/ha N to a low fertility Rockdale soil. An increase at frequency of application from 2 to 3, but not from 3 to 4 or 5 tended to increase yield and number of cormels/ha when a 25% organic fertilizer of a 7.5-8.6-9 formula was applied at 336-168-336-168 kg/ha N-P-K-Mg, respectively, plus micronutrients to a Rockland soil. Linuron or diuron at 1.4 to 1.68, or linuron at 1.12 plus alachlor 1.12 kg a.i./ha were effective in controlling most of the predominant weeds. They were toxic when sprayed broadcast over the crop, but did not cause residual toxicity to malanga. The total plant fresh and dry wt increased faster from 106 to 198 days after planting than in any other part of the growing season.

255 Effect of Urea and Urea-Sulfur on 'Giant Cavendish' Banana Production in Guapiles, Costa Rica. Ramiro Jaramillo and Rufo Bazan (Union Cia Centroam., S. A., San Jose, Costa Rica). *Turrialba 26* (1), 90-5 (1976) (Span.). This study was carried out in a banana plantation where mean annual rainfall is ~ 3830 mm and mean annual temperature is ~ 25.7°. Plain urea (46% N) and S-coated urea (38.3% N and 14% S) fertilizers were tested at levels of 0, 16, 31, 47, 68, 136, 205, 272, 341, and 409 kg N/ha and applied at intervals of 4, 6, 8, 10, 12, and 14 weeks. Highest yields were obtained at the 47 kg N/ha level applied at 12 weeks interval; however S-coated urea yielded ~ 18% higher than regular urea.

256 The Effect of Controlled-Availability Nitrogen Fertilizers on Mature Pecan Trees. D. T. Sullivan, G. A. O'Connor, and E. Herrera-Aguirre (New Mexico State Univ., Las Cruces). *Soil Sci. Soc. Am. J. 40* (3), 470-2 (May-June 1976). Two controlled-availability N fertilizers, S-coated urea (SCU) and NH_4NO_3 plus N-Serve, were compared with NH_4NO_3 alone applied to 30-yr-old pecan trees (*Carya illinoensis* Koch) in a 2-yr study. Leaf N contents were increased both yr by N fertilization, but yield and nut wt were not significantly affected. Yields in 1973 were correlated with 1972 leaf N contents, but not with 1973 leaf N contents. The SCU treatment was effective in controlling N release in 1973, but not in 1974. The N-Serve treatment was ineffective both yr of the study. The ineffectiveness of the controlled N sources were attributed to: (1) poor incorporation of the materials, (2) inherent slow response of mature pecan tree to N fertilization, and/or (3) sufficient variability within treatments to mask fertilizer source difference.

257 Response of Cranberry Bogs to Sulfur-Coated Urea. A. Y. Shawa (Coastal Washington Res. Ext. Unit, Long Beach) and C. B. Kresge. *Sulphur Inst. J. 12* (3-4), 6-9 (Fall-Winter 1976). In order to reduce labor and traffic in Washington's cranberry bogs, it was desirable to find a fertilizer formulation that would uniformly release an adequate amount of N for growth, flower bud set, and fruit development throughout the growing season. A single application of S-coated urea, ranging from 18 to 40% in dissolution rate, applied at a rate of 22.4-44.8 kg N/ha replaced multiple applications of urea. The S-coated urea was economical, increased yield without causing excessive cranberry vegetative growth, and performed well when cranberry fruit set parameters were measured.

258 Effect of Slow-Release Nitrogen on Cranberries: Sulfur-Coated Urea and Isobutylidene Diurea. A. Y. Shawa. *Pullman, Washington: Washington State Univ. Bull.* No. 0880; 4 pp. (Aug. 1979). Sulfur-coated urea (SCU) and isobutylidene diurea (IBDU), two slow-release N formulations, were shown to be suitable sources of N for cranberries in western Washington. They can be applied once during April or May, in

contrast to the customary grower practice of three or four applications of urea during the growing season. This prevents trampling of plants while fertilizing during the growing season which causes vine and berry damage and is reflected in lower yields during the current yr and subsequent yr. Plots receiving a single 44.8 kg/ha application of 1:1 combination of SCU-18 and SCU-40 or IBDU, size 0.7-2.0 mm, produced higher yields than urea-fertilized plots. Fruit set was improved by the SCU-18 plus SCU-40 combination. Berry volume and wt, soluble solids, acidity, and percentage breakdown during storage were not affected by treatments (15 ref).

259 Response of Cranberry Bogs to Sulfur-Coated Urea. A. Y. Shawa (Washington State University, Pullman). *HortScience 11* (3 Sect 2), 322 (1976). During the period 1971-75 sulfur-coated urea (SCU) was shown to be a suitable source of N for cranberries in western Washington. This N source can be applied in one application in May, compared to three or four applications of urea. Trampling of plants while fertilizing during the growing season often causes vine and berry damage which is reflected in lower yields. Yields of berries receiving the single application of SCU with dissolution rates of 18 and 40% produced yields 10 and 9%, respectively, higher than those from urea; and a 1:1 combination of SCU-18 and SCU-40 gave yields 25% greater than those from urea. Fruit set was improved by the highest rate of SCU-18 + SCU-40 during 1973. In 1974 and 1975 few urea and SCU treatments increased, over the check, the number of fruiting buds per unit area, length of upright and the number of berries per upright.

260 Response of Cranberry Bogs to Sulfur-Coated Urea: A Slow Releasing Nitrogen. A. Y. Shawa (Washington State University, Pullman). *HortScience 7* (3), 29 (June 1972). Four sulfur-coated urea (SCU) formulations with dissolution rates of 4, 13, 18, and 26% and standard urea 46% were applied at the rate of 0, 10, 20, 30, and 40 lbs N/acre to McFarlin cranberry vines. Sulfur-coated urea 26% applied at the rate of 20 lbs N/acre increased yield significantly. Volume, berry weight, soluble solids, and pH showed no significant differences.

261 Comparison of Urea and Sulfur-Coated Urea as Nitrogen Sources for Lowbush Blueberries Growing on a Colton Gravelly Loamy Sand. J. M. Smagula and P. R. Hepler (Maine Univ., Orono). *J. Am. Soc. Hort. Sci. 103* (6), 818-20 (1978). Fertilization with 98 or 196 kg N/ha from urea or sulfur-coated urea (SCU) resulted in higher amounts of K_2SO_4-extractable ammonium N in the 0-7.6 cm but not in the 7.6-15.2 cm soil layer. There was no difference due to N sources. Application of 98 kg N/ha from either urea or SCU to five clones of lowbush blueberry (*Vaccinium angustifolium*) increased leaf N concentration, size and wt of leaves, flower bud formation, and yield from 4870 to 6565 (urea) and 6630 kg/ha (SCU).

ORNAMENTALS AND TURF

262 Sulfur-Coated Urea Fertilizer for Controlled-Release Nutrition of Container-Grown Ornamentals (*Ceanothus cyaneus, Camellia japonica, Prunus taurocerasus*). Tokuji Fureta, R. H. Sciaroni, and J. R. Breece. *Calif. Agr. 21* (9), 4-5 (1967). *Biol. Abstr. 49*, 80614. Nursery experiments show that S-coated urea was excellent as a slowly available form of N for ornamental plants in containers. Best plant growth resulted when the S-coated urea was incorporated in the potting mix and the plants received fertilizer applications during the growing season. Even without additional fertilization, the controlled-release urea was able to supply adequate amounts of N for several months' growth. Excessively heavy applications resulted in plant injury and death.

263 Effect of Nine Controlled-Release Fertilizers on Chrysanthemum Growth and Foliar Analysis. G. C. Sharma and A. J. Patel (Alabama A&M Univ., Normal). *J. Am. Soc. Hortic. Sci. 103* (2), 148-50 (Mar. 1978). Single application of nine controlled-release fertilizers applied prior to planting and liquid fertilization applied at each watering were evaluated on pot chrysanthemum, *Chrysanthemum morifolium* Ramat cultivar Sunny Mandalay. Three rates (20, 40, and 60 g N/35 L of mix) were applied of the following controlled-release fertilizers (N-P-K): Sulfur-coated urea (36-0-0 as SCU-A and SCU-B), Osmocote (14-6.1-11.6 and 18-2.6-9.8), Mag AmP (7-17.5-5.0 as fine and coarse), Precise (8-4.8-4.1 and 12-2.6-5.0), and Agriform (14-1.7-5.0). Liquid fertilization applied 200 ppm N, P_2O_5, and K_2O with each watering. Generally 60 g N/35 L resulted in higher quality plants than did the lower rates. Effect of Osmocote (14-6.1-11.6) on plant dry wt, visual rating and plant spread was not significantly different from liquid fertilizer. Precise (8-4.8-4.1), Osmocote (18-2.6-9.8), and coarse Mag AmP produced marketable plants of slightly lower quality than those obtained with liquid feed. Problems observed were primarily those of nutrient balance: very low P (SCU) and high P content (Mag AmP); P-induced Mn deficiency (Mag AmP); some lower leaf burn with initial high N release (Precise) and injury probably caused by ammonium and high rates of urea formaldehyde-based fertilizer (Agriform). The low initial release of N to support vegetative growth was also an important limitation with Agriform and other fertilizers.

264 The Effect of Different Nitrogen Fertilizers and Fritted Trace Elements on the Micronutrient Nutrition of Chrysanthemum Plants Grown in Soilless Potting Media. C. B. Christie (National Plant Materials Center, Palmerston North, New Zealand). In *Development and Use of Soil-less Media for Horticulture. Wellington, New Zealand: Ministry of Agriculture and Fisheries;* pp. 17-1 to 17-10 (1979). *Soils Fert. 43*, 8006. Cultivar Nob Hill chrysanthemum plants were grown for 10 weeks in peat/perlite or peat/pumice mixtures with the addition of Osmocote (26:0:0) (NH_4^+ + NO_3^-) or sulfur-coated urea (NH_4^+). Half the plants in each treatment also received 0.2 g/L fritted trace elements. The N source exerted more influence on the foliar micronutrient level in peat/perlite than in peat/pumice. Copper and Zn contents of plants tended to be higher with NH_4^+-N only in the medium, compared with the mixed N source. This effect occurred irrespective of the fritted trace element level. Plant Mn and Fe levels were increased by the mixed N source when fritted trace elements were used.

265 Comparison of Sulfur-Coated Urea and Nitroform in Potting Soils. R. L. Self, C. T. Pounders, Jr., and R. B. Diamond (Auburn Univ. Agric. Exp. Stn., Auburn, Alabama). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* pp. 154-5 (1974). Sulfur-coated urea formulations SCU-15 and SCU-30 were compared with the Nitroform formulation of ureaformaldehyde at 1.25, 2.5, and 5.0 lb of material/cubic yard of growing media. Plants used were

compacta and Burford holly, golden euonymus, variegated chinese privet, Red Wing, and Hershey Red azalea. Media for the two azalea cultivars consisted of equal parts German peat, pine bark, and Birmingham slate and the other four species were planted in a mixture having an additional part sandy topsoil. Six lb of dolomite, 3 lb superphosphate, 2 lb gypsum, one-fourth lb Nu-Iron, and one-fourth lb micronutrients/cubic yard were incorporated into both mixtures. The privet, euonymus, and two holly species were planted on September 28, 1973 and the two azalea cultivars were planted on January 21, 1974. Six-inch azalea pots were used for all planting. Treatments were maintained without additional fertilization in a 65°F greenhouse (night temperature) until May 14, 1974. The best general treatment was 1.25 lb of SCU-15; 5 lb Nitroform and 1.25 lb SCU-30. Poorest were SCU-15 and 30 at 5 lb.

266 Turfgrass Fertilization with Sulfur-Coated Urea. D. V. Waddington (Pennsylvania State Univ., University Park). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.*: p. 156 (1974). Turfgrass response to fertilization with sulfur coated urea (SCU) has been determined in several studies. Sulfur-coated urea (sulfur and wax plus microbicide coatings, and a dissolution rate of 21% in 7 days) was used to fertilize Kentucky bluegrass, *Poa pratensis* L., and creeping bentgrass, *Agrostis palustris* Huds. Sulfur-coated urea and 11 other fertilizers, having different N sources and amounts of water insoluble N, were applied on Kentucky bluegrass in September, May, and July (0.73 kg N/100 m^2 on each date). Sulfur-coated urea gave intermediate growth response during the 1st yr and had the greatest increase in response for the 2nd yr, when it also had the darkest color and gave the most uniform growth of the highest yielding treatments. A single spring application of SCU (2.92 kg N/100 m^2) on Pennpar creeping bentgrass did not have enough residual effects for good fall response. Performance was similar to that of other slow-release fertilizers. Response of Merion bluegrass to spring applications (1.95 kg N/100 m^2) of different formulations of SCU indicated that for similar dissolution rates, release was quicker when coatings were sulfur and wax rather than sulfur alone.

267 Use of Sulfur-Coated Urea on Turfgrass. D. V. Waddington (Pennsylvania State, University Park). In *Agronomy Abstracts 1975 Annual Meetings* (held Knoxville, Tennessee, Aug. 24-30, 1975). *Madison, Wisconsin: Am. Soc. Agron.*: p. 174 (1975). Sulfur-coated urea (SCU) has been evaluated on different turfgrass species under various management systems. Results were affected by the wt and composition of the coating. It appears that a 7-day dissolution rate of at least 25% is required for good response in the first season of use. Lower dissolution rates have resulted in delayed release that has lasted longer than one season. In several studies on cool-season grasses, single spring applications of SCU gave excessive spring growth and did not last long enough to give good growth and color throughout the growing season. Split applications seems appropriate with these formulations. In formulations having the same dissolution rate, release was quicker with a sulfur plus wax coating than with sulfur alone. Limitations of SCU include high cost, mower pick-up and close-cut turf, and damage to coatings by traffic or mower blades. As a slow-release N source, SCU has the advantages of long-term release, fewer applications, reduced hazard of fertilizer burn, and an efficiency greater than that of some other slow-release N sources.

268 Effectiveness of a Slow Release Nitrogen Fertilizer on Sports Turf. A. R. Woolhouse. *J. Sports Turf Res. Inst.* No. 50: 34-46 (1974). *Soils Fert. 39*, 1452. A single application of 94 kg of S-coated urea fertilizer Gold-N/ha, to a turf containing ryegrass did not last the whole season. The application of 188 kg of Gold-N/ha, in two applications given 12 weeks apart greatly improved the performance in the later part of the season.

269 Abnormal Color Response of Turf Ryegrass to Top-Dressed Isobutylidene Diurea. G. M. Volk and A. E. Dudeck (Univ. Florida, Gainesville). *Agron. J. 68* (3), 534-6 (1976). Isobutylidene diurea (0.7 to 1.4 diameter pellets) was used in single applications at 1 to 7.3 kg N/are rates on winter ryegrass (*Lolium perenne* L.) and at 1.5 to 5.9 kg N/are on bermudagrass (*Cynodon* sp.), the latter in all combinations with 0, 0.25, and 0.50 kg urea-N/are every week, and of 0 and 2.4 kg $Ca(OH)_2$/are at initiation tests. A 2.2 kg N/are rate of IBDU resulted in chartreuse green ryegrass when soil pH was above 7.0. At 3.3 to 7.3 kg IBDU-N/are the ryegrass was chartreuse-yellow at 1 month after application, regardless of soil pH. Tissue analysis showed an excellent inverse correlation with Mn content. There was no off-color response to sulfur-coated urea or ureaform applied at N rates equivalent to those above. Color assessment by chlorophyll extraction with methanol supported visual observations. There was no toxic response of bermudagrass to IBDU at soil pH 5.1 to 7.3 or at any combination of IBDU with and/or urea.

270 Response Curves of Various Turfgrasses to Application of Several Controlled-Release Nitrogen Sources. G. M. Volk and G. C. Horn (Univ. Florida, Gainesville). *Agron. J. 67* (2), 201-4 (Mar.-Apr. 1975). Responses of turfgrasses to controlled-release N sources, especially the newer materials, have not been adequately evaluated under field conditions. This study obtained N time-release curves as measured by clippings taken periodically after the initial response to readily available N in such products had subsided. Materials were surface-applied once, or at widely spaced intervals, to six different turfgrasses. Three to 4-day growth clippings were taken periodically to assess current N uptake rate against that from a standard treatment consisting of a continuous, uniform weekly application of NH_4NO_3. Sulfur-coated urea (SCU of 9% dissolution rate) gave the most desirable type of response for summer fertilization, followed by isobutylidene diurea (IBDU), activated sewage sludge (Milorganite), and ureaform (UF). The latter two were quite similar in latent response characteristics. The IBDU was superior to the other materials for winter usage, because it did not show the cold weather depression of latent N release exhibited by Milorganite, SCU, and UF. It is postulated that an initial slow N-release rate of IBDU, and the favorable cold weather response curve is the result of the differential effect of temperature on nitrification and, therefore, on acidity and dissolution rate of IBDU in the microenvironment of the pellet. Responses to IBDU of various pellet-size ranges corroborates that surface dissolution is the N-release mechanism, and that varying the pellet size is a valuable method for controlling the N-release rate.

271 Sulfur-Coated Urea New Type of Slow-Release Fertilizer. D. V. Waddington (College of Agric., Agricultural Exp. Stn., University Park, Pennsylvania). *Sci. Agric. 26* (3), 13 (Spring 1979). Research results have shown that various formulations

of S-coated urea are satisfactory for turfgrass fertilization. Sulfur-coated urea can be used alone or in combination with soluble sources in mixed fertilizers. Slow release nitrogen offers the advantages of (1) longer duration of N release, (2) fewer applications, (3) low leaching losses, and (4) safety from the standpoint of fertilizer burn. Disadvantages of slow-release nitrogen sources are the higher cost and the low efficiency that often occurs in the first yr or two of use. Sulfur-coated urea seems most likely of the slow-release fertilizers to become a major turfgrass fertilizer because of its lower cost.

272 Evaluation of Slow-Release Nitrogen Fertilizers on Pennpar Creeping Bentgrass. D. V. Waddington and J. M. Duich (Pennsylvania State Univ., University Park). *Agron. J. 68* (5), 812-15 (Sept.-Oct. 1976). As new fertilizer materials become available for turfgrass fertilization, their relative merits should be evaluated under various field conditions so that sound recommendations can be made concerning their use. In this study on 'Pennpar' creeping bentgrass (*Agrostis palustris* Huds.), single applications of four slow-release N fertilizers and multiple applications of urea applied to fine, mixed, mesic Typic Hapludalf soil were compared for four consecutive growing seasons. Split applications of slow-release materials were also included in the fourth season. Clipping yields and turf color were used to evaluate response to fertilization. Growth patterns varied from yr to yr, but certain relationships between treatments generally remained the same: (1) greatest initial response occurred with IBDU (isobutylidene diurea); (2) yields from slow-release treatments equalled or exceeded those from the urea treatment for 13 to 14 weeks, thereafter urea gave higher yields; (3) response from S-coated urea (21% 7-day dissolution rate) and resin-coated fertilizer (Agriform CRF 19-3-11) was intermediate between IBDU and ureaform (Uramite). Split applications of slow-release sources reduced the flush of spring growth and increased turf color in the fall to an acceptable level. Color was unacceptable in the fall when single spring applications were used. The delay in response noted after IBDU applications on Kentucky bluegrass (*Poa pratensis* L.) in other experiments was not as apparent under the conditions of this study, possibly due to the incorporation of fertilizer by aerating and topdressing at the time of application and more liberal watering on the bentgrass area.

273 Evaluation of Sulfur-Coated Urea Fertilizer on Merion Kentucky Bluegrass. D. V. Waddington and T. R. Turner (Pennsylvania State Univ., University Park). *Soil Sci. Soc. Am. J. 44* (2), 413-17 (Mar.-Apr. 1980). Five experimental formulations of sulfur-coated urea (SCU) from the Tennessee Valley Authority and Gold-N, a product of Imperial Chemical Industries, were applied to 'Merion' Kentucky bluegrass (*Poa pratensis* L.) at a rate of 195 kg N/ha in the spring of 1974, 1975, and 1976. Coating weights of S on TVA materials had been varied to obtain laboratory 7-day dissolution rates of 17, 26, and 35% from material coated with S only; and 16 and 26% from material coated with S plus a wax sealant. Gold-N was coated with S plus a paraffin sealant and had a dissolution rate of 36%. Clipping weights and turf color were used to evaluate turfgrass response. With S-only coatings, turfgrass response increased as coating wt decreased (dissolution rate increased). Differences due to coating wt were greatest in the 1st yr, and diminished in the following yr. In yield and color comparisons over 3 seasons, a low dissolution rate treatment never produced more response than a higher dissolution rate treatment. In comparison of materials with similar dissolution rates but with different coating methods, release of N was more rapid with a S plus wax coating than with a S-only coating. The 7-day dissolution rate was not dependable in predicting field response when coating method was varied (13 ref).

274 Spotted Response of Overseeded Ryegrass to Sulfur-Coated Urea. G. M. Volk (Univ. Florida, Gainesville). *Agron. J. 67* (6), 838-40 (Nov.-Dec. 1975). Sulfur-coated urea (SCU) shows excellent potential as a controlled-release N source for turfgrasses, but highly spotted appearance has always resulted during 3 yr of tests in which SCU was used as an early application of winter ryegrass (*Lolium perenne* L.) overseeded on verticut bermudagrass (*Cynodon* sp.) Darker green spots 5 to 15 cm in diameter constituted 20-50% of the surface area, with lighter green grass between the spots. The spots became smaller and the contrast greater as the season progressed. Chlorophyll content determined by methanol extraction of fresh grass was 8.5 mg/g on dry grass basis in representative darker green spots versus 6.6 mg/g for lighter green interspot areas. Apparently, in the absense of retentive thatch, the large round SCU pellets were readily moved by sprinkler irrigation and rainfall, and concentrated into zones of stability. Poor initial distribution and mower pickup were not determining factors. Where effective thatch is lacking some means of incorporation sufficient to anchor the pellets should be devised.

FOREST

275 Trials with Sulfur-Coated Urea and Other Nitrogenous Fertilizers on *Pinus radiata* in New Zealand. D. J. Mead, R. Ballard, and M. Mackenzie (Forest Res. Inst., Rotorua, New Zealand). *Soil Sci. Soc. Amer. Proc. 39* (5), 978-80 (Sept.-Oct. 1975). Sulfur-coated urea fertilizers were included in six experiments with seedlings of *Pinus radiata* D. Don. The fertilizers were applied in notches alongside seedlings about 2 months after planting, and tree growth was measured for 2 or 3 yr. After slash burning on a strongly weathered clay soil, slow-release N fertilizers, including three formulations of S-coated urea, proved more effective than urea. On a more fertile pumice soil, on both slash burnt and unburnt sites, no response to N fertilizers was detected. However, where the topsoil of this soil type had been either completely or partially removed a response to N occurred. In these two disturbed areas S-coated urea showed no advantage over conventional soluble NH_4-N fertilizers. There were no differences between the effectiveness of three formulations of S-coated urea at any of the experimental sites.

276 Slash Pine Growth Response to Different Nitrogen Fertilizers. R. F. Fisher (Univ. Florida, Gainesville). In *Agronomy Abstracts 1980 Annual Meetings* (held Detroit, Michigan, Nov. 30-Dec. 5, 1980). *Madison, Wisconsin: Am. Soc. Agron.;* p. 201 (1980). Slash pine were fertilized at planting with 20 and 80 kg N/ha as urea, urea formaldehyde, sulfur coated urea, NH_4SO_4, and $NaNO_3$. Semi-mature slash pine were fertilized with 50 and 200 kg N/ha as urea, urea formaldehyde, NH_4SO_4, and NH_4NO_3. Newly planted stands were located on Plummer fine sand and Mascotte fine sand. Tests in semi-mature stands were located on Plummer fine sand, Leon sand, Ruston sandy loam, and Lakeland sand. Nitrate and NH_4^+ content of the soil solution at a depth of 70 cm was monitored in the young stands. Ninety days following treatment NH_4^+ was significantly elevated beneath all but the urea formaldehyde treatment. Two years after application,

NH_4^+ remained elevated under the NH_4SO_4 treatment. During the first 90 days NO_3^- was significantly elevated beneath urea and $NaNO_3$ treatments. This elevation persisted throughout the 1st yr in the $NaNO_3$ treatment. After 5 yr young trees were significantly taller when N had been added. Semi-mature stands on Plummer and Leon soils responded significantly to N addition, while stands on Ruston and Lakeland soils did not. No significant difference in response to different fertilizers occurred in either the young or semi-mature stands.

277 Nitrogen Fertilization of Sycamore, Sweetgum, and Green Ash Seedlings in Forest Nurseries. J. Deines and C. B. Davey (North Carolina State Univ., Raleigh). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 148 (1974). Sulfur-coated urea, urea, and ammonium nitrate were applied at varying rates to two soils to test the source, rate, and amount of nitrogen fertilizer materials needed to produce quality seedlings of sweetgum (*Liquidambar styraciflua* L.), sycamore (*Platanus occidentalis* L.), and green ash (*Fraxinus pennsylvanica* Marsh.). Nitrogen rates were 0, 112, 224, and 448 kg/ha as ammonium nitrate (five equal applications) and 224 kg/ha as urea (five equal applications) and sulfur-coated urea (single application). Diameter at ground line, height, and the green and over-dry wt of leaves, stems, roots, tops, and total plant were measured on samples of the seedlings. Soil and foliage analyses were also conducted to supplement growth results. Sweetgum and sycamore grew best in the silt loam soil when N was applied at 112 kg/ha and when urea was the source. In equal amounts, five applications of commercial urea was not significantly better than a single application of sulfur-coated urea. On the sandy loam soil, N at 448 kg/ha produced the greatest plant growth of green ash and urea was the best source. Urea was significantly better than sulfur-coated urea in stimulating growth response in sandy soil.

278 Effects of Different Sources of Fertilizer Nitrogen on Growth and Nutrition of Western Hemlock. M. A. Radwan and D. S. DeBell (USDA, For. Sci. Lab., Olympia, Washington). *Portland, Oregon: USDA, For. Ser. Res. Paper PNW-261;* 15 pp. (Feb. 1980). Twelve different N fertilizer treatments were tested on potted western hemlock seedlings. Fertilizers affected soil N and pH, and growth and foliar chemical composition of seedlings. Urea plus N-Serve and S-coated urea appeared more promising for promoting growth than other fertilizers tested. Results, however, do not explain reported variability in response of hemlock stands to N fertilization (22 ref).

279 Transformation of Nitrogen Fertilizers and Movement of Nutrients from the Surface of a Rhyolitic Pumice Forest Soil. R. Ballard (North Carolina State Univ., Raleigh). *N.Z. J. For Sci. 9* (1), 53-67 (Aug. 1979). The transformations and movement of urea, diammonium phosphate (DAP), $(NH_4)_2SO_4$ (AS), NH_4NO_3 (AN), calcium ammonium nitrate (CAN), sulfur-coated urea (SCU), and isobutylidene diurea (IBDU) were followed over a 16-week period using intact cores from the surface 10 cm of a rhyolitic pumice forest soil. Fertilizer was applied at equivalent to 200 kg N/ha and the cores were leached with 5 cm of distilled water/week. Ammonium sulfate, AN, and CAN exhibited similar, rapid leaching rates with over 90% of the applied N passing through the cores in 10 weeks: 50% of the N applied as NH_4-N passed through in this form while the remainder was nitrified and passed through as NO_3-N. Urea and DAP showed a slower initial leaching, but this increased as nitrification peaked at 7 weeks. After 16 weeks about 70% of the N applied in urea and DAP had passed through the cores with about 70% of this as NO_3-N. The two slow-release fertilizers, SCU and IBDU showed steady leaching patterns, identical to each other. About 50% of their N was leached over the 16 week period, nearly all as NO_3-N. Very little unhydrolyzed urea was leached from any of the urea-based sources. The bulk of the residual fertilizer N appeared to be in organic form, but it was readily mineralizable. All fertilizers greatly increased the leaching rate of Ca, Mg, and K, with AS having the greatest and DAP the least effect. The fertilizers had little effect on the movement of P in this soil (21 ref).

MISCELLANEOUS

280 Winter Leaching of Nitrate From Autumn-Applied Calcium Nitrate, Ammonium Sulfate, Urea, and Sulfur-Coated Urea in Bare Soil. T. M. Addiscott and D. Cox (Rothamsted Exp. Stn., Harpenden, Herts., United Kingdom). *J. Agric. Sci. 87* (2), 381-9 (Oct. 1976). In a flinty clay loam at Rothamsted, NO_3 concentrations in 0-13 and 13-26 cm layers of plots given all N-sources at 100 kg N/ha in early October were very small by mid-January. Incorporating the fertilizer in the first 13 cm slightly accelerated this loss. Sulfur-coated urea (SCU) maintained smaller NO_3 concentrations than other sources in both layers. By early March SCU plots alone had slightly larger NO_3 concentrations than the controls in the 0-26 cm layer, while in the 26-52 cm layer all N plots had slightly larger concentrations than the controls. Spring barley, given no more N and harvested green at ear emergence, took more N from all N plots than from the controls, most from $(NH_4)_2SO_4$ and least from urea and SCU, but differences between sources were not significant. The NO_3 loss had a negligible effect on soil pH and exchangeable cations. Calcium nitrate leaching data were used to test the equation of Burns and other simple equations which considered the effects of successive percolations in a two-layer system assuming that the layers either could or could not become temporarily oversaturated. All the equations underestimated leaching unless the most inaccessible soil water was left out of the calculations and gave best results when only gravitational water was taken into account.

281 Comparison of Leaching Losses of Nitrogen From Soluble and Slow-Release Fertilizers. L. A. Nnadi (Samaru Ahmadu Bello Univ., Zaria, Nigeria). *Samaru Agric. Newsl. 17* (2), 82-5 (1975). *Soils Fert. 39*, 2183. In the savannah zone of Nigeria, lysimeter experiments were carried out to compare the leaching losses from different sources of N applied to early maize. Generally losses of N from application of S-coated urea, $Ca{\cdot}NH_4NO_3$, and urea, were low. The lowest losses were from the S-coated urea treatment. Highest maize yields were obtained with $Ca{\cdot}NH_4NO_3$. Sulfur-coated urea produced slightly higher yields than did urea.

282 Leaching of Soluble and Slow-Release Nitrogen and Potassium Fertilizers from Lakeland Sand Under Grass and Fallow. G. L. Terman and S. E. Allen (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Soil Crop Sci. Soc. Fla. Proc. 30;* pp. 130-40 (1970). Two greenhouse lysimeter experiments were conducted on 6- x 24-in. columns of Lakeland sand under fallow or 4 cuttings of grass sod receiving 2 or 4 in. of water/week. Nutrients other

than N or K were applied uniformly with all N or K treatments. Amounts of N in leachates collected weekly under fallow for 16 weeks in the N-source experiment were in the order: ammonium nitrate (AN) > urea > sulfur-coated urea (SCU, 18% initial dissolution in water) > SCU (6% initial dissolution) > no applied N. Amounts of leached N were greater with amount applied (365, 730, and 1460 mg/culture), with 4 than with 2 in. of water/week, and much higher under fallow than under sod. Effects of N source on K leached under fallow were: AN > SCU > no N > urea. Only traces of P were leached. Under ryegrass, significant amounts of N were leached only with the 4-in. rate of water from the higher rates of AN and urea; this was reflected in lower yields and N uptake. The SCU-18 was more effective than AN or urea at the higher water rate with 1460 mg of applied N. Lower effectiveness of SCU-19 in other situations and of SCU-6 was reflected by large amounts of N recovered from the granule residues after cropping.

283 Nitrogen Distribution Between Soil and Plants After Sulfur-Coated Urea and Urea Fertilization. G. S. Pettygrove, M. D. Dawson, and V. V. Volk (Oregon State Univ., Corvallis). In *Agronomy Abstracts 1974 Annual Meetings* (held Chicago, Illinois, Nov. 10-15, 1974). *Madison, Wisconsin: Am. Soc. Agron.;* p. 153 (1974). Sulfur-coated urea (SCU 4) and urea were fall applied to tall fescue at rates of 400 and 800 kg N/ha. Soil solution samples from a Woodburn silty clay loam were collected at monthly intervals for 6 months with ceramic tension lysimeters installed at a depth of 90 cm. The nitrate concentration in the percolation water was assayed and, using estimates of drainage vol, nitrate percolation losses were calculated. Nitrate-nitrogen concentration ranged from less than 1 to 10 ppm on SCU-fertilized plots and from less than 1 to 25 ppm on urea-fertilized plots. Nitrogen recovery in plants and residual soil nitrate and ammonium were measured to allow calculation of a N balance. Nitrate-N leaching losses from urea fertilization and from a fallow plot approximated 90 kg N/ha in a drainage vol of 115 cm. Nitrate losses from each sulfur-coated urea application were 15 kg N/ha during the winter months.

284 Nitrogen Management on Irrigated Sands. L. M. Walsh and C. B. Tanner (Univ. Wsiconsin, Madison). In *Agronomy Abstracts 1977 Annual Meetings* (held Los Angeles, California, Nov. 13-18, 1977). *Madison, Wisconsin: Am. Soc. Agron.;* p. 186 (1977). Several studies have been conducted to attempt to reduce N losses on irrigated loamy sand soils in Central Wisconsin. In one study, lysimeters were used to compare a conventional program for managing water and N with an improved program. The improved program resulted in irrigating more often (every 3 days versus every 5 days) applying less total irrigation water (45 cm versus 27 cm), applying less total N (256 kg/ha versus 168) and applying N more frequently (11 applications as compared to 3 applications). The carefully managed improved program maintained yields, improved grade-out and decreased NO_3-N leaching from 200 to 120 kg N/ha. In another study, it was determined that nonuniform infiltration of water occurs beneath the hills of sprinkler irrigated potatoes. Irrigation and fertilizer management could be improved if this nonuniform infiltration pattern is taken into account. Other studies included the use of slow release N materials and nitrification inhibitors. In general, sulfur-coated urea (SCU) and nitrapyrin (N-Serve) treated urea did not increase the yields of potatoes or corn as compared to conventional urea.

285 Nitrogen Release from Sulfur-Coated Urea, as Affected by Coating Weight, Placement, and Temperature. S. E. Allen, C. M. Hunt, and G. L. Terman (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Agron. J. 63* (4), 529-33 (July-Aug. 1971). Greenhouse and laboratory studies were conducted to measure the factors controlling release of N from S-coated urea (SCU). Results of two greenhouse pot tests with common bermudagrass (*Cynodon dactylon*) and a third with uncropped soil in controlled environment regimes showed that the rate of dissolution of SCU increased greatly with higher temperatures of cropping or incubation. Dissolution rates of SCU granules were decreased by heavier coating with S, by inclusion of 0.5% coal tar oil microbicide in the coating, and by surface application, as compared to mixing with the soil. Satisfactorily coated urea (SCU) or split applications of uncoated ammonium nitrate (AN) or urea both resulted in more uniform distribution of forage production and N uptake than did a single application of urea or AN at time of seeding. Greater yields of forage were obtained from single applications of some SCU products than from urea or AN. Apparent volatilization losses of surface-applied urea were severe, particularly at higher growth or incubation temperatures. Losses of N were reduced, but not entirely eliminated by S-coating.

286 Testing the Difference Between Limiting Yields in Quadratic Fertilizer Response Curves. H. R. Tejeda (Int. Fert. Development Center, Muscle Shoals, Alabama). *Agron. J. 73* (1), 136-8 (Jan.-Feb. 1981). Knowledge of whether or not fertilizer response curves have the same limiting yield is useful when comparing fertilizers and estimating their availability coefficient. A statistical procedure to test the difference between limiting yields of two quadratic response curves is presented. The test is contingent to the assumption that the estimated nutrient rates corresponding to the limiting yields are constants. Application of the procedure is illustrated when comparing rice (*Oryza sativa* L.) response to two sulfur-coated ureas (SCU's) differing in solubility with split application of urea. Only the SCU with lower solubility produced a significantly larger limiting yield than split application of urea.

287 Sulfur-Coated Urea and the Alaska Pipeline. C. B. Kresge (TVA, National Fertilizer Development Center, Pullman, Washington). *Sulphur Inst. J. 12* (2), 8-11 (Summer 1976). Analysis of 826 composite soil samples taken along the 800-mile length of the Alaska pipeline indicated an N deficiency for the entire length. Slow-release N fertilizers were used to insure an adequate but not excessive supply of N for establishment and subsequent growth of seeded grasses. Slow-release sources were S-coated urea (SCU) and urea-formaldehyde. Other N sources where NH_4NO_3, NH_4 phosphate, and KNO_3. Rate of application for revegitation during and immediately after construction was 90-100 lb N/acre, up to 70% of which was provided by a slow-release source. Maintenance applications, scheduled to continue for 1-2 yr after pipeline completion, were at the rate of 40 lb N/acre of which 54% was in the slow-release form. About 70% of the pipeline area was deficient in S. Some S was supplied by SCU but water-degradable elemental S, $CaSO_4$, and $(NH_4)_2SO_4$ were the principal S sources. Application rates ranged from 9-43 lb S/acre during construction and 15-37 lb S/acre during maintenance. The fertilizer was applied by hand, by ground equipment, and by plane depending upon the size, steepness, and wetness of the area.

288 Surface Runoff Losses of Fertilizer Elements. E. P. Dunigan, R. A. Phelan, and C. L. Mondart, Jr. (Louisiana Agr. Exp. St., Baton Rouge). *J. Environ. Qual. 5* (3), 339-42 (1976). Surface runoff losses of fertilizer N, P, and K were measured from a Loring silt loam soil with an average slope of 5%. Plots seeded to pearl millet (*Pennisetum typhoides*) in 1973 and 1974 were fertilized at the rate of 112-49-93 kg/ha of incorporated N, P, and K using two different fertilizer blends, a 33.3-8.7-26.6 and an 8-3.5-6.6. The percent of water-soluble fertilizer elements lost in 1973 from the higher and lower blend concentrations, respectively, were N, 0.50 and 0.30%; P, 0.14 and 0.06%; and K, 0.67 and 0.92%. In 1974, N losses were 0.89 and 0.41%; P, 0.35 and 0.20%; and K, 0.42 and 0.35%. Precipitation during the experimental periods was 20.40 cm in 1973 and 11.03 cm in 1974. Two of the millet plots were then topdressed with NH_4NO_3 at the rate of 112 kg/ha. Topdressed fertilizer-N losses were 2.68% in 1973 and 1.82% in 1974. Precipitation during these second tests was 27.97 cm in 1973 and 27.69 cm in 1974. Ryegrass (*Lolium multiflorum*) plots were fertilized with sulfur-coated urea (SCU) and uncoated urea (U) at the rate of 224 kg N/ha during the growing seasons of 1973 and 1974. Total N losses (U versus SCU) were 9.52 and 0.26% in 1973, and 1.67 and 0.42% in 1974. Precipitation was 23.89 cm in 1973 and 29.57 cm in 1974. A 10.08-cm rainfall on the third day of the test in 1973 caused almost three-fourths of the 9.52% N lost from the uncoated urea to be lost in that runoff and while it was still in the urea form. The sulfur coating prevented large surface losses of N from the SCU.

289 Getting Nutrients to Flooded Rice. O. P. Englestad and J. H. Parker (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *World Farming 15* (5), 16-21 (May 1973). In 1968, the U.S. Agency for International Development requested that the Tennessee Valley Authority undertake research to improve the effectiveness of fertilizers for rice grown in countries where farmers cannot maintain continuous flooding. Tests to compare SCU with uncoated urea were conducted in TVA greenhouses and in field experiments in India, Thailand, Philippines, Peru, and Brazil. Sulfur-coated urea looked extremely promising in most of these tests. Losses of N were reduced and rice yields were generally higher with SCU as the source of N. Out of a total of 56 comparisons, 46 showed SCU superior to uncoated urea when both were applied at transplanting time. In 19 of the comparisons, the N was applied as split applications. Sulfur-coated urea was superior in 12 of the 19 comparisons. Five experiments in Peru included treatments in which all the uncoated urea was added as topdressing. Sulfur-coated urea applied at transplanting was superior to topdressed urea in 19 of 26 comparisons. This pattern showing general superiority of SCU over urea under conditions of intermittent flooding agrees quite well with data obtained in the U.S. where flooding was delayed after application in connection with direct seeding.

290 Soil-Fertilizer-Plant-Research 1975-78. *Muscle Shoals, Alabama: TVA, National Fertilizer Development Center,* Bull No. Y-141; 40 pp. (1979). Nitrogen fertilizers are discussed, including dissolution studies with sulfur-coated urea, the fate of applied N, the use of N by rice, denitrification of applied N, leaching and denitrification of N in soils, the use of N by bell peppers in Florida, leaching of N in Alabama, and tillage system effects on N use in Ohio. Phosphorus fertilizers are reviewed, including the effectiveness of phosphate rocks, reactions of ammonium ortho- and polyphosphates in soil, P source evaluation, and the use of P adsorption isotherms, micronutrients and heavy metals (sorghum response to Fe sources, corn and rice response to Zn, soybean and red clover response to MO, redox effects on EDTA and DTPA in soil, heavy metal contaminants in fertilizers), nutrient and heavy metal movement in soils, cereal crop nutrition, methodology of fertilizer-soil-plant research, field crop results (coastal bermudagrass, soybean, cotton, grape), waste heat utilization for soil heating, industrial and urban waste utilization, strip mine spoil reclamation, and forest fertilization are also discussed.

291 Evaluation of Sources and Methods on Nitrogen Application Efficiency Under Upland Cropping in the Tropics. S. Ahmed, H.P.M. Gunasena, and M. Sadiq (Res. Systems Inst., East-West Center, Honolulu, Hawaii). *J. Natl. Agric. Soc. Ceylon (Sri Lanka) 15*, 81-96 (1978). *Abstr. Trop. Agric. 6*, 30107. Field studies were conducted in Iran, Bangladesh, India, Pakistan, and Western Samoa under the INPUTS Project of the East-West Center, Hawaii, to evaluate N sources [normal urea and sulfur-coated urea (SCU)] and methods of their application (broadcasting and incorporating, broadcasting, and banding) for crops grown under upland conditions. The test crops used were sugar beet (Iran), rice (Bangladesh and W. Samoa), maize (Pakistan), and sorghum (India). Sulfur-coated urea showed no advantage over normal urea for sugar beet in two experiments, probably as it requires most of its N during early stages of growth. Similar results were also recorded for rice in Western Samoa and for fodder sorghum in India. Sulfur-coated urea was superior to normal urea for maize in Pakistan, the effect being attributed to heavy losses of urea N due to leaching. The general trend over all locations indicates normal urea to be better than SCU and banding to be superior to other methods of N application (23 ref).

292 Use of Sulfur-Coated Urea for Revegetation of Blast Furnace Slag. R. P. Gemmell (East Cliff County Offices, Preston, Lancashire, England). *Nature 247* (5438), 199-200 (Jan. 25, 1974). Blast furnace slag is a mineral waste problem in the United Kingdom. Revegetation of the slag is extremely difficult because of its high pH (10.2-10.5) and high porosity which permits added soluble nutrients to be lost quickly from the planting medium. A randomized block experiment was set up on a levelled sight which had been exposed to the weather for 4 months (this reduced the surface pH to 9.0). Five treatments were used: 0, 50, and 100 kg N/ha as urea and 50 and 100 kg N/ha as S-coated urea. Phosphate was applied to all plots at 75 kg P_2O_5/ha. Grass (*Festuca rubra*) was sown in June 1972. In September 1972 all plots were refertilized for maintenance with 125 kg P_2O_5/ha and three N treatments (0 and 100 kg N/ha as urea and 100 kg N/ha as S-coated urea) were superimposed on the initial treatment according to a split plot design. Treatment effects were evaluated in May 1973 using visual observations by four individuals. The residual slow-release N responses were significantly better than those obtained by the use of uncoated urea. On the basis of a visual acceptability rating of 1-10, plots with no N were rated 1.00 and with the double treatment of S-coated urea were rated 7.15; a double treatment of uncoated urea received a rating of 4.80. A rating of 6.0 was the minimum for satisfactory appearance.

293 Establishment of Grass on Waste from Iron Smelting. R. P. Gemmell (Greater Manchester Counc. Preston, Lancashire,

England). *Environ. Pollut. 8* (1), 35-44 (Jan. 1975). Vegetation trials were established on a leveled tip of blast furnace slag in the Furness area of Cumbria. The major factors limiting growth were high pH and serious deficiencies of the macronutrients, nitrogen and phosphate. Exposure to natural leaching caused a reduction in surface pH and increased the growth potential of the waste. High rates of initial and maintenance phosphate applications were required to support growth, the high pH causing phosphate immobilization during the early stages of sward development. Repeat applications of nitrogen were essential because of leaching problems and it was shown that slow-release nitrogen fertilizer as sulfur-coated urea was more efficient than uncoated urea. Species trials demonstrated that Festuca rubra was relatively tolerant of the waste.

294 Nitrogen Utilization by Lambs Fed a High Roughage Ration and Supplemented with Compacted Starch Urea or Sulfur-Coated Urea. N. N. Umunna and W. R. Woods. *J. Sci. Food Agric. 26* (4), 413-20 (1975). In two metabolism studies lambs were fed pelleted brome hay supplemented with compacted starch-urea or S-coated urea to examine their potential as slow ammonia release products and their effect on N utilization. In study one, lambs supplemented with the compacted starch-urea product had a nonsignificant decrease in level of rumen ammonia as compared to lambs supplemented with feed grade urea; there was no increase in N retention. In study two, S-coated urea decreased rumen ammonia concentration when compared to feed grade urea; S-coating also resulted in decreased N digestibility and increased fecal N. Nitrogen retention of lambs fed these products was not improved as compared to lambs fed feed grade urea.

MARKETING

ECONOMICS

295 Fertilizer Coating System, A Development of Thiokol. *Oil, Paint Drug Reptr. 192* (22), 7 (Nov. 27, 1967). Development of a controlled-release coating system that could reduce the cost of fertilizing high-value crop land in many locations is reported by Thiokol Chemical Corporation, Trenton, New Jersey. The system comprises a thin coating of flexibilized sulfur and a method of applying it to several types and shapes of fertilizer particles. It is said to make possible commercial production of slow-release fertilizers at one-quarter to one-half the cost of comparable existing products. Potential advantages of controlled release include reduced leaching, reduced hazards to crops from high rates of fertilizer application, reduced frequency of application (with resulting labor savings), better growth due to continuous supply of nutrients, and greater flexibility in scheduling fertilizer applications.

296 Fertilizer Services from TVA Include Help for Air Pollution, Sulfur-Coated Urea Fertilizer. *Chem. Mark. Rep. 201* (2), 7, 20 (Jan. 10, 1972). In the annual report for fiscal yr 1971, Tennessee Valley Authority reports several important advances in fertilizer production technology. When production techniques are perfected, TVA expects the major market for SCU to be in production of rice. The product appears well suited for use under two of the three water management systems, with rice-delayed flooding and intermittent flooding. In test demonstrations rice yields were substantially higher with SCU than with uncoated urea with farmer returns increasing from $19 to $133/acre in the U.S. and from $60 to $133 in other countries.

297 Slow-Release Fertilizers, Particularly Sulfur-Coated Urea. L. H. Davies. *Fert. Soc. Proc.* No. 153; 64 pp. (1976). Those materials in use as slow-release fertilizers which have been commercially manufactured, are examined and their properties and field performances are reviewed. Particular emphasis is placed on S-coated urea (SCU). The markets for large scale sales of slow-release fertilizers have been found where premium prices are available for the crop grown or the savings on fertilizer application costs have been substantial. Only where the cost of the slow-release component has been diluted by the lower costs of other ingredients of a compound fertilizer have they been acceptable on lower value crops. A range of crops that have a high demand for N over a short period such as maize, sorghum, wheat, and barley, are unlikely to show yield benefits after the use of slow release fertilizers, though benefits such as improving the protein value of the grain are possible. Sulfur coatings offer the possibility of lower cost slow release of nutrients. Also it is possible to radically alter the pattern of nutrient release by varying the level and quality of the coating.

298 Sulfur-Coated Urea—A Manufacturer's Viewpoint. T. B. Lynch (Canadian Industries Ltd., Ontario, Canada). In *Products Techniques Plant Nutrient Efficiency. London, England: British Sulphur Corp. Proc. 2nd Int. Conf. Fert.* Paper No. XIII; pp. 1-28 (1978). Sulfur-coated urea (SCU) an effective and economical slow-release N fertilizer, is produced by Canadian Industries Ltd. using TVA technology and the modifications developed at ICI, Billingham. Local refineries provide economical sources of wax and S, while prilled urea is used as substrate. This gives a product size range more compatible with subsequent blends than the larger-sized granular urea. Sulfur is sprayed hydraulically to reduce potential explosion and pollution problems. Coating thickness is controlled to give product 7-day release rates $< 35\%$. Product is shipped to customers in bulk or bags for mixing with additives in blends such as 18-6-9 and 25-4-10. Parameters to be considered in the design and operation of an SCU facility, together with quality control and agronomic features important in marketing this product are discussed (20 ref).

299 Sulfur-Coated Urea. E. O. Huffman, A. R. Shirley, Jr., G. M. Blouin, and B. P. Dana (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Fert. News 21* (3), 31-6 (Mar. 1976). Sulfur was selected as the least expensive coating agent for control of N release from urea. Preheated urea granules are sprayed with molten S as they fall from special flight arrangements in a rotary drum. In another rotating drum, the S-coated granules are sprayed with a wax to seal flaws in the coating. The material is cooled to 43° in a fluidized-bed apparatus and conditioned with diatomaceous earth in a third drum to prevent caking and to make the granules sink when placed in H_2O, as in flooded rice culture. The usual product contains 15-19% S, 2% sealant, and 2.5-3% conditioning agent. Process variables are discussed, and optimum operating conditions are present. Production cost for granular S-coated urea (SCU) is estimated to be ~ one-third more/mt N than for uncoated urea; the cost for coating the smaller prilled area is somewhat higher because more S is

required. In many agricultural situations, the S itself, is a needed addition to the soil. Agricultural evaluations show favorable benefit-to-cost ratios for SCU on rice under delayed and intermittent flooding, pineapple, sugarcane, fruits, and vegetables on sandy soils, turf, and forage crops.

300 Slow Release Fertilizers. *Fert. Int.* No. 133; 8 (July 1980). A small, but profitable and expanding, sector of the fertilizer market in developed countries is taken up by slow release fertilizers. These fertilizers find their principal outlet in the horticultural and amenity sectors of the market and are, at present, the concern of relatively few producers who have carried out the pioneering work on their development. However, a growing number of companies are looking with interest towards this market, notably those with a strong horticultural side, as an area for future expansion. The current state of development of the market for slow release fertilizers is examined and the directions in which it is moving are presented. This part of the article considers the producers and their products.

COST

301 Slow-Release Fertilizer Cost Could Tumble. *Chem. Eng. News 46:* 20-1 (Jan. 8, 1968). Thiokol's process for sulfur-coated slow-release fertilizer is a subject of licensing talks with fertilizer makers. The process of sulfur-coating prilled urea could cut the cost of slow-release fertilizer drastically. Thiokol predicts from as high as $500/ton to just over $100/ton. The new price reflects 10-20% addition by the coating to the basic price of urea ($90/ton). Such a price reduction opens several new markets to the slow-release fertilizer. There is already a 1.4-million-ton/yr specialty market in turf and horticulture. Now the coated product may also find a 3-million-ton market in high value crops such as fruits, a 6-million-ton outlet for crops in low-nutrient efficiency (high-leaching) areas such as the east, south, and central states, a 3-million-ton usage in low-sulfur soils such as those on the Pacific coast, and a large market abroad.

302 New and Improved Fertilizer Material Based on Urea. T. P. Hignett (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *UNIDO Paper Presented at 2nd Interregional Fertilizer Symposium, Kiev, Ukrainian S.S.R. Sept. 21 to Oct. 1, 1971, New Delhi, India, October 2-12, 1971. Muscle Shoals, Alabama: TVA, National Fertilizer Development Center,* Circular Z-28; 30 pp. (n.d.). Estimates indicate that the cost of coating granular urea in a plant of 450-mt/day capacity would be about $16/ton, including a 15% return on investment. If the price of straight urea (46% N) is $77/ton, the estimated price of coated urea (36% N) would be $76/ton, which is about 26% more per unit of N. It is recognized that initial production on a smaller scale will be more expensive. Also, transportation costs per unit of N will be greater for the coated material because of its lower N content. However the results of agronomic tests indicate that there are many cases in which the value of increased yield would more than pay for the higher cost. Moreover, a major advantage of coated urea is the potential reduction in costs by applying the nitrogen only once at the time of planting rather than having the added costs of top- or side-dressing. In addition to the controlled-release characteristics, coated urea has excellent storage and handling characteristics and might even be handled in bulk in humid climates.

303 Low-Cost Slow-Release Fertilizer Developed. S. E. Allen, D. A. Mays, and G. L. Terman (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Crops Soils 21:* 13-15 (Dec. 1968). A sulfur-coating technique developed by TVA may put slow-release N within reach of many crop growers. The slow-release fertilizer (35% N) developed by TVA will cost 25-50% more per lb of N than urea (45% N). Urea granules are sprayed with molten S and sealed with mineral wax containing 0.5% coal tar oil. Sulfur-coated urea has been tested in greenhouse and field experiments and performed well in metering out N for months.

304 TVA Shows Sulfur-Coated Urea. *Sulphur Inst. J. 4* (3), 2-6 (Autumn 1968). A brief description is given of the process for coating urea with S as developed by the Tennessee Valley Authority. The process has been demonstrated with pilot plant equipment and several variables have been evaluated. Laboratory, greenhouse, and field tests have shown that coating urea with S, wax, and a microbicide does control the rate of N release. An 18% S coating protected some urea granules in the soil for at least 16 weeks. Sulfur coatings were found to reduce the toxicity of soluble N to plants, promote more uniform growth of grasses, reduce luxury consumption of N, and give a better seasonal distribution of both forage and protein. Estimates based on a daily production of 200 tons of S coated urea (35% N, 19% S) show that coating will cost $15.50/ton of product or 44 cents/unit of N at the plant site.

305 Sulfur-Coated Urea: Estimated Cost in a Developing Country. G. M. Blouin (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Muscle Shoals, Alabama: TVA, National Fertilizer Development Center;* Bull. Y-82, 11 pp. (Oct. 1974). An estimate is given of the production cost and in-plant price for S-coated urea (SCU) at a capacity of 200 mt/day for a developing-country situation. Three alternate cases were chosen for the basis of the estimate: (1) An existing pan-granulation unit will provide urea of -6 +10 mesh for feed to the SCU unit; the pan is assumed to handle the full urea plant output. (2) A small pan-granulation unit must be added to the larger complex to provide urea of -6 +10 mesh for the SCU unit; only part of the urea plant output is processed. (3) An existing urea prilling unit will provide urea of -8 +14 mesh for the SCU unit. Flow diagrams of the three case processes are shown. Detailed data are given for each case showing the plant investment, the production cost, and the in-plant price of the SCU. It is estimated that in the developing countries the in-plant price of SCU would be 25-40% more than that projected for uncoated urea in 1977, and about one-half the price of other commerical controlled-release N products, such as ureafoam and IBDU. High benefit:cost ratios have been demonstrated for SCU on intermittently flooded rice and on sugarcane and pineapples.

306 A Brief Summary of TVA's Research and Development on Improving Fertilizers for Developing Countries. J. T. Shields (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Proc.: Planning and Organization Meeting, Fertilizer I.N.P.U.T.S. (Increasing Productivity Under Tight Supplies) Project, Honolulu, Hawaii; East-West Food Institute, East-West Center;* pp. 85-91 (1975). Work in several countries on the field-testing of sulfur-coated urea for rice and technical aspects of the use of rock phosphate is discussed. Recent developments in the engineering phase of producing sulfur-coated urea have resulted in a vast improvement in the

sulfur-coating process. For instance, the falling curtain technique has led to a more uniform coating of either the urea prill or granule, eliminated the need for a wax sealant, increased production rates, and thereby, shows promise to reduce production costs. Recent engineering estimates incorporating these new improvements indicate SCU should cost no more than 15%-20% more per unit of N than regular urea.

307 Sulfur Coating on Nitrogen Fertilizer to Reduce Dissolution Rate. D. W. Rindt, G. M. Blouin, and J. G. Getsinger (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *J. Agr. Food Chem. 16* (5), 773-8 (Sept.-Oct. 1968). Coating of urea granules with S may provide an effective controlled-release N fertilizer at relatively low cost. Potential benefits are higher yield/unit of applied N and lower application cost. In small-scale tests with a 22-in. diameter rotary pan, the coating was applied by spraying atomized molten S onto a rolling bed of granules. The coating was sealed with a film of microcrystalline wax containing a microbicide and the granules were dusted with clay, diatomaceous earth, or vermiculite to assure good flowability. A product with about 20% of its wt as coating (16% S, 3% sealant, 0.5% microbicide, and 1% conditioner) had a dissolution rate in H_2O at 100° F of about 0.2%/day as compared with 100% for uncoated urea. The coated urea also gave better N utilization in greenhouse and field tests. Estimated cost of coating urea in a 200 tons/day plant is about $0.33/unit N which is about 20% of the market price of uncoated urea.

308 Experiences in Development of Sulfur-Coated Urea. R. B. Diamond (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). In *Agronomy Abstracts 1975 Annual Meetings* (held Knoxville, Tennessee, Aug. 24-30, 1975). *Madison, Wisconsin: Am. Soc. Agron.*; p. 173 (1975). Development of sulfur-coated urea (SCU) has continued for more than 10 yrs. Production technology has progressed from laboratory-scale equipment to a continuous process producing 1 to 2 tons/hr and now to the design of a 10-ton/hr demonstration-scale plant. Production is planned in the new plant in the fall of 1976. Production cost is predicted to be 30% greater than urea per unit of N. Agronomic tests have been conducted in 48 states and in more than 50 countries for a variety of crops, soils, and climatic conditions. These tests indicate that SCU has little or no value over soluble sources for maize, sorghum, small grains, cotton, and cool season forage grasses. Sulfur-coated urea is advantageous for vegetable production in some situations. In the U.S., the greatest potential for SCU is for rice (delayed and intermittently flooded), sugarcane, warm season forages, turf grasses, and ornamentals.

SUPPLY-DEMAND

309 Controlled-Release Fertilizers. T. P. Hignett (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Fert. News 16* (12), 42-8 (Dec. 1971). Control of the rate of nutrient release from fertilizers has been cited as a potential means for improving the efficiency of nutrient uptake for minimizing losses of nutrient through various mechanisms, for cutting the number of fertilizer applications, and for avoiding contact damage to vegetation. These potential advantages are realizable in various degrees through N fertilizers of two general types—those inherently slow in dissolving and those coated with a barrier film that slows their dissolution. The first type is illustrated by ureaform, isobutylidene diurea (IBDU), and crotonylidene diurea (CDU)—the second by S-coated urea (an experimental product at TVA) and commercial products in which the coating is a copolymer of dicyclopentadiene with a glycerol ester (trade name, Osmocote). Aside from their specialty uses on lawns, golf courses, and the like, controlled-release N fertilizers are likely to prove practical for some field crops in some situations, particularly for high-value crops in areas where labor is costly. Prospects are remote for improving P and K fertilizers through controlled-release.

310 GOLD-N, A Sulfur-Coated Urea From ICI. L. H. Davies (Imperial Chemical Industries, Billingham Teesside, England). *Sulphur Inst. J. 10* (2), 6-10 (Summer 1974). Development work on a slow release N by coating urea granules with S was started by Tennessee Valley Authority about 10 yr ago. Technology for manufacturing sulfur-coated urea was studied concurrently at Imperial Chemical Industries, Ltd. (ICI) which resulted in a S-coated urea being placed on the United Kingdom market in 1972 as GOLD-N. GOLD-N is produced at ICI's Teesside plant. Urea prills are coated with S to give a product containing 32% N, 30% S, and about 2% wax. The premium price above conventional fertilizers does not make its use universally attractive. The properties of GOLD-N indicate that it is a profitable commercial product for heavily irrigated crops, grasses on parks, golf courses, etc., and land reclamation. The ICI is continuing to explore applications for GOLD-N.

311 Controlled Release New From Gro-Power. *Western Landscaping News 19* (9), 22 (Sept. 1979). Gro-Power has recently announced the addition of another product to their fertilizer line. Marketing has begun for the new product, Gro-Power Controlled Release. Controlled Release is a blend of long release sulfur-coated urea, phosphorus, potash, and trace minerals. Humus and humic acids are added to aid the plant to assimilate the necessary nutrients for lush growth. Under normal conditions Gro-Power Controlled Release will release steadily over 3 to 4 months, eliminating overfeeding due to heavy rainfall, over-irrigation, and excessive heat. The sole manufacturer of this new product is Southern California Organic Fertilizer.

312 Sulfur-Coated Urea: A Progress Report. *Sulphur Inst. J. 8* (4), 2-5 (Fall 1972). Interest in the production and use of SCU has increased rapidly over the last 4-5 yr. Pilot-scale plants have been built in England, Germany, Switzerland, and possibly in other countries. TVA is presently considering building a 250-ton/day plant, representing a scaleup by a factor of 10. This plant would undoubtedly stimulate the interest of U.S. fertilizer producers to build full-scale SCU plants. While it is unlikely that SCU will replace other N fertilizers in all applications, it appears to have a considerable market potential for several crops in a number of applications. It has become customary to describe controlled-release fertilizers of the urea-formaldehyde type as "specialty fertilizers." The more favorable economics of SCU, coupled with the attractive properties of the product, puts it in a different class. Perhaps SCU should be described as a "very special fertilizer."

313 Use Sulfur In Fertilizers. Jan Platou (Sulphur Inst., Washington, DC). *Hydrocarbon Process 51* (7), 86-8 (July 1972). The author deals with the agricultural market sulfur where about one-half of sulfur used is consumed by the fertilizer industry, most of it for making phosphate and

ammonium sulfate fertilizers. Bioagricultural considerations have brought a conclusion that sulfur deficiencies of North American crop land will require about 2.8 million ton of direct sulfur application annually, and that SO_2 abatement, required by law, paradoxially can increase this demand. The use of sulfur-coated urea (SCU) as a slow-release nitrogen fertilizer is also discussed in terms of the new market for sulfur.

314 Sulfur Status of the Middle Atlantic States. J. D. Beaton. *Sulphur Inst. J. 8* (1-2), 6-9 (1972). There appears to be a great potential use for SCU on coarse-textured soils of the Atlantic Coastal Plain, not only for its slow-release N characteristics but also for its plant nutrient S content. The combination of coarse-textured soils with climatic conditions of high temperatures and high-intensity rainstorms suggests a need for improving the efficiency of fertilization, especially with N and perhaps also with K. These conditions are also conducive to S deficiency and as mentioned previously, crop responses to this nutrient are quite common in soils of the Atlantic Coastal Plain. Because oxidation of elemental S to plant-available SO_4-S is favored by adequate soil moisture and warm temperatures, the S coating is expected to begin to supply available S to crops within reasonable periods after application.

315 Sulfur-Coated Urea. O. R. Lunt (University of California, Los Angeles). *Sulphur Inst. J. 3* (2), 5-8 (Summer 1967). Controlled availability fertilizers could play an important role in the development of new crop management practices. The potential advantages of these types of fertilizer are: (1) greater efficiency of use through reduced leaching losses, (2) less hazard of injury from high rates of application, (3) reduction of labor costs by reduced frequency of application, (4) better growth due to continuous supply of nutrients, and (5) greater flexibility in scheduling of fertilizer application. Some of the techniques which have been employed for achieving controlled availability of fertilizers are: (1) organic compounds not rapidly mineralized by microorganisms, (2) sparingly soluble minerals, (3) coating of granular-soluble fertilizers, (4) ion exchange resin fertilizers, and (5) nitrification inhibitors. There is presently a modest use of controlled availability fertilizers in the nonfarm market (turfgrass, landscape use, and ornamental horticulture). Results of a number of agronomic tests with sulfur-coated urea are given.

316 Sulfur-Coated Urea. L. H. Davies (Imperial Chemical Industries, Billingham, United Kingdom). In *Marketing of Sulfur-Containing Fertilizers. Proc., Symp., Paris 1974. London, United Kingdom: The Sulphur Institute;* pp. 28-33 (1975). *Soils Fert. 39,* 346. Characteristics of a sulfur-coated urea manufactured by ICI are discussed. The N release rate of the fertilizer is not greatly changed by variations of temperature, moisture, pH, or other soil conditions.

317 TVA's Development of Sulfur-Coated Urea. R. D. Young (TVA, National Fertilizer Development Center, Muscle Shoals, Alabama). *Muscle Shoals, Alabama: TVA, National Fertilizer Development Center;* Bull. Y-79, 49 pp. (Aug. 1974). Sulfur-coated urea (SCU) is the culmination of about 15 years of Tennessee Valley Authority work on the development of controlled-release N fertilizers. A review is given of the development work from laboratory and bench-scale studies of SCU, through a small pilot plant of 300-600 lb/hr capacity, and then to a large pilot plant of 1-2 tons/hr capacity. The laboratory and pilot-plant equipment are described, operating conditions are outlined, and results of the test work are evaluated. In the latest work good controlled-release properties were indicated with a somewhat heavier S coating without the use of wax and microbicides. Changes in equipment and operating conditions that resulted in the improved coatings are described. The economics of the production of SCU were estimated and the results are given. Plans for a demonstration-scale plant are outlined. Under the best practical conditions established in pilot-plant tests, the N in SCU is estimated to cost only ~ 27-34% more per unit than regular urea. This is with urea produced at the facility at an f.o.b. price of $120/ton and S delivered at $34/ton. Results from agronomic tests of SCU in 39 U.S. states, two U.S. territories, and 26 other countries are summarized. Significant advantages are shown for SCU on several crops and in a variety of cropping situations. Crops for which SCU showed particularly good results include rice under delayed or intermittent flooding, sugarcane, pineapples, fruits and vegetables, forages, and turf. The product also would be very good for horticultural and other specialty fertilizer use. SCU has improved storage and handling properties and the S is available as a secondary nutrient. The product is also compatible with other fertilizer materials, such as unammoniated superphosphate, that are not compatible with regular urea. Sulfur-coated KCl and S-coated KCl plus urea are also discussed briefly.

318 The Next Generation of Fertilizer Materials Goes into the Semiworks Stage at the Tennessee Valley Authority. *Chem. Eng. News 48* (2), 49 (Jan. 12, 1970). Tennessee Valley Authority will scale up its small pilot plants for two new types of fertilizers with funds from the recently passed Public Works Appropriations Act. One new material, which TVA says could be the most versatile fertilizer ever developed, is urea-ammonium phosphate (UAP). The UAP can be produced in grades up to 60% plant food. It would replace mixed fertilizers used today. The second new material is sulfur-coated urea (SCU), which releases its N slowly throughout the growing season. Experiments show crop yields from a single application of SCU to be equal or superior to multiple applications of soluble fertilizers, TVA says.

319 Sulfur-Coated Urea Plant. *Chem. Engr. 84* (25), 130 (Nov. 21, 1977). Ag Industries Mfg. Corp., a wholly-owned subsidiary of Lakeshore Equipment & Supply Co. (Elyria, Ohio), will construct a sulfur-coated urea plant in Columbia, Alabama. Licensed through the Tennessee Valley Authority under several patents, this will be the first such plant in the United States, and only the second in the world. The plant is expected onstream in early 1978.

320 Sulfur-Coated Urea Sales. *Farm Chem. 141* (12), 75 (Dec. 1978). Ag Industries Mfg. Corp. has appointed H. J. Baker & Bros., Inc. its agent for sales of sulfur-coated urea to the fertilizer industry.

321 Coating of Fertilizers. *Kirk-Othmer Encyclopedia of Chemical Technology, 2nd Edition 9,* 78 (1966). The objective of coating fertilizers is to establish a mechanical barrier between nutrient and soil. The commerical application of this method in the United States has been restricted to soluble nitrogen fertilizer, such as urea with a resin, to form a relatively impermeable membrane on the surface. Good results have been reported for a coating of about 12% of the product

weight; the cost of the resin is a major handicap. Coating with S offers more promise of economy. More sulfur is required probably 20-25% of the product weight, but S is low in cost and has some nutrient value.

322 Enter–Sulfur-Coated Urea–Slow-Release Fertilizer. *Chem. Eng. 81* (27), 32 (1974). Changing from air atomized S sprays to hydraulic atomization at high sulfur-pump pressures reduced S dust by 90% in a SCU pilot plant at Tennessee Valley Authority. This new technology is going into a 5 ton/hr $750,000 commercial plant that Canadian Industries Ltd. plans to bring on stream in mid 1975 at Courtright, Ontario. Tennessee Valley Authority itself will build a 10 tons/hr unit in 1976. Pilot plants or semicommercial units are also in operation in Japan and England. A flow sheet is given and the economics of production are discussed.

323 Sulfur-Coated Urea–A "Time Pill" for Plants. J. E. Rosenthal (Agency for International Development, Washington, DC). *War on Hunger 7* (1), 7-9, 13-17 (Jan. 1973). Sulfur-coated urea (SCU) has been tested in the United States and 29 foreign countries with the help of the Agency for International Development. It has been particularly effective with rice under intermittant flooding. The S coating releases N from the urea granule at a slow, even rate. The coating also makes SCU more durable than uncoated urea, improves handling ability, reduces caking, and resists humidity.

324 Sulfur Fertilizer Sources. J. F. Reed (Univ. Georgia, Athens). In *Agronomy Abstracts 1979 Annual Meetings* (held Fort Collins, Colorado, Aug. 5-10, 1979). *Madison, Wisconsin: Am. Soc. Agron.;* p. 222 (1979). For yrs the fertilizer industry, like the farmer, paid little attention to the sulfur content of fertilizers. Sulfur was inadvertently supplied largely by ordinary superphosphate and ammonium sulfate. Since these products constitute a relatively smaller portion of P and N carriers today, sulfur is added through other sources. These include solids such as sulfur coated urea, prilled or granular sulfur with clay, TSP-sulfur, AP-sulfur and mixtures of sulfates with urea or ammonium nitrate. Also fluids are used such as ammonium thiosulfate, ammonium polysulfide, sulfur slurries, and sulfate solutions. The properties, availability, and effectiveness of these sources are discussed.

RESEARCH PROJECT LISTINGS

(These Projects Were Ongoing August 1, 1979)

NATIONAL

Tennessee Valley Authority
National Fertilizer Development Center
Muscle Shoals, Alabama

R1 **Dissolution Studies with Sulfur-Coated Urea.** S. E. Allen.

R2 **Crop Yield, Nitrate-Nitrogen and Total Nitrogen and Potassium Concentration Relationships.** S. E. Allen.

R3 **Nutrient Effectiveness in Relation to Rates Applied for Pot Experiments.** J. J. Mortvedt.

ALABAMA

Alabama Agricultural and Mechanical University
Normal, Alabama

R4 **SCU As A Nitrogen Source for Ornamentals.** G. C. Sharma and D. A. Mays.

R5 **SCU for Container-Grown Nursery Stock.** G. C. Sharma and D. A. Mays.

ALASKA

University of Alaska
Fairbanks, Alaska

R6 **Fertilizer Test and Demonstrations.** W. M. Laughlin and W. J. Sharratt.

ARIZONA

University of Arizona
Tucson, Arizona

R7 **Fertilizer Tests and Demonstrations.** D. A. Bryant and W. J. Sharratt.

COLORADO

Colorado State University
Fort Collins, Colorado

R8 Management of Plant Nutrients in Field Crop Production. J. O. Reuss, A. E. Ludwick, and E. J. Langin.

FLORIDA

University of Florida
Agricultural Research and Education Center
Belle Glade, Florida

R9 Nutrition and Associated Cultural Practices for Sugarcane. G. J. Gascho and P. M. Lyrene.

University of Florida
Gainesville, Florida

R10 Maximizing Efficiency of Fertilizer and Water Use for Vegetables. J.G.A. Fiskell and D. A. Graetz.

R11 Fertilizer Requirements of Watermelons. S. J. Locascio.

R12 Comparison of Different Nitrogen Sources on Tifway and Tifgreen Bermudagrasses. J. B. Sartain and G. L. Slappey.

University of Florida
Agricultural Research and Education Center
Homestead, Florida

R13 Maximizing Efficiency of Fertilizer and Water Use for Vegetables. H. H. Bryan and P. G. Orth.

R14 Fertilization of Fruit Trees on Shallow, Rocky, Calcareous Soil with Slow-Release Fertilizer. P. G. Orth and G. A. Slappey.

University of Florida
Agricultural Research Center
Immokalee, Florida

R15 Maximizing Efficiency of Fertilizer and Water Use for Vegetables. P. H. Everett.

R16 Sulfur-Coated Urea Studies with Bell Peppers Grown with Full-Bed Polyethylene Mulch. P. H. Everett and G. A. Slappey.

University of Florida
Agricultural Research and Education Center
Lake Alfred, Florida

R17 Comparison of Sulfur-Coated Urea and Ammonium Nitrate as Sources of Nitrogen for Citrus. R.C.J. Koo, D.P.H. Tucker, and G. L. Slappey.

University of Florida
Agricultural Research Center
Leesburg, Florida

R18 Fertilizer Requirements for Watermelons. G. W. Elmstrom.

GEORGIA

University of Georgia
Athens, Georgia

R19 Liquid and Solid Fertilizers for Coastal Bermudagrass. H. D. Morris.

University of Georgia
Georgia Coastal Plain Experiment Station
Tifton, Georgia

R20 Characterization of Soil-Plant-Water Relations of the Southeastern Coastal Plain. T. C. Keisling.

HAWAII

University of Hawaii
Honolulu, Hawaii

R21 Evaluation of Grasses and Their Management for Turf in the Tropics. C. Murdoch.

IDAHO

University of Idaho
Research and Extension Center
Parma, Idaho

R22 Efficiency of Sulfur-Coated Urea and Urea for Mint Production. B. D. Brown and C. B. Kresge.

KANSAS

Kansas State University
Manhattan, Kansas

R23 Kansas River Valley Irrigation Experimental Field. N. E. Humburg and L. D. Maddux.

R24 Efficiency of Nitrogen Fertilizers for Cool Season Grasses. D. A. Whitney.

LOUISIANA

Louisiana State University
Baton Rouge, Louisiana

R25 Increasing Nitrogen Fixation in Soybeans. E. P. Dunigan.

R26 Sulfur-Coated Urea on Rice. P.S.C. Reddy and J. A. Kovar.

MARYLAND

University of Maryland
College Park, Maryland

R27 Leaching of Nitrate-Nitrogen from Several Fertilizer Sources Applied to Soils of Various Textures. V. A. Bandel.

R28 Comparison of Sulfur-Coated Urea and Other Nitrogen Sources on Corn and Small Grains. C. E. Rivard.

MICHIGAN

Michigan State University
East Lansing, Michigan

R29 Soil Management Investigations for Sod Production and Turf. P. E. Rieke.

R30 Organic Soil Investigations. D. D. Warncke.

MISSOURI

University of Missouri
Columbia, Missouri

R31 Sulfur-Nitrogen Material Evaluation. G. W. Colliver and J. C. Kramer.

MONTANA

Montana State University
Bozeman, Montana

R32 Sulfur Fertilization. P. O. Kresge and H. A. Kittams.

R33 Forest Fertilization. R. Wilson, E. O. Skogley, and H. A. Kittams.

NEBRASKA

University of Nebraska
Lincoln, Nebraska

R34 Adaptation, Improvement, and Management of Turfgrasses and Other Ground Covers for Nebraska. E. J. Kinbacher and R. C. Shearman.

R35 Improving Grain Sorghum, Wheat, and Forage Crop Production Through Improved Soil Fertilizer Practice. D. H. Sander.

NEW MEXICO

New Mexico State University
San Juan Branch Station
Farmington, New Mexico

R36 Rangeland Fertilization. G. Donart and Y. C. Smith.

NORTH CAROLINA

North Carolina State University
Raleigh, North Carolina

R37 Study Lethal Quality of Liquid Nitrogen Fertilizer on Animal Parasite Larvae on Pasture Grass. J. Burns, L. Goode, and D. J. Moncol.

NORTH DAKOTA

United States Department of Agriculture
Mandan, North Dakota

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R39 Nitrogen Fertilizer Sources for Northern Great Plains Crops, Ranges, and Grasslands. J. Alessi and J. F. Power.

R40 Investigations of Plant Nutrient Deficiencies and Toxicities in Northern Great Plains Soils. J. Alessi and J. F. Power.

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College Station, Texas

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Pacific Northwest Forest and
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Coastal Research and Extension Unit
Long Beach, Washington

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R58 Nutrient Sources for Cranberries. A. Y. Shawa and C. B. Kresge.

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Pullman, Washington

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R60 Fertilizer Use Management for Wheat and Forage Crops Production in Eastern Washington. E. T. Field, A. R. Halvorson, F. E. Koehler, and C. B. Kresge.

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University of Wisconsin
Madison, Wisconsin

R61 Effectiveness of Sulfur-Coated Urea as a Source of Nitrogen. D. R. Keeney and L. M. Walsh.

R62 Effectivess of Sulfur-Coated Urea and Urea-Ammonium Polyphosphate on an Irrigated Plainfield Sand. I. Effectiveness of Sulfur-Coated Urea on Irrigated Corn and Potatoes. II. Effectiveness of Banded and Seed-Placed Urea-Ammonium Polyphosphate on Irrigated Corn. E. A. Liegel.

AUTHOR INDEX

Abruna, Fernando 219
Adams, P. 225
Addiscott, T. M.. . . . . 247, 280
Agboola, A. A. 103
Ahmad, N.. 42
Ahmed, S. 291
Ahmed, Saleem 101
Alessi, J. R38, R39, R40
Allen, S. E.. . .55, 190, 191, 195, 203, 224, 282, 285, 303, R1, R2, R48

Bains, D. S. 105
Baker, D. F. 131
Bakhtiari, G.. 176
Baldwin, C. S.. 130
Ballard, R. 275, 279
Bandel, V. A. 151, R27
Bazan, Rufo 255
Beale, A. J.. 254
Beaton, J. D.. . . . . 26, 314
Beauchamp, E. G.. 141
Bertrand, J. E.. 180
Bishnoi, U. R. 163
Bishop, J. C.. 232
Blatt, C. R.. 177
Blouin, G. M. 5, 15, 299, 305, 307
Blue, W. G.. 217
Boersma, L. . . . 61, 63, 64, R42
Boonduang, A. 204
Bouldin, D. R.. 148
Breece, J. R.. 262
Briones, A. G. 27
Brown, B. D.. . . . . R22
Brown, J. F. 234
Bryan, H. H.. . . . . R13
Bryant, D. A. R7
Buren, L. L. 169
Burns, J. R37
Burns, M.. . . . . R54
Byrnes, B. H. 107

Cahoon, G. A.. 253
Caro-Costas, Ruben. 219
Carson, A. G. 102
Carson, P. L.. 189
Case, N. L.. 21
Chang, Y. R54
Cheng, Jung-Hsien 92
Chiang, Ching-Tsun 29
Christie, C. B. 264
Cocks, P. S. 185
Coffey, D. L. 234
Colliver, G. W.. . . . . R31
Cordero, A. 75
Cox, David. 247, 280
Craswell, E. T.. . . .93, 107, 109, 113, 126
Croissant, R. L. 212

Daigger, L. A. 205, 206
Dalal, R. C. 136, 138, 139, 154, 168
Dana, B. P.. . . . . 15, 299
Dantzman, C. L.. 184
Dattoo, R. F. 154
Davey, C. B. 277
Davies, L. H.. . . . 221, 297, 310, 316
Dawson, M. D.. . . 283, R42, R43
De Datta, S. K. . . 108, 109, 110, 125
De Haan, S. 249
DeBell, D. S.. 278
Deines, J.. 277
Diamond, R. B. . . . 13, 86, 117, 265, 308
Dilday, J. T.. 25
Doll, E. C. 114
Donart, G. B. 179, R36
Doughty, C. C. R59
Dressel, J. 162
Dudeck, A. E.. 269
Duich, J. M. .272, R46, R47, R48
Dunavin, L. S.. . . . 180, 183, 187
Dunigan, E. P.. . . . . 288, R25

Eastwood, David 164
Eichhorn, M. M., Jr. 201
El Wali, A.M.O. 143, 173
Elmstrom, G. W. . 238, 243, 244, 245, R18
Engelstad, O. P.. . . . . 118, 289
Engle, C. F. 161
Enis, J.. . . . . R41
Everett, P. H. R15, R16
Evers, G. E. 182

Fanning, C. 197
Ferree, D. C.. 253
Field, E. T.. . . . . 161, R60
Figarella, Jacinto 219
Fisher, R. F.. 276
Fisher, T. E.. 156
Fiskell, J.G.A.. . . 233, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, R10
Fitts, J. B. 73, 85
Follett, R. H. 129
Fox, R. H.. 148
Fox, R. L.. 26
Freeman, W. H. 71
Frye, W. W. 140
Fulgham, K. O. 179, 209
Fureta, Tokuji. 262

Gallagher, P. A. 228
Garcia, J. L. 99
Gascho, G. J. . . . 143, 165, 166, 172, 173, R9
Geist, J. M.. 213
Gemmell, R. P. 292, 293
Getsinger, J. G. 118, 307
Giordano, P. M. 80, 220
Goh, K. M.. 68
Goode, L. R37
Gopalakrishnan, R. 123
Graetz, D. A. R10
Graves, C. J.. 225
Grove, T. L. 144
Grzesiuk, W.. 49
Gunasena, H.P.M.. . . . 101, 291

Halvorson, A. R. R60
Hamissa, M. R. 96
Han, K. H.. 74
Haque, I.. 149
Harms, C. L.. 214
Hashimoto, Isao. 56, 57, 62
Hatfield, J. D. 57
Hepler, P. R.. 261
Herrera-Aguirre, E. 256
Higashi, T.. . . . . 119, 120
Hignett, T. P. 302, 309
Hong, C. W. . 54, 69, 72, 97, 115
Horn, G. C. 270
Huffman, E. O. 15, 299
Humburg, N. E. R23
Hunt, C. M. 55, 190, 285
Hunter, F. 216

Indalsingh, T. 154
Islam, M. S. 43
Isobe, M.. . . . . 169, 171

Jacq, V. A.. 98
Jaramillo, Ramiro. 255
Jarrell, W. M. . . . 59, 61, 63, 64, 67, R44
Jones, M. B. 192
Jones, R.A.D. 116
Joshi, B. S.. . . . . 157, 158
Joshy, D.. 216
Jung, J.. 162

Kanehiro, Y.. 204
Katyal, J. C. 71
Keisling, T. C.. . . . . R20
Kennedy, H. G. 195
Kenney, D. R.. . . . . R61
Keogh, J. L. 174
Kilmer, V. J.. 48
Kinbacher, E. J.. . . . . R34
Kittams, H. A.. . . . . .R32, R33
Klock, G. O.. . . . . 213, R56
Koehler, F. E.. . . . . R60
Koo, R.C.J. R17
Kovar, J. A. R26, R41
Kramer, J. C. R31
Kresge, C. B.. . . . . 251, 257, 287, R22, R58, R60
Kresge, P. O.. . . . . R32
Kroth, E. M.. 211
Kulkarni, K. R. 84
Kumar, V. 178
Kunkel, R.. 251

Lamond, R. E.. . . . . 210, 215
Langin, E. J.. . . . . .R8
Laughlin, W. M.. . . . . .R6
Laws, W. D' 128
Le Grande, F. 143, 173
Lee, C. C. 89
Lee, Y. J.. 54
Lessman, G. M. 234
Lian, Shen 92
Liegel, E. A. 152, 248, R62
Locascio, S. J.. . . .233, 235, 237, 238, 239, 240, 241, 242, 244, 245, R11
Lorenz, O. A. 232
Ludwick, A. E. 207, R8
Lugo-Lopez, M. A. 252
Lundy, H. W. 240
Lunt, O. R. 135, 315
Lutrick, M. C. 137
Lynch, T. B.. 298
Lyrene, P. M. R9
Mabbayad, B. B.. 110
Machado, C. P. 78
Mackenzie, A. F. 132
Mackenzie, M.. 275
Maddux, L. D.. . . . . R23
Magalhaes, A. F.. . . . . 78, 160
Magnaye, Carmelita. 81
Mahapatra, I. C.. 76, 77, 100, 116
Mahdavi, A. F.. 176
Mahendrappa, M. K. 46
Maples, Richard 174
Martin, F. G.. . . . . 239, 243
Marumoto, T. 119, 120
Maschmedt, D. J. 185
Mathur, K. B. 28
Matocha, J. E.. . . . .40, 188, R52
Mattas, R. 211
Maxur, A. R.. . . . . R49
Mays, D. A. 186, 191, 193, 194, 200, 202, 203, 303, R4, R5, R43
McClellan, G. H.. . . . 30, 31, 32, 33, 35, 36
McCutchen, Tom 159
McNeal, B. L. 251
Mead, D. J.. 275
Meinke, L. 211
Meisen, A. 28
Meline, R. S.. 14
Miller, P. L. 132
Mislevy, P. 184
Mississippi Chemical Corp.. . . 16
Miyamoto, S. R53
Mohanty, K.. 87
Moline, W. J.. 127, 145, 205, 206
Moncol, D. J. R37
Mondart, C. L., Jr. 288
Moore, F. D., III 226
Moore, O. E.. 5
Morris, H. D.. . . . . R19
Mortvedt, J. J.. .80, 134, 220, R3
Mugwira, L. M. 163
Mullins, R. C. 56, 62
Murdoch, C. L. 204, R21
Murphy, L. S. 150
Myers, F. J. 4, 11, 117

Naderman, G. C., Jr. 144
Nair, K.P.P. 41, 45
Nair, R. R.. 123
Nejad, B. K. 176
Nelson, S. D.. 128
Newman, J. S.. . . . . R55
Nnadi, L. A.. 281

O. M. Scott & Sons Co.. 23
Obigbesan, G. O. 103
O'Connor, G. A. 256
Oerther, G.. 218
Oertli, J. J.. . . . . .38, 53, 133
Olin Corp. 24
Olson, R. A. 52
Onken, A. B.. 153
Oommen, M.. 112
Orth, P. G.. . . . . .230, R13, R14

Parashar, K. S.. 170
Park, C. S. 74
Parker, J. H.. 289
Parks, C. L. 199

AUTHOR INDEX

Parsons, J. W. 43
Partohardjono, Soetjipto. . 73, 85
Patel, A. J. 60, 231, 263
Patro, G. K. 87
Pesek, John 21
Pettygrove, G. S. . . 61, 66, 196, 283, R45
Phelan, R. A. 288
Pieper, R. D. 179
Pillai, K. G. 71
Pisharody, P. W. 123
Platou, Jan. 313
Porter, J. B. 50
Pounders, C. T., Jr. 265
Powell, Robert 18, 19
Power, J. F. .208, R38, R39, R40
Prasad, M. 39, 58, 168, 228
Prasad, Munoo. 222
Prasad, Rajendra . . . 37, 44, 47, 111, 157, 158, 175
Prine, G. M. 155

Quansah, J. E. 102

Radwan, M. A. 278
Rajale, G. B. 37, 47
Rajan, M.S.S. 100
Ram, Pati 90
Ramasubbareddy, G. 121
Rao, C.U.M. 91
Raymundo, S. A. 116
Reddy, P.S.C. R26
Reddy, R. N. S. 44
Reed, J. F. 324
Remick, B. W. 198
Reuss, J. O. 212, R8
Rieke, P. E. R29
Riewe, M. R51
Rindt, D. W. 5, 307
Ritchey, K. D. 144
Rivard, C. E. 146, 151, R28
Robertson, W. K. 137
Robison, L. R. 128
Rosenthal, J. E. 323
Roth, J. A. 156
Rubio, J. L. 70
Ruckman, J. E. 192
Rumburg, C. B. 207
Russel, D. A. 11

Sabbe, W. E. 174
Sadiq, M. 122, 291
Sahoo, B. C. 87
Saleem, M.A.M. 181
Salonius, P. O. 46
Samin, A. Q. 147
Sanchez, P. A. 124
Sander, D. H. . . . 127, 145, R35
Sartain, J. B. R12
Savant, N. K. 108, 125
Scheib, R. M. . 31, 32, 33, 35, 36
Sciaroni, R. H. 262
Self, R. L. 265
Seshadri, V. 175
Shand, C. 42
Sharma, G. C. 60, 231, 263, R4, R5
Sharma, K. C. 95
Sharma, P. B. 45
Sharma, S. N. 82, 111
Sharma, V. P. 41
Sharratt, W. J. R6, R7
Shawa, A. Y. 257, 258, 259, 260, R57, R58, R59
Shearman, R. C. R34
Shelton, J. E. 227, 229
Shields, J. T. 306
Shinde, J. E. 91
Shirley, A. R., Jr. .13, 14, 15, 299
Shockley, P. A. 83
Shuford, James 131
Siemer, E. G. 207
Singh, Jagrup 105
Singh, K. P. 178
Singh, Rajinder 105
Singh, S. 90
Skipper, H. D. R49
Skogley, E. O. R33
Slack, A. V. 20
Slappey, G. A. . . R12, R14, R16, R17
Smagula, J. M. 261
Smith, A. W. 182
Smith, Y. C. . . . R36, R51, R53, R55
Snyder, G. H. . . . 165, 166, 172
Soltanpour, P. N. 226, 250
Soundara Rajan, M. S. . . . 76, 77
Southard, C. B. 197
Spies, C. D. 197
Sponagle, A. G. 177
Stanford, George 21
Stangel, P. J. 118
Stevenson, C. K. 130
Stewart, W. G. 212
Su, Chun-Tao 92
Su, N. R. 88
Sudjadi, Mohamad 94
Sullivan, D. T. 256

Talleyrand, H. 148, 252
Tanner, C. B. 284
Taylor, A. G. 142
Tejeda, H. R. 69, 72, 286
Tennessee Valley Authority . . 2, 3, 6, 7, 8, 9, 10, 34
Terman, G. L. . . . 134, 190, 193, 195, 202, 224, 282, 285, 303
Thasanasongchan, A. 110
Thiokol Chemical Corp. . . 17, 22
Thomas, J. R. 218
Thomson, J. B. 167
Tiedemann, A. T. R56
Tiedmann, A. R. 213
Tucker, D.P.H. R17
Turner, T. R. 273

Uchida, R. S. 167
Umunna, N. N. 294

Vaughn, C. E. 192
Vlek, P.L.G. . . . 69, 93, 97, 107, 113, 126
Volk, G. M. 269, 270, 274
Volk, V. V. 283, R42

Waddington, D. V. . . . 266, 267, 271, 272, 273, R46, R47, R48
Waerstad, K. R. 30
Wagner, D. F. R50
Walsh, L. M. . 152, 248, 284, R61
Warncke, D. D. R30
Watschke, T. L. R46, R47
Weir, B. L. 232
Wells, B. R. 83
Westfall, D. G. 79, 182
Whitney, D. A. R24
Wiedenfeld, R. P. 223
Wilcox, G. E. 246
Wilson, R. R33
Winsor, G. W. 225
Woodruff, J. R. 199
Woods, W. R. 294
Woolhouse, A. R. 268

Yamaski, Y. 169
Young, C. J. 167
Young, R. D. 11, 317
Youngdahl, L. J. 97

SUBJECT INDEX

Afghanistan, rate of application, corn, 147, wheat, 147
Ag Industries Manufacturing Corporation, new plant, Alabama, 319,
Agency for International Development, field test, rice, 118, 323
Agricultural Practices, sulfur, market potential, 313
Alabama A&M University
  nitrogen release, column study, 60
  rate of application, triticale, 163
  release rate, cabbage, 231, tomato, 231, turnip green, 231
  source comparison, chrysanthemum, 263, nursery stock, R5, ornamental, R4, triticale, 163
Alaska Pipeline, source comparison, revegetation, 287
All-India Coordinated Rice Improvement Project, nitrogen loss, rice, 71
Analysis
  crystallization, scanning electron microscope, 36
  physical, sulfur coating, 33
  quality control, coating weight, 35, dissolution rate, 35
Analytical Methods, coating, characterization, 31
Apple, rate of application, dwarfing variety, 253
Auburn University, source comparison, ornamental, 265
Australia, source comparison, ryegrass, 185
Bahiagrass, source comparison, Tennessee Valley Authority, 217
Banana, source comparison, field test, 255
Bangladesh Agricultural University, source comparison, rate of hydrolysis, 43
Bell Pepper, field test, source comparison, 234, University of Florida, 233
Bentgrass, source comparison, Pennsylvania State University, 272
Bermudagrass
  agronomic response, Tennessee Valley Authority, 203
  coating methods, Tennessee Valley Authority, 200
  field test, Tennessee Valley Authority, 117
  source comparison, University of Hawaii, 204

Blast Furnace Slag, revegetation, source comparison, 292
Blue Grama, source comparison, New Mexico State University, 209
Blueberry, source comparison, University of Maine, 261
Brigham Young University
rate of application, corn, 128
source comparison, corn, 128
Bromegrass
grass tetany, Kansas State University, 214
irrigation, rate of application, 212, source comparison, 212
source comparison, field test, 215
Cabbage, release rate, Alabama A&M University, 231
Canada, manufacturing process, spouted bed, 28
Canadian Industries Ltd., manufacturing process, review, 298
Cassava, source comparison, field test, 103
Central Rice Research Institute, source comparison, rice, 91
China, research and development, review, 29
Chrysanthemum
micronutrients, New Zeland, 264
source comparison, Alabama A&M University, 263
Clemson University
ornamental, research, R50
source comparison, coastal bermudagrass, 199
turf, research, R49
Coastal Bermudagrass
field test, Tennessee Valley Authority, 194
rate of application, Louisiana State University, 201
source comparison, Clemson University, 199, Louisiana State University, 201, Tennessee Valley Authority, 202
Coating
analysis, scanning electron microscopy, 33
characterization, release rate, 61
economics, Tennessee Valley Authority, 302, Thiokol, 301, United States, 321, variety of crops, 297
efficiency, factors controlling, 19
manufacturing process, technology, 21, Tennessee Valley Authority, 2, 3
physical improvement, plasticizing agent, 18
quality analysis, scanning electron microscope, 36
release rate, technology, 20, Tennessee Valley Authority, 1, 48, 51, 55, 56, 65
sulfur-deficient soil, middle Atlantic states, 314
Colorado State University
nutrient management, research, R8
source comparison, lettuce, 226
Container-Grown Plant, method of application, agronomic response, 262
Corn
field test, rate of application, 131, source comparison, 130, 131
leaching rate, University of California, 133
method of application, field test, 122
nitrogen efficiency, source comparison, 154
nitrogen loss, source comparison, 248
placement, field test, 95, Trinidad, 138
rate of application, Afghanistan, 147, Brigham Young University, 128, Kansas State University, 129, Trinidad, 138, University of Florida, 137, University of Wisconsin, 152
source comparison, Brigham Young University, 128, field test, 95, 103, 134, 135, 142, 144, Kansas State University, 129, 150, McGill University Canada, 132, Puerto Rico, 148, rate of application, 146, time of application, 146, Trinidad, 139, tropic, 136, University of Florida, 137, University of Maryland, 151, University of Nebraska, 127, 145, University of Wisconsin, 152
time of application, field test, 141, Tennessee Technical University, 140, University College Swaziland, 149
Costa Rica
rate of application, rice, 75
source comparison, rice, 75
Cotton, source comparison, field test, 174, 175
Cranberry
rate of application, economics, 257
source comparison, Washington State University, 258, 259, 260
Developing Countries
estimated cost, production, 305
producer-product, market, 300
East-West Center
method of application, tropic, 291
source comparison, tropic, 291
East-West Resource Systems Institute, source comparison, rice, 107
Economics
manufacturing process, Tennessee Valley Authority, 299, 304, 307, Thiokol, 295
rate of application, cranberry, 257
variety of crops, coating, 297
England, characteristic, Imperial Chemical Industries, 316
Environmental Control, blast furnace slag, vegetation, 293
Equipment
pilot plant, Tennessee Valley Authority, 14
scanning electron microscope, coating study, 32
Feed Supplement, source comparison, lamb, 294
Fertilizer Industry, marketing, H. J. Baker & Bros., Inc., 320
Fescue
coating methods, Tennessee Valley Authority, 200
field test, Tennessee Valley Authority, 194
nitrogen loss, source comparison, 195
source comparison, field test, 215, Missouri Farmers Association, 198, Purdue University, 197, Tennessee Valley Authority, 193
Field Test
Agency for International Development, rice, 323
agronomic response, sugarcane, 167
application methods, rice, 119
Bangladesh, rice, 101, sorghum, 101
coastal bermudagrass, Tennessee Valley Authority, 194
fescue, Tennessee Valley Authority, 194
India, rice, 101, sorghum, 101
method of application, corn, 122, rice, 122, sorghum, 122, sugar beet, 122
nitrification inhibitor, India, 41, placement, 162
nitrogen loss, rice, 71
placement, corn, 95, rice, 95, 96, wheat, 95
rate of application, apple, 253, bromegrass, 212, corn, 131, forage, 189, meadow grass, 205, muskmelon, 246, oats, 157, orchardgrass, 212, rice, 111, wheat, 160
revegetation, blast furnace slag, 292
source comparison, Alaska pipeline, 287, banana, 255, bell pepper, 234, bromegrass, 212, 215, cassava, 103, corn, 95, 103, 130, 131, 134, 142, 143, 144, 146, cotton, 174, 175, fescue, 215, forage, 187, 189, grass, 222, India, 45, International Fertilizer Development Center, 69, international, 289, lettuce, 222, meadow grass, 205, 206, 207, muskmelon, 246, nitrogen loss, 288, oats, 157, 158, orange, 254, orchardgrass, 212, pasture grass, 180, potato, 247, 249, 250, prairie grass, 208, rice, 78, 87, 95, 96, 97, 102, 103, 111, 120, spinach, 234, sugarcane, 164, 170, tobacco, 177, tomato, 227, watermelon, 241, 243, 245, wheat, 95, 160
sulfide accumulation, rice, 98
time of application, corn, 141, rice, 96,

turf, 268, wheat, 159
University of California, source comparison, 232
University of Florida, watermelon, 239
West Samoa, rice, 101, sorghum, 101
Forage
agronomic response, Tennessee Valley Authority, 186
nitrogen loss, Texas A&M University, 188
placement, greenhouse test, 190
rate, greenhouse test, 190
source comparison, field test, 187, Tennessee Valley Authority, 191, University of California, 192
Forest
rate of application, North Carolina State University, 277
source comparison, New Zealand, 275, North Carolina State University, 277, 279, United States Department of Agriculture, 278, University of Florida, 276
Grain, Sorghum, source comparison, University of Florida, 155, University of Missouri, 156
Grass
field test, Jealott Hill Research Station, 221, source comparison, 222
source comparison, release rate, 216, University of Missouri, 211
Grass, Cool Season, source comparison, Kansas State University, 210
Grass, Forage, field test, rate of application, 189, source comparison, 189
Grass, Meadow
source comparison, field test, 206, 207
subirrigated, rate of application, 205, source comparison, 205
Grass, Pasture, source comparison, field test, 180, University of Ibadan, 181
Grass, Rangeland, source comparison, New Mexico State University, 179
Greenhouse Test
available sulfur, orchardgrass, 213
mineralization rate, effect of moisture, 47
release rate, factors controlling, 285, flooded soil, 80
source comparison, leafy vegetable, 224, lettuce, 225, nitrogen loss, 173, Poland, 49, rice, 94, 99, tomato, 228
H. J. Baker & Bros., Inc., marketing, fertilizer industry, 320
Hawaii Sugar Plant Association, source comparison, sugarcane, 169
Hawaiian Sugar Planters Association, source comparison, sugarcane, 171
Heavy Metal, movement in soil, source comparison, 220
Imperial Chemical Industries
characteristic, release rate, 316
GOLD-N, product, 310
India
agronomic response, rice, 121
effect on quality, rice, 123
nitrification inhibitor, field test, 41
source comparison, field test, 45, laboratory test, 44, rice, 76, 84, 90, 105, 112, 178
Indian Agricultural Research Institute
nitrogen transformation, source comparison, 37
source comparison, rice, 77, 82, 100
Indonesia, source comparison, rice, 73, 85
International Fertilizer Development Center
greenhouse test, rice, 113
placement, rice, 109
source comparison, quadratic model, 69, 286, rice, 72
water management, rice, 114
International Rice Research Institute
deep placement, rice, 93
nitrogen efficiency, source comparison, 104
source comparison, flooded soil, 125, rice, 106, 108, 110
Iran
method of application, sugar beet, 176
source comparison, sugar beet, 176
Irrigation, release rate, Korea, 54
Jealott Hill Research Station, field test, grass, 221
Kansas State University
grass, research, R24
grass tetany, bromegrass, 214
irrigation, research, R23
rate of application, corn, 129
source comparison, corn, 129, 150, grass, 210, sorghum, 150, wheat, 150
Kentucky Bluegrass, source comparison, Pennsylvania State University, 273
Korea
agronomic response, rice, 115
field test, rice, 74
release rate, water management, 54
Laboratory Test
release rate, coating weight, 58, factors controlling, 38, Oregon State University, 66, placement, 58, soil moisture, 58, Tennessee Valley Authority, 57, 62
source comparison, India, 44, release pattern, 68
urea hydrolysis, effect of sulfur, 46
Lettuce
field test, source comparison, 222
source comparison, Colorado State University, 226, greenhouse test, 225
Lincoln College, New Zealand, source comparison, release pattern, 68
Louisiana State University
nitrogen fixation, research, R25
rate of application, coastal bermudagrass, 201
rice, research, R26
source comparison, coastal bermudagrass, 201
Manufacturing Process, pilot plant, Tennessee Valley Authority, 13
Market, producer-product, developing countries, 300
McGill University, Canada, source comparison, corn, 132
Michigan State University
organic soil, research, R30
turf, research, R29
Middle Atlantic States, sulfur deficiency, coating contribution, 314
Mineralization, source comparison, Bangladesh Agricultural University, 43
Mineralization Rate, effect of moisture, greenhouse test, 47
Mississippi Chemical Corp., manufacturing process, patent, 16
Missouri Farmers Association, source comparison, fescue, 198
Montana State University
forest fertilization, research, R33
sulfur, research, R32
Muskmelon, field test, rate of application, 246, source comparison, 246
New Mexico State University
range fertilization, research, R36
source comparison, blue grama, 209, grass, rangeland, 179, pecan tree, 256
New Plant, Ag Industries Manufacturing Corporation, Alabama, 319
New Product, gro-power, Southern California Organic Fertilizer, 311
New Zealand
micronutrients, chrysanthemum, 264
source comparison, forest, 275
Nigeria, source comparison, nitrogen loss, 281
Nitrification, source comparison, Trinidad, 42
Nitrogen, release rate, Alabama A&M University, 60
Nitrogen Efficiency, source comparison, corn, 154, grass, 216, International Rice Research Institute, 104, sudangrass, 154, Tennessee Valley Authority, 309, tropic, 219
Nitrogen Loss
irrigation, University of Wisconsin, 284
leaching, corn, 143, source comparison, 50, 195, 282, tomato, 230
physical improvement, plasticizing agent, 18
source comparison, corn, 135, 248, field test, 288, greenhouse test, 173, Nigeria, 281, Oregon State University, 283, potato, 248, rice, 126, Rothamsted Experimental Station, 280, Texas A&M University, 40, University of California, 315

Texas A&M University, forage, 188
volatilization, dissolution rate, 39, moisture level, 39, source comparison, 50, temperature, 39
water logged soil, rice, 86
Nitrogen Transformation
release rate, coating property, 53, sulfur texture, 32
source comparison, fluctuating moisture content, 37
Nitrogen Utilization, source comparison, feed supplement, 294
North Carolina State University
pasture grass, research, R37
rate of application, forest, 277
release rate, tomato, 229
source comparison, forest, 277, 279
O. M. Scott & Sons Co., manufacturing process, patent, 23
Oats
rate of application, field test, 157
source comparison, field test, 157, 158
Oklahoma State University, bermudagrass, research, R41
Olin Corp., manufacturing process, patent, 24
Orange, source comparison, field test, 254
Orchardgrass
greenhouse test, available sulfur, 213
irrigation, rate of application, 212, source comparison, 212
Oregon State University
fescue, research, R42
grass, research, R43
nitrogen release rate, computer program, 59
release rate, effect of moisture, 66, effect of temperature, 66, equation, 64 research, R44, R45, simulation model, 67, tall fescue, 196
source comparison, nitrogen loss, 283
Ornamental
method of application, agronomic response, 262
source comparison, Auburn University, 265
Pacific Northwest Forest Experiment Station, forest, research, R56
Patent
Dilday, J. T., supplemental coating, 25
Mississippi Chemical Corp., manufacturing process, 16
O. M. Scott & Sons Co., manufacturing process, 23
Olin Corp., manufacturing process, 24
Tennessee Valley Authority, coating process, 9, dissolution rate measurement, 34
horizontal rotary drum, 10, manufacturing process, 2, 3, 6, 7, 8
Thiokol Chemical Corp., manufacturing process, 17, 22
Pecan Tree, source comparison, New Mexico State University, 256
Pennsylvania State University
agronomic response, turfgrass, 267, 271,
source comparison, bentgrass, 272, Kentucky bluegrass, 273, turfgrass, 266
turf, research, R46, R47, R48
Pepper
placement, soil test, 236
rate of application, soil test, 236, University of Florida, 237
source comparison, soil test, 236, University of Florida, 235, 237
Peru, field test, rice, 124
Philippines, agronomic response, rice, 81
Pilot Plant, flowsheet, Tennessee Valley Authority, 12, 26
Poland, source comparison, greenhouse test, 49
Potato
effect on quality, source comparison, 249
nitrogen loss, source comparison, 248
rate of application, University of Wisconsin, 152
source comparison, field test, 250, Rothamsted Experimental Station, 247, University of Wisconsin, 152, Washington State University, 251
Prairie Grass, source comparison, field test, 208
Product, GOLD-N, Imperial Chemical Industries, 310
Production
estimated cost, developing countries, 305
new plant, Alabama, 319
technology, Tennessee Valley Authority, 322
Puerto Rico, source comparison, corn, 148, sorghum, 148
Purdue University, source comparison, fescue, 197
Release Rate, equation, Oregon State University, 64
Research
bell pepper, University of Florida, R16
bermudagrass, Oklahoma State University, R41
blueberry, Washington State University, R59
citrus, University of Florida, R17
corn, University of Wisconsin, R62
cranberry, Washington State University, R57, R58, R59
efficiency, Texas A&M University, R53, R55, University of Wisconsin, R61
fescue, Oregon State University, R42
forage, Texas A&M University, R52, Washington State University, R60
forest, Pacific Northwest Forest Experiment Station, R56
forest fertilization, Montana State University, R33
fruit tree, University of Florida, R14
grain, University of Maryland, R28, University of Nebraska, R35
grass, Kansas State University, R24, Oregon State University, R43, University of Hawaii, R21
irrigation, Kansas State University, R23
mint, University of Idaho, R22
nitrate leaching, University of Maryland, R27
nitrogen fixation, Louisiana State University, R25
nutrient efficiency, Tennessee Valley Authority, R3, University of Florida, R10, R13, R15, University of Georgia, R20, University of Missouri, R31
nutrient management, Colorado State University, R8
organic soil, Michigan State University, R30
ornamental, Alabama A&M University, R4, Clemson University, R50
pasture grass, North Carolina State University, R37
plant nutrient interaction, Tennessee Valley Authority, R2
potato, University of Wisconsin, R62
range fertilization, New Mexico State University, R36
release rate, Oregon State University, R44, R45
rice, Louisiana State University, R26
ryegrass, Texas A&M University, R51
soil-plant balance, United States Department of Agriculture, R40
source comparison, Alabama A&M University, R5, United States Department of Agriculture, R39
sulfur, Montana State University, R32
Tennessee Valley Authority, dissolution, R1
test demonstration, University of Alaska, R6, University of Arizona, R7
turf, Clemson University, R49, Michigan State University, R29, Pennsylvania State University, R46, R47, R48, University of Nebraska, R34
University of Florida, tifgreen bermudagrass, R12
University of Georgia, coastal bermudagrass, R19
vegetable, Texas A&M University, R54
watermelon, University of Florida, R18
wheat, United States Department of

Agriculture, R38, Washington State University, R60
Review
advantage, Tennessee Valley Authority, 70
agronomic response, Tennessee Valley Authority, 4
development, Tennessee Valley Authority, 317
manufacturing process, Canadian Industries Ltd., 298
operating experience, Tennessee Valley Authority, 15
research and development, China, 29, Tennessee Valley Authority, 306
research program 1975-78, Tennessee Valley Authority, 290
Rice
agronomic response, flooded soil, 80, India, 121, Korea, 115
application methods, field test, 119
Bangladesh, field test, 101
crop rotation, source comparison, 87
deep placement, International Rice Research Institute, 93
effect on quality, India, 123
field test, Agency for International Development, 118, Korea, 74, Peru, 124, source comparison, 78, Tennessee Valley Authority, 117
flooded soil, agronomic response, 81
greenhouse test, International Fertilizer Development Center, 113
India, field test, 101
method of application, field test, 122
nitrogen loss, field test, 71
placement, field test, 95, 96, International Fertilizer Development Center, 109
rate of application, Costa Rica, 75, field test, 111
release rate, source comparison, 90
source comparison, Central Rice Research Institute, 91, Costa Rica, 75, East-West Resource Systems Institute, 107, field test, 95, 96, 97, 102, 103, 111, flooded soil, 120, greenhouse test, 94, 99, India, 76, 84, 105, 112, 178, Indian Agricultural Research Institute, 77, 82, 100, Indonesia, 73, International Fertilizer Development Center, 72, International Rice Research Institute, 106, 108, 110, 125, nitrogen loss, 126, Sierra Leone, 116, Taiwan, 88, 89, 92, Texas Agricultural Experimental Station, 79, University of Arkansas, 83, water logged soil, 85
sulfide accumulation, field test, 98
time of application, field test, 96
water logged soil, nitrogen loss, 86
water management, International Fertilizer Development Center, 114
West Samoa, field test, 101
Rothamsted Experimental Station
nitrogen loss, source comparison, 280
source comparison, potato, 247
Rye, source comparison, rate of application, 183
Ryegrass
rate of application, Texas A&M University, 182
source comparison, Australia, 185, color response, 269, rate of application, 183, south central Florida, 184, Texas A&M University, 182
visual test, University of Florida, 274
Sewage Sludge, heavy metal, effect of nitrogen, 220
Sierra Leone, source comparison, rice, 116
Simulation Model
release rate, computer program, 63, Oregon State University, 67
yield response, quadratic response curve, 286
Slag, blast furnace, vegetation, 293
Small Grain, source comparison, University of Maryland, 151
Soil Test
placement, pepper, 236
rate of application, pepper, 236
source comparison, pepper, 236
Sorghum
Bangladesh, field test, 101
India, field test, 101
method of application, field test, 122
nitrogen loss, source comparison, 195
source comparison, Kansas State University, 150, Puerto Rico, 148
West Samoa, field test, 101
South Central Florida, source comparison, ryegrass, 184
Southern California Organic Fertilizer, new product, gro-power, 311
Spinach, field test, source comparison, 234
Stargrass, source comparison, tropic, 219, United States Department of Agriculture, 218
Sudangrass, nitrogen efficiency, source comparison, 154
Sugar Beet
method of application, field test, 122, Iran, 176
source comparison, Iran, 176
Sugarcane
agronomic response, Hawaii, 167
field test, Tennessee Valley Authority, 117, University of Florida, 172
release characteristic, factors controlling, 166
research, University of Florida, R9
source comparison, field test, 164, 170, Hawaii Sugar Plant Association, 169, Hawaiian Sugar Planters Association, 171, nitrogen loss, 173, University of West Indies, 168
time of application, University of Florida, 165
Sulfur
agricultural practices, market potential, 313
source, University of Georgia, 324
thermal change, dissolution rate, 30
urea hydrolysis, laboratory test, 46
Sweet Corn, irrigation, Texas A&M University, 153
Sweet Potato
rate of application, University of Puerto Rico, 252
source comparison, University of Puerto Rico, 252
Taiwan, source comparison, rice, 88, 89, 92
Tall Fescue, release rate, Oregon State University, 196
Technique, manufacturing process, patent, 25, Tennessee Valley Authority, 5, 318
Technology
coating, factors controlling, 19, manufacturing process, 21, release rate, 20
development, Tennessee Valley Authority, 296
experience, Tennessee Valley Authority, 308
manufacturing process, spouted bed, 27, 28, Tennessee Valley Authority, 303
progress report, world, 312
update, Tennessee Valley Authority, 11
Tennessee Technical University
source comparison, corn, 140
time of application, corn, 140
Tennessee Valley Authority
advantage, review, 70
agronomic response, bermudagrass, 203, forage, 186, review, 4
analysis, coating weight, 35, dissolution rate, 34, 35
coating, release rate, 1, 51
coating methods, bermudagrass, 200, fescue, 200
coating process, patent, 9
development, review, 317
dissolution, research, R1
economics, coating, 302
field test, bermudagrass, 117, coastal bermudagrass, 194, fescue, 193, 194, rice, 117, sugarcane, 117
greenhouse test, forage, 190, nitrogen loss, 282, release rate, 285
horizontal rotary drum, patent, 10
laboratory study, characterization, 31
manufacturing process, coating, 2, 3, cost, 307, economics, 299, 304,

patent, 6, 7, 8, pilot plant, 5, 13, 14, 26, 318, rotary drum, 15, spouted bed, 27, technology, 303
nitrogen efficiency, source comparison, 309
nitrogen loss, research, 50
nitrogen release, computer program, 59
nutrient efficiency, research, R3
pilot plant, flowsheet, 12
plant nutrient interaction, research, R2
release pattern, factors controlling, 55
release rate, coating, 48, colorimetric determination, 56, factors controlling, 52, 57, 65, laboratory test, 62
research and development, review, 306
research program, review 1975-78, 290
source comparison, bahiagrass, 217, coastal bermudagrass, 202, forage, 191, international, 289, vegetable, 224
technology, development, 296, experience, 308, production, 322, update, 11
thermal change in sulfur, dissolution rate, 30
Testing, coating thickness, release rate, 61
Texas A&M University
efficiency, research, R53, R55
forage, research, R52
irrigation, sweet corn, 153
nitrogen loss, forage, 188, source comparison, 40
rate of application, ryegrass, 182
ryegrass, research, R51
source comparison, ryegrass, 182
vegetable, research, R54
Texas Agricultural Experimental Station
field test, vegetable, 223
source comparison, rice, 79
Thiokol
coating process, economics, 301
manufacturing process, economics, 295
release rate, factors controlling, 52
Thiokol Chemical Corp., manufacturing process, patent, 17, 22
Tobacco, source comparison, field test, 177
Tomato
field test, source comparison, 227
greenhouse test, source comparison, 228
nitrogen loss, University of Florida, 230
release rate, Alabama A&M University, 231, North Carolina State University, 229
Trinidad
nitrification rate, source comparison, 42
nitrogen loss, volatilization, 39
placement, corn, 138
rate of application, corn, 138
release rate, coating weight, 58, placement, 58, soil moisture, 58
source comparison, corn, 139
Triticale, source comparison, agronomic response, 163
Tropic
method of application, east-west center, 291
source comparison, corn, 136, east-west center, 291, stargrass, 219
Turf, time of application, field test, 268
Turfgrass
agronomic response, Pennsylvania State University, 267, 271
source comparison, Pennsylvania State University, 266, University of Florida, 270
visual test, University of Florida, 274
Turnip Green, release rate, Alabama A&M University, 231
United States
economics, coating, 321
new plant, Ag Industries Manufacturing Corporation, 319
United States Department of Agriculture
soil-plant balance, research, R40
source comparison, forest, 278, research, R39, stargrass, 218
wheat, research, R38
University College, Swaziland, time of application, corn, 149
University of Alaska, test demonstration, research, R6
University of Arizona, test demonstation, research, R7
University of Arkansas, source comparison, rice, 83
University of California
coating property, release rate, 53
field test, source comparison, 232
laboratory test, release rate, 38
leaching rate, corn, 133
simulation model, release rate, 63
source comparison, forage, 192, nitrogen loss, 315
University of Florida
agronomic response, watermelon, 240, 242
field test, bell pepper, 233, sugarcane, 172
nitrogen loss, tomato, 230
nutrient efficiency, research, R10, R13, R15
rate of application, corn, 137, watermelon, 244
release characteristic, sugarcane, 166
research, bell pepper, R16, citrus, R17, fruit tree, R14, sugarcane, R9, tifgreen bermudagrass, R12, watermelon, R11, R18
source comparison, color response, 269, corn, 137, forest, 276, grain sorghum, 155, pepper, 235, turfgrass, 270, watermelon, 238, 244, 245
time of application, sugarcane, 165
University of Georgia
coastal bermudagrass, research, R19
nutrient efficiency, research, R20
sulfur, source, 324
University of Hawaii
grass, research, R21
source comparison, bermudagrass, 204
University of Ibadan, source comparison, pasture grass, 181
University of Idaho, mint, research, R22
University of Maine, source comparison, blueberry, 261
University of Maryland
grain, research, R28
nitrate leaching, research, R27
source comparison, corn, 151, small grain, 151
University of Missouri
nutrient efficiency, research, R31
source comparison, grain sorghum, 156, grass, 210
University of Nebraska
grain, research, R35
source comparison, corn, 127, 145
turf, research, R34
University of Puerto Rico
rate of application, sweet potato, 252
source comparison, sweet potato, 252
University of West Indies, source comparison, corn, 136, sugarcane, 168
University of Wisconsin
corn, research, R62
efficiency, research, R61
nitrogen loss, irrigation, 284
potato, research, R62
rate of application, corn, 152, potato, 152
source comparison, corn, 152, potato, 152
Vegetable
source comparison, Tennessee Valley Authority, 224
Texas Agricultural Experiment Station, field test, 223
Washington State University
blueberry, research, R59
cranberry, research, R57, R58, R59
forage, research, R60
source comparison, cranberry, 258, 259, 260, potato, 251, wheat, 161
wheat, research, R60
Watermelon
agronomic response, rate of application, 240, source comparison, 240, University of Florida, 242
field test, source comparison, 241
rate of application, University of Florida, 237, 244
research, University of Florida, R11
source comparison, field test, 243,

University of Florida, 237, 238, 244, 245
University of Florida, field test, 239
Wheat
field test, rate of application, 160,
source comparison, 160
nitrification inhibitor, field test, 162
placement, field test, 95
rate of application, Afghanistan, 147
source comparison, field test, 95,
Kansas State University, 150,
Washington State University, 161
time of application, field test, 159
World, technology development, progress report, 312

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