Urea as a Nitrogen Fertilizer for Great Plains Grasslands

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Highlight: *Economics and pollution standards indicate that urea may soon be the prime nitrogen fertilizer source in the Great Plains. Available literature was reviewed on the use of urea as a fertilizer for grasslands, particularly in semiarid regions. Results from only a few such experiments were found. However, these results agree with those from more humid or subtropical regions in that urea was as effective as ammonium nitrate at low, but not at high, rates of application. Maximum production attainable with urea is probably less than that attainable with ammonium nitrate.*

Several developments within recent years indicate that urea will become the primary nitrogen fertilizer source for semiarid grasslands in the near future. Among these developments are: (a) the need for N fertilizers, particularly on cool season grasses in the Great Plains, is rapidly becoming more apparent in order to meet livestock demands; (b) lack of suitable application methods essentially prohibits using anhydrous ammonia on these grasslands; and (c) nitrate-containing sources, especially ammonium nitrate, may soon become prohibitive in price because of technological difficulties in controlling the emission of nitrous oxides during manufacture. Thus, only ammonium sulfate and urea remain of the conventional fertilizer N sources, and the price of N as ammonium sulfate is frequently 40% greater than that of urea (Huston, 1971). Consequently, urea may become the predominant fertilizer N source for the Great Plains in the foreseeable future.

Unfortunately, available publications provide the fertilizer industry and user with only limited information on the effectiveness of urea as an N source for dryland grasses. It is commonly accepted that, as urea is hydrolyzed to ammonia and carbon dioxide, significant quantities of the ammonia produced may escape to the atmosphere. Conditions that are generally conducive to ammonia volatilization include neutral or alkaline soil pH, moderately restricted water supply, warm temperature, and presence of organic mulches. Several or all of these conditions apparently may be encountered in semiarid grasslands. Consequently, a very real question exists concerning the efficiency of urea as a fertilizer N source for semiarid grasslands.

This paper is a review of present information on the use of urea on semiarid grasslands. Although all pertinent references may not be included, the purpose of this paper is to point out to the reader the nature and extent of factual information available on the subject. Urea has been used as a fertilizer N source for semiarid grasslands in only a limited number of controlled field experiments. However, a number of laboratory and field experiments using urea with other crops or in other climates have been reported. Results of several pertinent experiments are reviewed in this paper.

Power and Alessi (1970) studied the effects of 90 and 180 kg N/ha as ammonium nitrate, ammonium sulfate, calcium nitrate, or urea upon crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.) production for 5 years. Nitrogen fertilizers were applied with or without surface broadcast P fertilizer. Dry weights for only the urea and ammonium nitrate treatments are shown in Table 1—yields for other N sources were generally similar to those obtained with ammonium nitrate. P fertilization increased dry matter production by 22% (10 to 50% range), regardless of N rate or source. At the 90 kg N/ha rate, N source had no significant effect upon yields. However, urea applied at 180 kg N/ha yielded no more than at the 90 kg/ha rate when no P was added. With P fertilization, there was also no response to the higher urea rate for the first 3 years of the study, but responses were evident the last 2 years. Inorganic N did not build up in soils receiving 90 kg N/ha annually, but frequently over 150 kg inorganic N/ha accumulated in the upper 90 cm of soil after 5 years of fertilization at 180 kg N/ha annually. A very noticeable exception was the treatment receiving 180 kg N as urea plus P fertilization, where no accumulation of inorganic was found. This difference was verified by unpublished data from this experiment on residual effects from these treatments where it was found that residual responses were much greater from ammonium nitrate than from urea. After 5 years of fertilization at 180 kg N/ha annually soil pH in the surface 15 cm decreased from 6.2 to 5.5 with ammonium nitrate and to 5.8 with urea.

In another experiment by Power et al. (1972) urea, ammonium nitrate, ammonium sulfate, and calcium nitrate were applied to both corn (*Zea mays* L.) and smooth brome (*Bromus inermis* L.) at rates of 55 and 110 kg N/ha (fine sandy

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loam, surface pH 6.5). At the 55 kg N/ha rate, dry matter production by corn following urea fertilization was approximately equal to that following ammonium nitrate fertilization (Fig. 1). With 110 kg N/ha however, only 73% as much dry matter was produced from urea as from ammonium nitrate. Average dry matter production by smooth brome receiving 110 kg N/ha as urea was not significantly greater than that receiving 55 kg urea N/ha. Soil pH did not change appreciably as a result of fertilization with either of these N sources.

Fertilization was discontinued in the above experiment, and both the areas formerly in corn and in bromegrass were uniformly cropped to barley without additional N application, until residual growth responses were no longer significant. The fate of the fertilizer N applied was then determined (Power et al., 1973). For urea, 47% of the fertilizer N applied at 110 kg N/ha could be accounted for by N uptake in tops plus inorganic N remaining in the root zone of the soil. Movement below the root zone was generally insignificant for smooth brome. N recovery averaged 82% for the other N sources. N recoveries for the corn area were 86 and 79% for urea and other N sources, respectively, when applied at the high N rate. The experiment was continued until growth responses resulting from residual effects of previous treatments were no longer statistically significant, indicating that little or no fertilizer N remained in plant roots, residues, or in available organic or inorganic forms. Thus, a large part of the fertilizer N was probably lost from the soil in gaseous form, especially by ammonia volatilization. Since all N fertilizers for corn were drilled about 6 cm deep but were surface broadcast on smooth brome, it appears that volatilization of ammonia from urea surface broadcast on a coarse-textured neutral grassland soil may become significant.

McGinnies (1968) recently published results from an experiment in which urea was applied to crested wheatgrass in eastern Colorado, but unfortunately no other N sources were used for comparison. Sneva (1973) found little difference between urea and ammonium nitrate when applied at 22 kg N/ha to several dryland grasses in Oregon. Dry matter production resulting from N fertilization increased about 20% over a 3 year period. A review of literature for the past decade revealed no further information from field experiments involving urea fertilization of semiarid grasslands in North America.

Limited investigations in the Soviet Union have resulted in variable results. Generally, little difference between fertilizer sources was observed when they were applied to several grasses on various types of chernozemic and semiarid soils (Kondrst'ev and Podkolzina, 1966). Lichev (1966) reported similar results on chernozemic soils in Bulgaria. Moraczewaski (1970) found ammonium nitrate produced 6.4% more grass than urea produced on Polish chernozems at N rates up to 300 kg/ha. N rate was not specified in the other eastern European studies. In Spain (Suarez and Ascension, 1965), urea applied to grassland was equal to or better than ammonium nitrate, but again N rate was not specified. In Australia, Henzell (1971) found urea to be less effective at rates up to 448 kg N/ha, and found fertilizer N losses from urea to be as much as 43%. Simpson (1968) reported similar losses from urea applied to ryegrass in the same region.

Table 1. Dry weight (kg/ha) of crested wheatgrass fertilized with ammonium nitrate and urea (kg N/ha), Mandan, N. Dak.

		Without P			With P		
Year	N fertilizer	0-N	90-N	180-N	0-N	90-N	180-N
1962	–	2,050	–	–	2,620	–	–
	NH_4NO_3	–	4,560	5,850	–	5,140	6,450
	Urea	–	4,650	4,850	–	4,950	5,240
1963	–	1,130	–	–	1,570	–	–
	NH_4NO_3	–	2,730	3,140	–	3,700	3,850
	Urea	–	3,330	2,980	–	3,610	3,600
1964	–	1,010	–	–	1,120	–	–
	NH_4NO_3	–	2,420	2,590	–	3,120	3,120
	Urea	–	2,460	2,290	–	3,180	3,300
1965	–	1,780	–	–	2,220	–	–
	NH_4NO_3	–	5,880		–	6,260	6,290
	Urea	–	4,800	5,240	–	5,760	6,860
1966	–	670	–	–	1,020	–	–
	NH_4NO_3	–	1,820	1,870	–	2,780	2,370
	Urea	–	2,040	1,740	–	2,280	2,690
Avg	–	1,330	–	–	1,710	–	–
	NH_4NO_3	–	3,360	3,860	–	4,200	4,410
	Urea	–	3,460	3,410	–	3,940	4,330

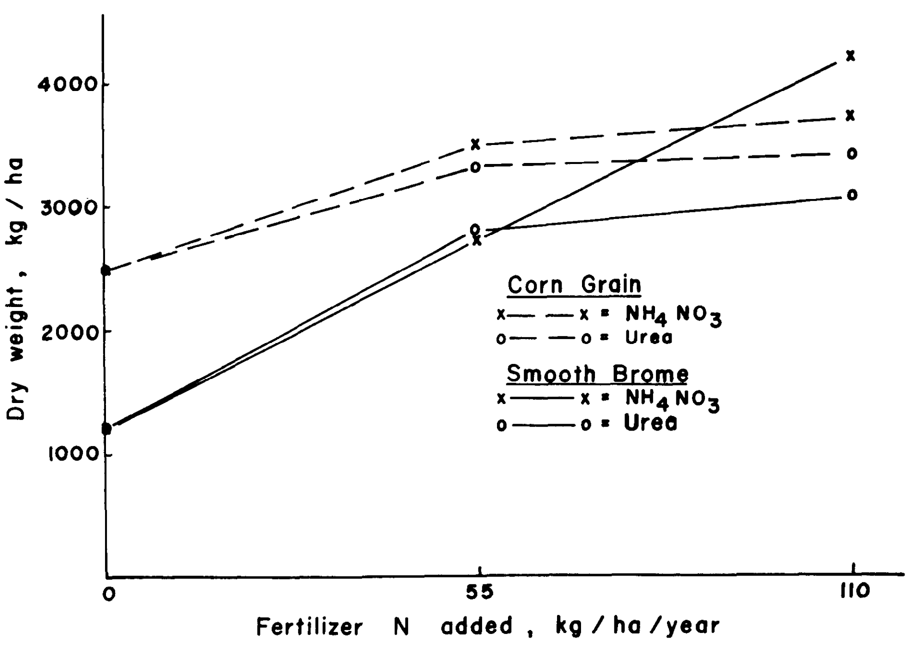

Fig. 1. *Effect of ammonium nitrate and urea on dry matter production of smooth brome and corn.*

Urea has been used more frequently as a fertilizer N source for grasslands in the fringe areas of the Great Plains where precipitation is often greater or evapotranspiration is less. Seamands (1971) found little difference between ureaforms, ammonium nitrate, and liquid urea applied at 112 kg/ha to mountain meadows in Wyoming. Cairns (1968) measured 55% recovery of ammonium nitrate, compared with 45% for urea, applied at 112 kg/ha to smooth brome on solonetzic soils with high water table in Alberta. Urea was as effective as ammonium nitrate when applied to coastal bermudagrass (*Cynodon dactylon* L.) in Oklahoma (Hill and Tucker, 1968) at 112 kg N/ha but was inferior at 224 kg N/ha.

Urea used on grasslands in temperate humid regions and in subtropical and tropical regions has been investigated in a number of studies. Urea was as effective as ammonium nitrate (Korenkov and Filimonov, 1968; Vlasova, 1968) in only a few eastern European countries, but in these cases the N rate was not specified. In Western Europe (Devine and Holmes, 1963 and 1965; Furunes, 1966; Johansson and Jonson, 1964: and Mundy, 1966), eastern United States (Mays and Terman, 1969), Alaska (Laughlin, 1963), and several tropical locations (Vicente-Chandler and Figarella, 1962; Volk, 1966) urea applied at moderate-to-high rates produced less dry matter than did ammonium nitrate.

Volk (1966) illustrated that hydrolysis of urea did not occur in a dry soil, and that the process was restricted in a soil temporarily wetted. However, soil surfaces continually wetted from a water table resulted in complete hydrolysis of urea in 7 days, 65% of which was then lost, presumably by ammonia volatilization. Kresge and Satchell (1960) showed that heavy watering restricted ammonia losses. Consequently, soil water contents in the range required for plant growth appear to be conducive to ammonia volatilization.

Simpson (1968) found that gaseous losses could be reduced to almost half by removing a centimeter or two of the grass sod surface, the soil zone in which urease activity was particularly high. Likewise, Jackson and Burton (1962) reported that gaseous losses from urea applied to bermudagrass were reduced if the stubble was burned or if the soil was plowed shallow prior to fertilizer application. These and other results support the theory that gaseous losses from urea are enhanced by organic mulch present on the soil surface.

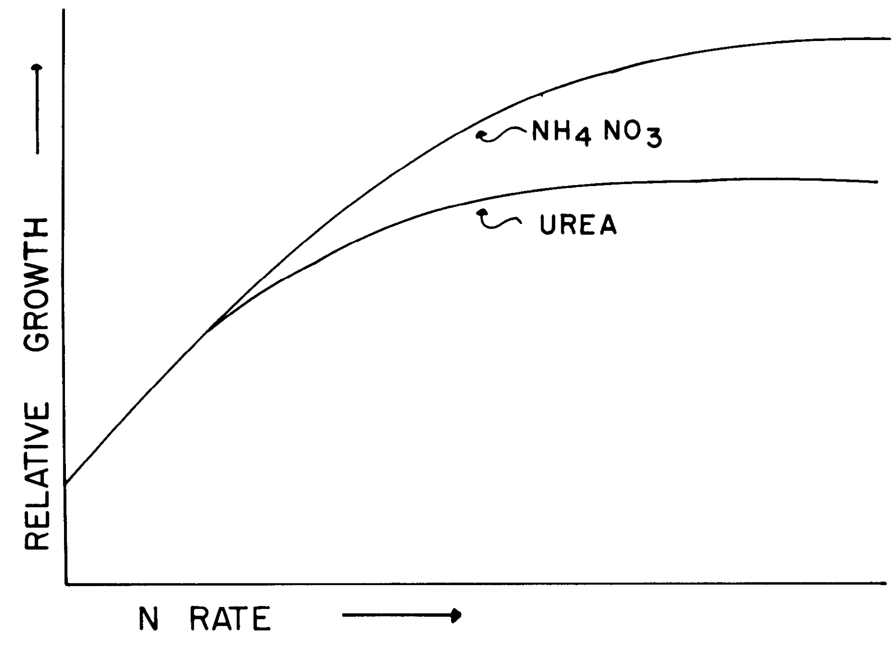

Fig. 2. *Diagram showing the relation between rate of fertilization with ammonium nitrate and urea to dry matter production from grassland soils.*

A review of literature therefore suggests that low to moderate rates of urea are often equally as effective as ammonium nitrate for grass production. However, results of most experiments using higher N rates on numerous kinds of soils in many climates indicate that urea is generally 5 to 40% less effective than ammonium nitrate. These relationships are expressed for low and moderate rates in Fig. 1, and diagrammatically for all N rates in Fig. 2. At low rates of N fertilization, urea produced essentially the same amount of grass forage as ammonium nitrate did. However, at intermediate rates, the curves began to diverge and the urea curve flattened out while the ammonium nitrate curve reached a maximum at a much higher N rate. Yields obtained with urea may never equal maximum yields obtainable from ammonium nitrate (Fig. 2). However, in none of the experiments cited did fertilizer rates go high enough to definitely establish this relationship. In the publications of Power et al. (1970, 1972), Henzell (1971), and Devine and Holmes (1963), data show that the response of urea compared with that of ammonium nitrate or other N sources decreased as rate of N fertilization increased for all rates studied. This suggests continued divergence of the response curves as N rate increases, as indicated by Fig. 2.

From the publications reviewed in this paper, urea at higher rates appears less efficient than ammonium nitrate, especially when applied to moderately moist soils that are near neutral or alkaline and are coarse in texture. Organic residues present on the soil surface may further reduce the efficiency of urea. All these conditions are frequently encountered in semiarid grasslands. Consequently, although actual field data are very limited, the data presented in the tables and figures here are somewhat typical of what might be expected in actual practice.

If further research proves these conclusions correct, the fact that urea is less efficient as an N source for grass production may not be as important as the fact that maximum yields obtainable with urea may be less than with ammonium nitrate. Much more research is needed to better answer these and related questions and to better establish the place of urea as an N source for semiarid grasslands.

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