Determination of Nitrogen Fertilizer Use Efficiency and Evaluation of Controlled-Release Nitrogen Fertilizer Products for Irrigated Corn.

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Corn production is becoming an increasingly important player in the Arkansas agricultural sector and corn's high yield potential and reduced operating costs make it a prime candidate for producers looking to increase profitability. No other nutrient is more challenging to manage than nitrogen (N), but no other nutrient provides more reward for its efficient use. For most producers, N fertilizer represents the largest line-item expenditure which can often reach 25% of the total operating costs, and is often the most limiting nutrient required to maximize yields. Fertilizer use efficiency, especially N use efficiency is controlled by the source of fertilizer, the rate of fertilizer, time of fertilizer application and the placement of fertilizer in relation to the crop. These four factors, when coupled properly, will result in the most efficient use of N fertilizer and often lead to higher producer profitability. Unfortunately in Arkansas, there is little data on the N fertilizer use efficiency of furrow-irrigated corn production systems and the current three-way-split that is most commonly used. A better understanding of how N fertilizer is taken up and distributed in the plant will help to complete at least a portion of the puzzle by allowing recommendations to be updated based on the most current and reliable research techniques. In addition to identifying the N fertilizer use efficiency of furrow-irrigated corn, an evaluation of controlled-release fertilizer products under Arkansas production environments will provide insight as to how Arkansas producers could benefit from the incorporation of controlled -release products into corn N fertilizer management. Increasing efficiency of N fertilizer is a primary concern from both an agronomic and environmental standpoint and will help to strengthen the long-term sustainability of Arkansas corn production.

Nitrogen use efficiency is often hard to determine, as the efficient use of N fertilizers can often be masked by the native soil N and the residual N from previous N fertilizer applications or crops. To determine how N enters and is ultimately distributed within the plant special techniques can be used that allow the N from fertilizer to be traced both in the soil and within the corn plant. A unique aspect of the chemical element N is that it occurs in two isotopes, which are both stable (non-radioactive) and allow researchers to trace this element through almost any terrestrial, plant or animal system. The majority of N found in the earth's atmosphere and crust is ^{14}N, which in layman's terms, means it weighs roughly 14 grams per mole and this form represents roughly 99.64% of all the N. The other isotope of N is slightly heavier (^{15}N) and represents roughly 0.36% of all N. Since these two forms of N are stable and non-radioactive they can be easily handled and used in a wide variety of settings with no restrictions or health concerns. The difference in weight between these two N atoms and the vast difference in their abundance make tracing the ^{15}N easy, but it often comes with a significant price tag. Standard urea used in agriculture generally costs $0.50 per lb. whereas ^{15} labeled urea used for agricultural research on N use efficiency can cost as much as $450.00 per lb. Although this is an expensive technique to use, the data acquired from the small-plot N trials using ^{15}N are invaluable and will determine beyond question what percentage of N in the plant came from the fertilizer that was applied and what portion was taken up from the soil. When used correctly ^{15}N is a remarkable tool that allows very specific production practices to be evaluated in regards to their impact on N use efficiency.

Nitrogen partitioning in the corn plant is well documented (Figure 1), but the majority of corn research has been based in the Upper Midwest where they implement significantly different production practices. Rather than relying on data from other states, which does not really apply to Arkansas producers, research was established to determine the N use efficiency of furrow-irrigated corn on silt loam soils. A N response trial featuring ^{15}N-labeled urea was established at the Rohwer Research Station in Southeast Arkansas. To better understand the N use efficiency of furrow-irrigated corn three N rates 0 (check), 140 (sub-optimum), and 210 (optimum) units of N/acre and three application timings preplant, sidedress and pre-tassel were chosen based in the commonly used three-way split, and were arranged in 8 treatment combinations. At physiological maturity whole plant samples were taken and separated into leaves, stalk, husk, cob and grain to allow researchers to determine exactly where the fertilizer N was deposited in the corn plant.

Applying ^{15}N labeled urea at a specific rate and time will enable direct calculation of the N use efficiency of that specific N fertilizer application. Nitrogen fertilizer use efficiency is expected to be lowest for the preplant urea application as corn plants are still relatively small and unable to fully utilize the fertilizer N. Sidedress N applications should have a higher efficiency than the preplant N, because by this point the corn has a substantial root system and is beginning to enter a period of rapid growth where it can take up and incorporate as much as 3 lb N per day. The highest N use efficiency will probably occur for the pre-tassel application due to the size of the corn plants and their root systems. Although the pre-tassel N fertilizer application should result in the highest N uptake efficiency, the pre-tassel N application may have little to no influence on corn yield if the preplant and side-dress N rates were sufficient. The highest yields obtained during the first year of this study were observed when 210 units N /acre were applied as 45 units N/acre preplant + 165 units N/acre sidedress (Table 1). When the same total N rate was applied, but a pre-tassel was included there was a significant decrease in corn yield. These results indicate the importance of pre-plant and sidedress N fertilizer applications for setting corn yield and that yield losses due to under fertilization early in the corn plant's development cannot be fully recovered with a pre-tassel N application.

Controlled-release fertilizers represent a significant portion of the fertilizer industry and are widely used in the Upper Midwest. Environmentally Smart Nitrogen or ESN is one of the more common controlled-release products on the market and is a standard urea prill that has a micro thin polymer coating (Figure 2). This thin polymer coating allows the urea prill to remain intact until water can imbibe the prill and dissolve the urea (Figure 3). The release of N into the soil solution from ESN is most closely linked to soil temperature. As soil temperature increases the release of N from the ESN product should also increase. A major limitation of ESN is that the polymer coating makes the product quite buoyant and it will easily float. Due to the ability of ESN to float and move with the rain or irrigation water it should only be considered as a preplant N fertilizer product or be incorporated after application. Benefits of ESN include the ability to apply higher N rates preplant with ground application equipment and limit trips across the field or the need for aerial application. Using ESN preplant can also increase corn yields when excessive spring rains prevent or delay sidedress N applications. Data from this spring indicates that ESN applied preplant performed better than urea applied preplant (Table 2) and may be attributed to the high rainfall amounts that were seen following corn emergence. Although ESN applied preplant outperforms urea applied preplant the added cost for ESN may not make it cost effective compared to a traditional preplant/sidedress urea split. One benefit of ESN is that it provides a type of "insurance" that N will be available to the growing corn plant under wet conditions when producers may not be able to get into the field. Further studies are planned to effectively evaluate these products under a wide range of environmental conditions and to help determine the cost effectiveness under a range of circumstances.

Nitrogen fertilizer and its management are important not only to be agronomically sound and profitable, but are an important component of environmental stewardship. As technology and fertilizer costs continue to rise it is important to have the best information available to make well-informed production decisions. The data compiled from this research will provide insight on the efficiency of our current N fertilizer practices on furrow-irrigated corn and allow future N fertilizer recommendations to be as efficient as possible. In addition to understanding our N fertilizer efficiency, the evaluation of controlled-release fertilizer products under Arkansas production practices will provide information on alternative N fertilizer sources that could reduce application costs and provide a type of insurance when facing wet soil conditions following corn emergence.

Table 1. Comparison of corn grain yields when total N rates are split across different application times.

Total N Rate	Preplant N Rate	V6 (Sidedress) N Rate	Tassel N Rate	Grain Yield*
units of N/acre				Bu/acre
0	0	0	0	124c
140	45	95	0	160b
140	45	50	45	161b
210	45	165	0	191a
210	45	120	45	169b

* - Corn grain yields not connected by the same letter are significantly different at the 0.05 level.

Table 2. Comparison of corn grain yields as influenced by fertilizer source averaged across N rate of 70, 140 and 210 units of N/acre.

N Fertilizer Source	Grain Yield* Prairie County	Grain Yield* Pine Tree
Bu/acre		
No N	113c	47c
Urea-Preplant	171b	159b
Urea-Split	180ab	174a
ESN-Preplant	196a	176a

* - Corn grain yields within the same column not connected by the same letter are significantly different at the 0.10 level.

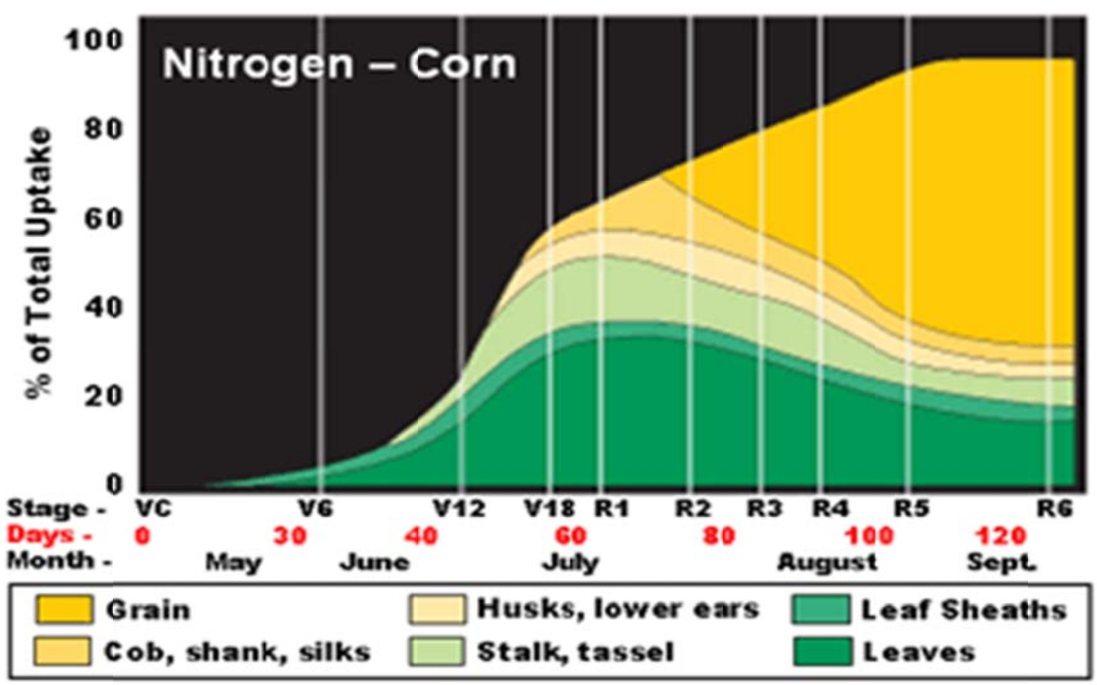

Figure 1. Partitioning of N within the corn plant throughout the growing season. (pioneer.com) Adapted from Richie, S. W., J.J. Hanway and G.O. Benson. 2005. How a Corn Plant Develops. Iowa State University Cooperative Extension Service. Ames. Special Report No. 48. 21 pp

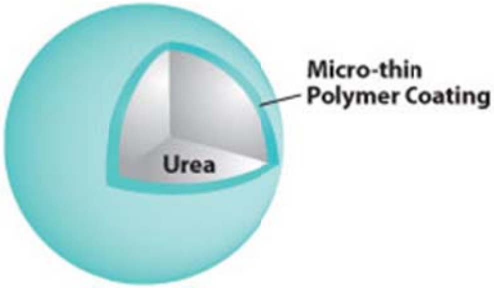

Figure 2. Environmentally Smart Nitrogen (ESN) is a controlled-release fertilizer product that contains a thin polymer coating which controls the release of N from the prill. (http://www.smartnitrogen.com/environmentally-smart-nitrogen-fertilizer-how-the-technology-works.aspx)

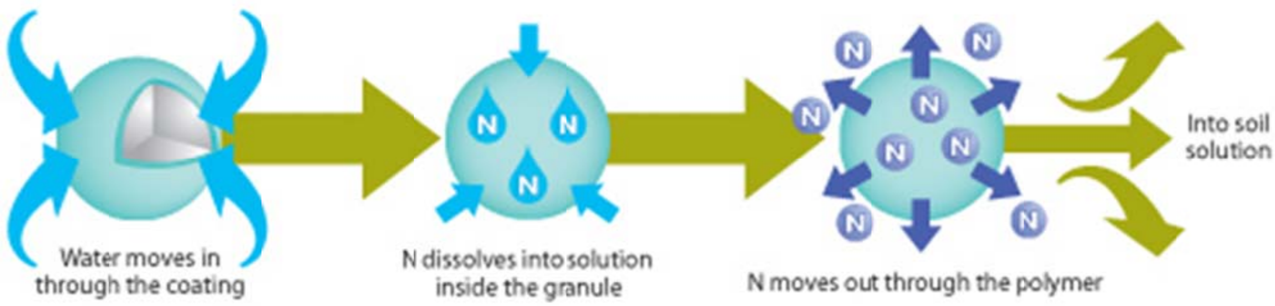

Figure 3. Diagram explaining the release of N from ESN as controlled by water flux through the polymer coating. (http://www.smartnitrogen.com/environmentally-smart-nitrogen-fertilizer-how-the-technology-works.aspx)