Comparison of Nitrogen Use Efficiency Indices for Corn Fertilized with Commercial Urea & Poultry Litter

► **Learn benefits of various nitrogen use efficiency (NUE) indices in dryland corn production. Know how to calculate and compare indices for crops fertilized using urea and broiler litter.**

Nitrogen (N) is the most limiting plant nutrient in the soil. It must be supplied externally through synthetic fertilizers or manure to achieve an optimum agronomic yield.

Soil N retention is usually low in agricultural systems. Applied nitrogen is either harvested in crop biomass and becomes part of a microbial pool or lost from the cropland via surface runoff, leaching, ammonia volatilization, denitrification, and/or with soil erosion. Despite this low retention, producers must avoid excess N application as it results in economic loss and can negatively impact the environment and human health.

For these reasons, it is crucial for producers to understand the efficiency of the externally applied nitrogen they are using.

Importance of Nitrogen Use Efficiency

Nitrogen use efficiency (NUE) is the efficiency with which plants use applied N. It is also defined as the plant dry mass produced per unit N applied.

Nitrogen use efficiency measurements by agronomists are used to evaluate crop response to applied N under different management scenarios, assess the cropping system's efficiency, and indicate potential N loss to the environment. Calculating NUE helps to optimize N inputs; this results in lower production costs, decreased N losses, and increased agricultural productivity.

Calculating NUE

Several indices are used to calculate agronomic NUE and have different interpretations. These indices generally are calculated by comparing crop yield and aboveground plant N uptake (plant biomass) at physiological maturity in the fertilized versus unfertilized plots. The indices can be compared between years as well as between two different fields to judge the efficiency of N application. Table 1 summarizes commonly used agronomic indices for determining NUE.

Example

Corn yield in an N fertilized plot was 200 bushels per acre^{-1} or 11,200 lb. per acre^{-1} (1 bushel of corn = 56 lb.).

Corn yield in an unfertilized plot was 90 bushels per acre^{-1} or 5,040 lb. per acre^{-1}.

Amount of N applied via fertilizer was 180 lb. per acre^{-1}.

Aboveground plant N uptake in an N fertilized plot was 120 lb. per acre^{-1}.

Aboveground plant N uptake in an unfertilized plot was 50 lb. per acre^{-1}.

Calculating Various NUE Indices

1. Partial factor productivity (PFP) = 11,200/180 = 62 lb./lb. or 1.1 bu./lb.

2. Agronomic efficiency (AE) = (11,200 - 5,040)/180 = 34 lb./lb. or 0.60 bu./lb.

3. Apparent recovery efficiency (RE) = (120 - 50)/180 = 0.39 or 39%

4. Physiological efficiency (PE) = (11,200 - 5,040)/(120 - 50) = 6,160/70 = 88 lb./lb. or 1.6 bu./lb.

Table 1. Common Agronomic N Use Efficiency Indices

Index	Calculation*	Interpretation
Partial factor productivity (PFP)	PFP = Y/F	The combined contribution of soil N and fertilizer N to crop yield.
Agronomic efficiency (AE)	AE = $(Y - Y_0)/F$	The contribution of fertilizer N alone to crop yield.
Apparent recovery efficiency (RE)	RE = $(U - U_0)/F$	Percentage of fertilizer N taken up by the crop
Physiological efficiency (PE)	PE = $(Y - Y_0)/(U - U_0)$	Yield increase per unit of fertilizer N uptake by crop

*$\mathbf{Y}$ = crop yield (lb. per acre^{-1}) in an N fertilized plot; $\mathbf{F}$ = amount of N applied (lb. per acre^{-1}); $\mathbf{Y_0}$ = crop yield (lb. per acre^{-1}) in an unfertilized plot; $\mathbf{U}$ = aboveground plant N uptake at maturity (lb. per acre^{-1}) in an N fertilized plot; $\mathbf{U_0}$ = aboveground plant N uptake at maturity (lb. per acre^{-1}) in an unfertilized plot

Comparison of Corn NUE Fertilized with Broiler Litter & Commercial Urea

Crops NUE varies due to several factors. It can be improved by applying the right source at the right rate of N at the right time.

Referring to a 2019 study conducted at the Tennessee Valley Research and Extension Center (TVREC), we compared various NUE indices between corn fertilized with broiler litter and commercial fertilizer urea (table 2).

The corn was fertilized with either broiler litter or urea at N rates of 150 and 300 lb. per acre^{-1}. The broiler litter or urea was applied in a single application at planting (treatments 1, 2, 5, and 6 in table 2) or applied as a split application, where 25 percent N was applied at planting and the remaining 75 percent at the V6 (sixth leaf with collar visible) growth stage (treatments 3, 4, 7, and 8 in table 2).

Two additional treatments were also studied. Treatment 9 consisted of 1.25 tons of broiler litter per acre (75 units of N) applied 1 week prior to planting, followed by urea application with 75 units of N at the V6 growth stage. Treatment 10 consisted of 2.5 tons of broiler litter per acre (150 units of N) applied 1 week prior to planting, followed by urea application with 150 units of N at the V6 growth stage. A nonfertilized control also was included in the study for a total of 11 treatments. Table 2 provides treatment-wise NUE indices measured in the study.

Table 2. Comparison of Agronomic N Use Efficiency Indices for Urea & Broiler Litter Treatments

Treatment[1] (Source/Rate/Time)	PFP[2]	AE[3]	RE[4]	PE[5]
1. Urea/150/Single	46	20	0.40	50
2. Urea/300/Single	23	10	0.42	24
3. Urea/150/Split	52	25	0.28	89
4. Urea/300/Split	31	18	0.31	56
5. BL[6]/150/Single	41	15	0.30	50
6. BL/300/Single	25	11	0.22	53
7. BL/150/Split	31	5	0.21	24
8. BL/300/Split	20	7	0.14	48
9. BL + Urea/150/Split	48	22	0.24	90
10. BL + Urea/300/Split	29	16	0.32	49

[1] Rate: lb. N per acre^{-1}; time: single (100% N rate at planting) and split application (25% N rate at planting + 75% N rate at V6 growth stage)
[2] PFP: partial factor productivity
[3] AE: agronomic efficiency
[4] RE: apparent recovery efficiency
[5] PE: physiological efficiency
[6] BL: broiler litter

Variability in estimates of NUE indices was observed among treatments. For urea treatments (treatments 1 through 4), treatment 3 (150 lb. of N per acre applied in a split application) had the greatest PFP, AE, and PE. For broiler litter treatments (treatments 4 through 8), treatment 5 (150 lb. of N per acre applied in a single application) had the greatest PFP, AE, and RE.

The partial factor productivity index decreased with a greater N rate irrespective of the N source. In general, crop yield and plant N removal increases with increasing N input, reaching a plateau, and crop yield becomes unresponsive to further N additions while N losses increases rapidly.

Applied N increased corn yield up to 25 lb. per lb. N, or 0.45 bushel per unit N, compared to no N control plots (the highest AE in table 2). The RE indicates how much of the applied N ended up in crop plants, with the remaining subjected to potential N losses in the environment.

The highest RE of 0.42 in table 2 suggests an N uptake of 42 percent of the applied N. The remaining 58 percent portion was not harvested by crop biomass and may get retained in soil into various inorganic (nitrate and ammonium) and organic (soil organic matter and microbial biomass) N pools or potentially lost to the environment.

Low AE and RE in the study suggested high soil inorganic N or mineralizable N supply, which contributed substantially to corn yield and N uptake. In such scenarios, native soil N supply may adequately meet plant demand and obtain optimum yields with little to no fertilizer applications. However, this N pool may deplete over the long term and not sustain favorable crop yields, thus necessitating additional N.

Physiological efficiency indicates how a plant uses the absorbed N to produce grain, which is related to cultivar type. The variability observed in PE from 24 to 89 lb. grain lb.$^{-1}$ of absorbed N in the same cultivar suggested that the PE can be significantly influenced by genotype × crop management × environmental interactions.

Summary

Estimating NUE indices for individual fields is helpful for growers but requires establishing control plots (zero-nitrogen application). It is important to use different NUE indices simultaneously when evaluating any N management practice on the farm.

The PFP, AE, and PE of applied N in the study indicated that split application of urea or a single application of broiler litter at a rate of 150 lb. N per acre^{-1} (2.5 tons of broiler litter) was the most efficient N management practice for dryland corn production. The crop N removal was only 28 percent
(42 of 150 lb. N applied per acre^{-1}) for split urea application and 30 percent (45 of 150 lb. N applied per acre^{-1}) for single broiler litter application. This observation suggests that both N sources are equally good when applied to meet 150 lb. N per acre^{-1} for dryland corn in the TVREC region.

References

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