In-Season Decision Support Tools for Estimating Sidedress Nitrogen Rates for Corn

By Bee Khim Chim, Paul Davis, Tyler Black, and Wade Thomason

Four different in-season N rate decision support tools were equally effective in generating yield, but differences in N use efficiency were detected.
The Virginia Corn Algorithm (VCA) approach appeared best able to prescribe best fit, sidedress N rates under varying preplant N supply options.
The ability to provide a seasonally adjusted sidedress N rate reduces the emphasis on preplant N rates to allow a better match with crop demand and improved N use efficiency.

Nitrogen is frequently the most limiting factor in cereal crop production and 115 million metric t of nitrogenous fertilizers are applied annually to support crop production (FAO, 2015). Fertilizer nitrogen use efficiency (NUE), is estimated to be 33% and 42% for global cereal and U.S. corn production, respectively (Raun and Johnson, 1999). Improving N fertilizer management necessitates the application of the right amount of N using the right source at the right timing, in the right place (Bruulsema et al., 2009). While determining the best approach for any of these factors is complicated, rate is perhaps the most difficult due to the complexities of the N cycle.

There are many tools to assist in the determination of optimum corn sidedress N rate; however, those that can be used in real time do not require extensive sampling and should be inexpensive. Experiments that evaluated four strategies for in-season rate determination were conducted in New Kent, Virginia Beach, Lottsburg, and Blacksburg, Virginia from 2012-14. Experiments had 16 treatments using four different pre-plant N rates (0, 40, 80, 120 lb/A) applied as urea (46% N) that were combined with sidedress rates prescribed by: 1) the Virginia Corn Algorithm (VCA), 2) the Maize-N® simulation model, 3) the Nutrient Expert® for Hybrid Maize (NE-Maize) simulation model, and 4) the standard yield-goal based rate. Fertilizer source for all sidedress applications was liquid urea ammonium nitrate-UAN (30% N). An indicator used to compare nutrient use efficiency in crop production called Partial Factor Productivity (PFP) was calculated by dividing the grain mass (lb/A) by the total N applied (lb/A).

Decision Support Tools

The standard rate was determined based on guidelines in the Virginia Nutrient Management Standards and Criteria (Virginia DCR, 2014). Yield estimates were based on the soil productivity assigned to the dominant soil series for each site. Nitrogen rate recommendations are based on prescribing 1 lb N/bu of expected grain yield and subtracting the appropriate amount of pre-plant fertilizer applied, if any.

The Maize-N simulation model is a subunit of the Hybrid-Maize® simulation model. It relies on a database of rate-to-response studies paired with historic climate data to develop N rate estimates. The program predicts corn yield potential, estimates recovery efficiency of applied N fertilizers, and estimates the economically optimal N rate (EONR) of fertilizer for the current corn crop (Yang et al., 2006). The Hybrid-Maize model was used because the user may edit almost all parameters relevant to model output allowing for local calibration, it is relatively simple to use, and it has been validated in multiple environments.

Sidedress application of liquid urea ammonium nitrate (UAN) application across plots receiving different amounts of preplant N.

The NE-Maize model is a nutrient decision support software that uses the principles of site-specific nutrient management (SSNM) and allows development of field-specific fertilizer recommendations. Nutrient Expert incorporates the most important factors affecting nutrient management recommendations using a systematic approach. The algorithm for calculating fertilizer requirements in NE-Maize is determined from on-farm trial data using SSNM guidelines (IPNI, 2016).

The VCA utilizes a deterministic approach to estimate N needs, based on the previous rate to response studies where NDVI data were collected at sidedress time, in addition to yield response. Rate estimates are determined from the difference in NDVI between the 120 lb N/A and 0 N reference plots at sidedressing time divided by the days from seeding to estimate the current plant N uptake and the potential N response index (Thomason, 2011).

Abbreviations and notes: N = nitrogen; NDVI = normalized difference vegetation index.

Table 1. Corn grain yield and realistic expected yield at each experimental location, 2012-2014.

Year	Site	Grain yield, bu/A	Realistic expected yield, bu/A†
2012	New Kent	116	150
2013	New Kent	163	180
	Virginia Beach	164	170
	Blacksburg	92	150
2014	New Kent	184	180
	Lottsburg	147	150
	Blacksburg	123	150

† Virginia Department of Conservation and Recreation, 2014.

Grain Yield and Sidedress N Rate

Average grain yield over all locations was 141 bu/A, which is slightly greater than the statewide average yield in Virginia (134 bu/A) over the same period of time. Yields ranged from 92 to 184 bu/A at the various sites (**Table 1**) mostly due to variation in rainfall. Grain yields were similar among in-season N recommendation systems over the various preplant rates at all sites. This is likely because all approaches provided N at agronomically appropriate or higher rates.

Sidedress N rate recommendations were affected by recommendation system, pre-plant N rates, and the interaction at all locations (**Table 2**). All systems recommended decreasing sidedress rates with increasing preplant N application rates, however, not all systems accounted for the preplant application in the same manner as the decrezase was not uniform. The lowest recommended rates were prescribed by the VCA and the highest by NE-Maize (**Table 2**). Models developed in other ecoregions may not adequately assess the severity of acute moisture stress that often occurs in these sandy soils with low water holding capacity, resulting in an overestimate of N need. In contrast with the other systems, utilization of in-season canopy sensors with the VCA may allow more accurate estimatation of temporal N need.

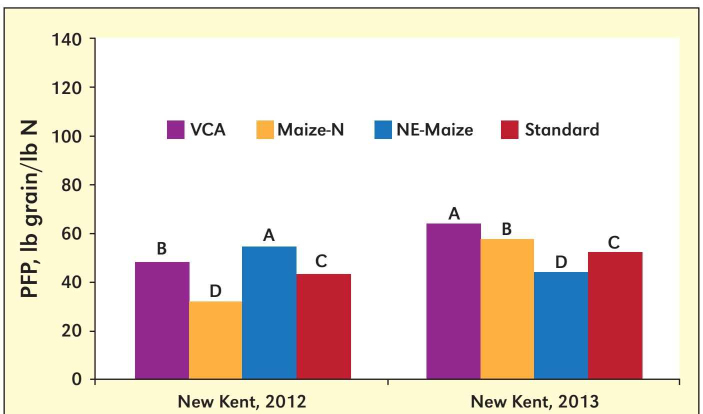

Figure 1. Partial factor productivity (PFP) of N for four in-season N sidedress recommendations systems at New Kent, 2012 and 2013. Means for a given location labeled with the same letter are not significantly different at $p = 0.05$. VCA = Virginia Corn Algorithm; Maize-N = Subunit of the Hybrid-Maize® simulation model; NE-Maize = Nutrient Expert® for Hybrid Maize simulation model; Standard = yield-goal based rate.

Table 2. Preplant N rates and sidedress N rates prescribed by four in-season strategies, 2012-2014.

Year	Location	Preplant N rate	VCA	Maize-N	NE-Maize	Standard
		- - - - - - -	- - - -	lb/A	- - - -	- - - - - - -
2012	New Kent	0	122	198	116	150
		40	70	155	82	110
		80	55	120	48	70
		120	40	82	16	30
2013	New Kent	0	130	150	200	180
		40	100	110	170	140
		80	70	70	130	100
		120	30	30	100	60
2013	Virginia Beach	0	100	150	180	170
		40	60	100	150	130
		80	30	70	120	90
		120	0	30	80	50
2013	Blacksburg	0	100	70	170	150
		40	70	30	129	110
		80	30	0	89	70
		120	0	0	49	30
2014	New Kent	0	90	170	150	180
		40	50	100	90	140
		80	0	40	70	100
		120	0	0	30	60
2014	Lottsburg	0	120	210	170	150
		40	100	150	130	110
		80	50	80	90	70
		120	15	20	50	30
2014	Blacksburg	0	100	120	170	150
		40	60	90	130	110
		80	20	70	90	70
		120	0	50	50	30
Source		- - - - - - -	- - - -	Pr > f	- - - -	- - - - - - -
System		***	***	***	***	***
Preplant N		***	***	***	***	***
System*PreN		***	***	***	***	***

***significant at $p = 0.01$. VCA = Virginia Corn Algorithm; Maize-N = Subunit of the Hybrid-Maize® simulation model; NE-Maize = Nutrient Expert® for Hybrid Maize simulation model; Standard = standard yield-goal based rate.

Partial Factor Productivity of Nitrogen

The effect of sidedress recommendation system on PFP of N was only significant at New Kent in 2012 and 2013. At New Kent in 2012, the highest PFP (averaged over N rates) occurred with the NE-Maize (55 lb grain/lb N applied), while in 2013 the VCA had the greatest PFP (64 lb grain/lb N) (**Figure 1**). Rainfall totals and grain yield were lower in 2012 and the NE-Maize model more accurately predicted N need under these conditions.

Sidedress N rate recommendations were affected by preplant N at all other sites. There were significant differences

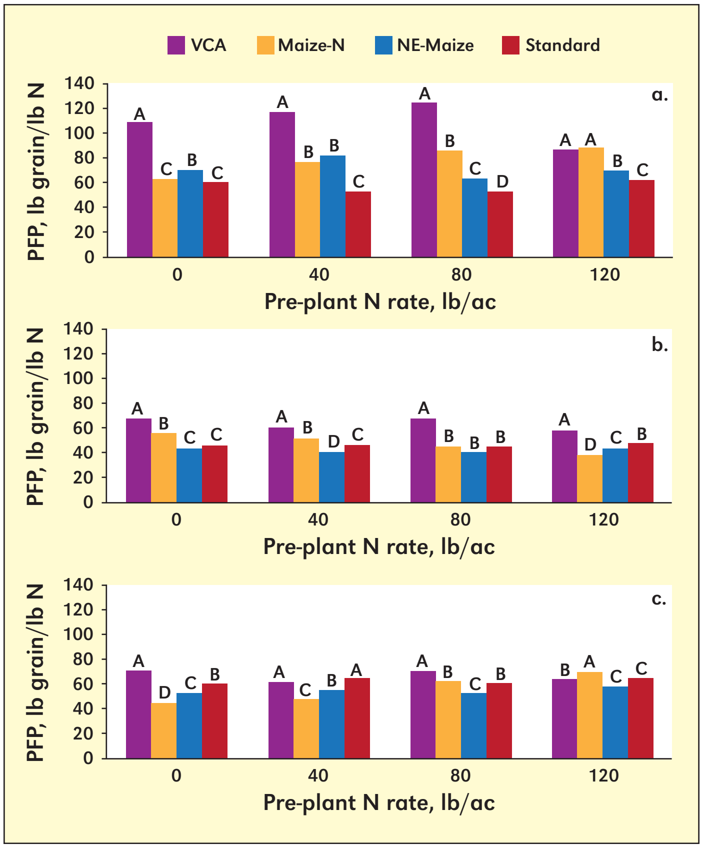

Figure 2. Partial factor productivity (PFP) of N for four in-season N sidedress recommendations systems at four preplant N rates at New Kent (a), Blacksburg (b), and Lottsburg (c), 2014. Columns labeled with the same letter within a preplant rate are not significantly different at $p = 0.05$. VCA = Virginia Corn Algorithm; Maize-N = Subunit of the Hybrid-Maize® simulation model; NE-Maize = Nutrient Expert® for Hybrid Maize simulation model; Standard = yield-goal based rate.

in PFP among systems at Blacksburg in 2013 when 0, 40, and 80 lb N/A was applied but not 120 lb N/A. The highest PFP at Blacksburg and Virginia Beach in 2013 was associated with the rates prescribed by Maize-N and the VCA, respectively. Similar to what happened in New Kent in 2012, yields in Blacksburg in 2013 were limited by lack of late-season rainfall, but the Blacksburg site was a silt loam soil and the Maize-N model was likely more capable of estimating N need under these combined conditions.

In 2014 at New Kent, the highest PFP was observed with use of the VCA at 0, 40, and 80 lb/A preplant N rates and was equal to Maize-N at the 120 lb/A preplant rate (**Figure 2a**). At Blacksburg, the greatest PFP was similarly associated with use of the VCA, but overall, PFP for the VCA at this site was less (64 lb grain/lb N) than at New Kent (**Figure 2b**). No approach consistently produced the highest PFP at Lottsburg in 2014 (**Figure 2c**), but PFP was highest at 59 lb grain/lb N for the VCA, overall. While the performance of the various sidedress N recommendations varied among sites, PFP for the VCA approach was greatest in four of seven locations and averaged 68 lb grain/lb N.

Corn plot harvest near New Kent, Virginia.

Summary

Yields were similar among systems at all sites, indicating that all approaches provided adequate N to support the measured yield. There were significant differences in sidedress rates prescribed among systems. At four of seven locations, sidedress rates prescribed by the VCA were significantly less than the other systems, especially at lower preplant N rates. Overall, PFP declined with increasing preplant N rate, regardless of in-season N recommendation system. This is not surprising since in-season applications typically better match N supply with crop demand, resulting in increased NUE. The greatest PFP usually resulted from implementing the in-season N rate recommendations generated from the VCA approach (four of seven locations), though the Maize-N model also shows promise in this environment. Growers should consider new techniques that utilize current season data, such as the VCA, to refine sidedress N rates. BC

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