Nitrogen: Better placement & timing for environmental and economic sustainability

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Nitrogen is a leading cause of eutrophication of coastal waters (Howarth & Marino, 2006), and its use in agricultural production has recently garnered much attention because of the Des Moines Water Works' allegations of elevated nitrate levels in drinking water due to agricultural applications of nitrogen in upstream watersheds (Meinch, 2015). However, nitrogen is also a critically important input for modern agricultural production. Therefore it is unsurprising that the (over)use of nitrogen is agricultural production is one of the most hotly debated topics in the world of agriculture today among its myriad stakeholders, which would include scholars, agricultural producers themselves, and the general public. Two of the most problematic agricultural practices related to nitrogen management are also two relatively easily resolvable issues: placement of nitrogen relative to the target crop, and timing of application. In the following paper I detail the issues associated with nitrogen placement and timing and propose a possible solution that is fruitful for further investigation and that I believe merits both the attention and funding from INFEWS.

Corn plants (*Zea mays* L.) take up nitrogen in both the ammonium and the nitrate forms (Schortemeyer, Feil, & Stamp, 1993); however, research indicates that the assimilation of nitrate nitrogen requires plants to expend more energy than the assimilation of ammonium nitrogen (Raven, 1985). Additionally, research suggests that supplying plants with nitrogen as a combination of roughly equal parts ammonium and nitrate increases root and shoot dry matter, total root length, root surface area, ammonium and nitrate uptake and concentration of nitrogen in the shoots (Schortemeyer, et al., 1993; Schrader, Domska, Jung, & Peterson, 1972). These, in turn, can increase yield. However, these benefits can only be realized if both the ammonium and the nitrate forms of N are evenly distributed in the soil (Schortemeyer, et al., 1993). Achieving an even distribution of these nitrogen forms in the soil in general, and more specifically in the root zone, is difficult given the immobility of ammonium nitrogen, particularly when the nitrogen is placed in-between rows, as is currently one of the most common placement practices (Cameron & Haynes, 1986; Obcema, De Datta, & Broadbent, 1983).

One possible means of placing a combination source of both nitrate and ammonium (i.e., UAN) closer to the plant is the 360 Y-Drop™ from 360 Yield Center™. The Y-Drop™ places nitrogen fertilizer within 4” of the base of the plant (pictured Left). Research has shown that placing nitrogen fertilizer near the base of the plant can dramatically increase yields, while simultaneously affording the farmer the opportunity to reduce rates (see Figure 1, which has been adapted from Vossenkemper, 2010)

Note that in Figure 1, 40 lbs of nitrogen preplant + 80 lbs (i.e., 120 lbs total N) topdressed in the 0-4" zone away from the row dramatically out yielded 40 lbs preplant + 120 lbs topdressed 12" from the row (i.e., 160 lbs total N). One plausible explanation for these results is that corn plants may take up as much as 63% of their N from a radius 7" or less (Hodgen, Ferguson, Shanahan, & Schepers, 2009). The same research found that corn plants acquired only 5-13% of N that was placed 15" away from the row. As such, it is unsurprising that researchers have recommended row by row N application (Edmonds, 2006; Ghaffarzadeh, Préchac, Cruse, & Harbur, 1998).

Figure 1: Yields as affected by N rate and N placement (2008)

Pre-Plant N	Sidedress N rate (lbs)	Distance from row	Yield*	lbs N/ bushel
40	80	0	147.63	.81
40	80	4"	154.96	.77
40	80	8"	142.26	.84
40	80	12"	126.99	.94
40	120	0	169.90	.94
40	120	4"	156.34	1.02
40	120	8"	127.38	1.26
40	120	12"	122.03	1.31

*Yield converted from kg/ha^{-1} with the following formula: (kg/ha^{-1} *.016)

Placing nitrogen fertilizer near the base of the growing corn plant also helps to ensure that the applied N is utilized by the corn plant as opposed to promoting weed growth. Nitrogen that is applied in the middle of the row is more readily available to weeds (Reddy & Reddy, 1993). Many weeds consume large quantities of nitrogen and thus limit its availability to crops (Blackshaw & Brandt, 2008). Banding N near the row may help suppress weeds by increasing crop uptake and thus giving the crop a competitive advantage over the weeds (Blackshaw, Semach, & Janzen, 2002).

Another benefit of the Y-Drop™ system on a high clearance sprayer is that it allows growers to apply the bulk of their nitrogen much later in the growing season, closer to when the majority of N uptake by the corn plant actually occurs. **Much like the efficiency gained through better placement, the possibility exists that growers may be able to substantially reduce their N rates when they apply nitrogen closer to the time of major plant uptake, saving money and minimizing environmental impact associated with N loss.**

Although growers may be understandably hesitant to dramatically reduce their nitrogen inputs, research has shown as little as 3% yield decrease by waiting until V11 to apply *any nitrogen whatsoever* (Scharf, Wiebold, & Lory, 2002). While I am *not* advocating that growers wait until V11 to apply any nitrogen, I *do* believe that growers will benefit both economically and environmentally from split-applying their nitrogen through the Y-Drop™ system such that the majority of their nitrogen be applied not prior to V10.

For this reason I believe that the **NSF should promote and fund a research initiative in which farmers and scholars combine better placement (i.e., using the 360 Y-Drop™) and better timing (i.e., applying N later in the plant's vegetative stages) to test the lower limits of**

nitrogen application to discover the lowest threshold of nitrogen application at which corn can be grown.

This research differs significantly from both previous university work and from the OEM's recommendations (i.e., 360 Yield Center) I believe, in part, because the aforementioned parties have been reticent to suggest such research out of fear that the participating farmers would necessarily run out of nitrogen and consequently suffer yield loss. Previously, university researchers have recommended nitrogen application rates of 1.2 lbs of nitrogen be applied per bushel expected to be produced. However, I believe that on nearly every soil type in which the slope of the terrain is not a barrier to application, we should be able to produce a bushel of corn on 0.5 lbs of applied nitrogen. In order to prove this to the agricultural community we need the financial assurance that yield loss suffered en route to gathering this evidence be offset with funding and/or financial incentives. Ultimately, I believe that running replicated, randomized split-blocks designs and following a protocol similar to that of Scharf et al. (2002), could help usher in a new era of nitrogen management – one that is more environmentally and economically sustainable.

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