Using Deep Profile, Residual Nitrogen for Corn Production

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Introduction

Corn is widely rotated with cotton annually on approximately one million hectares in Texas and is the most important crop grown for feed and bio-fuel feedstock in the United States. Improving management of nitrogen (N) fertilizer for corn production is necessary from both economic and environmental standpoints but the optimum N rate can be elusive (Moebius-Cline et al., 2013). Applied N in corn cropping systems is subject to biological interactions and loss through leaching, runoff, and volatilization. Movement of excess residual NO_3-N out of the plant rooting zone represents an economic loss to producers and has negative implications for water quality (Baker and Johnson, 1981), even after decades of time (Sebilo, et al., 2013).

Previous studies in cotton across all production regions of Texas identified high residual NO_3-N concentrations in soil profiles (Hons et al., 2004). Using 15N-enriched fertilizer, Provin et al. (2007) demonstrated that uptake by cotton plants was effective down to a 106 cm soil depth and fertilizer uptake efficiency increased at greater depths as the growing season progressed. Additional information was needed about how effectively corn grown in Texas could utilize elevated amounts of deep, residual N, particularly that resulting from prolonged drought in a prior season.

Objective

Evaluate the ability of corn to utilize residual soil NO_3-N for contribution to grain yield at 15, 30 and 60 cm soil depths.

Materials & Methods

Studies utilized corn hybrids adapted to growing conditions in the Upper Gulf Coast of Texas and planted on cooperator farms in late February to mid March. Pre-plant soil samples from each study site were collected to a 1.22 m depth in December to February and submitted for routine nutrient analysis. Establishment of N treatments was based on a representative yield goal for the area and analysis of residual NO_3-N in sample cores to 15 (current University approach), 30, and 60 cm depths. Nitrate-N was determined in 1M KCl extract via Cd-Reduction.

Experimental design for each study was a randomized complete block with experimental units replicated five times. Plots were four rows wide with intra-row spacing of 0.97 m and length of 21.3 to 25.9 m.

Liquid urea ammonium nitrate (UAN, 32-0-0) was used in all studies and N treatments were side-dress banded soon after emergence or before planting. All plots received subsurface, side-dress banded P at rates recommended by soil tests.

Percentages of normal monthly rainfall ranged from 40 to 70 across study sites in 2008 and 2009 (Table 1). Contrastingly, seasonal rainfall totals ranged from 92 to 151 percent of the long-term average across study sites in 2010 and 2012. Corn experienced extremely-dry growing conditions in 2011 with seasonal rainfall ranging from 16 to 35 percent of normal.

Table 1. Monthly rainfall accumulation during the corn growing season near study sites in the Upper Gulf Coast of Texas. 2008-2012.

Site-Year	Cumulative Precipitation						
	February	March	April	May	June	July	Total
	---mm---						
Colorado 2008[†]	65[‡] (72[§])	52 (74)	48 (91)	6 (146)	15 (128)	111 (67)	297 (578)
Wharton 2009	14 (68)	57 (72)	173 (67)	22 (129)	26 (123)	38 (85)	330 (544)
Colorado 2009	49 (72)	106 (74)	209 (91)	2 (146)	23 (128)	18 (67)	407 (578)
Calhoun 2009	7 (64)	66 (70)	37 (73)	70 (115)	11 (119)	18 (86)	209 (527)
Calhoun 2010	99 (64)	43 (70)	21 (73)	19 (115)	129 (119)	187 (86)	498 (527)
Colorado 2010	68 (72)	57 (74)	37 (91)	189 (146)	85 (128)	255 (67)	691 (578)
Victoria 2010	86 (52)	41 (57)	129 (75)	120 (130)	156 (126)	247 (74)	779 (514)
Wharton 2010	64 (68)	43 (72)	14 (67)	93 (129)	69 (123)	219 (85)	502 (544)
Calhoun 2011	10 (64)	14 (70)	1 (73)	24 (115)	32 (119)	4 (86)	85 (527)
Colorado 2011	12 (72)	10 (74)	1 (91)	17 (146)	89 (128)	59 (67)	188 (578)
Victoria 2011	7 (52)	6 (57)	0 (75)	36 (130)	25 (126)	7 (74)	81 (514)
Wharton 2011	16 (68)	3 (72)	0 (67)	0 (129)	82 (123)	88 (85)	189 (544)
Victoria 2012	81 (52)	108 (57)	37 (75)	60 (130)	40 (126)	201 (74)	527 (514)

[†]Study received approximately 51 mm irrigation in late July followed by the same watering during mid-August 2008.
[‡]Source: Crop Weather Program – cwp.tamu.edu
§Represents 30-year average rainfall, 1961-1990, U.S. Climate Data – usclimatedata.com

Depending on the site-year, corn grain yield was determined by hand harvesting 3.05 m or machine harvesting the entire plot length (25.9 m) from each of two center rows per plot. Statistical significance of main effects was determined by analysis of variance using SAS Proc Mixed and means separated with t-tests according to the PDIFF option within LS Means statements.

Results & Discussion

Cumulative amounts of residual soil NO_3-N ranged from 23 to 114 kg/ha across study environments in the Upper Gulf Coast of Texas (Table 2). Based on seasonal surveys of local fertilizer pricing, residual soil NO_3-N to 61 cm was worth from 30 to 189 dollars/ha across study sites. In six out of 13 study locations, the greatest amounts of residual NO_3-N was measured within the 30 to 61 cm soil depth. Based on this observation, we surmise that there had been downward movement of N from applied N fertilizer in previous seasons, a nutrient resource that could potentially support corn production in the current season.

Table 2. Mean amounts and value of pre-plant, residual NO_3-N at incremental soil depths and site-years for studies in the Upper Gulf Coast of Texas. 2008-2012.

Site-Year	Cumulative Amount and Value of Residual Soil NO_3-N				
	0 to 15 cm	15 to 30 cm	30 to 61 cm	0 to 61 cm	Value[†]
	---kg N/ha---				$/ha
Colorado 2008[†]	6.7	17.9	17.9	42.5	47
Wharton 2009[§]	28.0	22.4	31.4	81.8	90
Colorado 2009	26.9	16.8	22.4	66.1	73
Calhoun 2009	29.1	20.2	26.9	76.2	84
Calhoun 2010	3.4	20.1	71.7	95.2	92
Colorado 2010	28.0	21.3	29.1	78.4	76
Victoria 2010	3.4	7.8	24.7	35.9	37
Wharton 2010	12.3	5.6	29.1	47.0	45
Calhoun 2011	10.1	14.9	22.4	47.4	63
Colorado 2011	7.8	29.1	24.7	61.6	85
Victoria 2011	6.7	7.8	9.0	23.5	30
Wharton 2011	6.7	11.2	13.5	31.4	43
Victoria 2012	31.6	49.3	33.6	114.5	189

[†]Based on surveys of retail fertilizer pricing for that year and location.

The site-year by rate of applied N interaction for grain yield of corn was highly significant (Table 3).

Table 3. Type 3 tests of main effects related to corn yield and crediting nitrogen fertilizer rates according to pre-plant, residual NO_3 at incremental soil depths along the Upper Gulf Coast of Texas. 2008-2012.

Type 3 Tests of Main Effects for Corn Yield				
Effect	Num DF	Den DF	F Value	Pr > F
Site-year	12	48	50.3	0.0001
N Rate	4	177	51.2	0.0001
Site-year X N Rate	42	177	7.6	0.0001

Corn grain yield responded to addition of N fertilizer in 5 of 13 site-years (Table 4). Compared to corn that received crop goal amounts of N fertilizer, yield of corn in plots with reduced rates of N based on soil test NO_3-N to 61 cm or shallower depth was statistically the same in each of 13 site-years. These findings were similar to results from studies conducted primarily in the Central Blackland region of Texas (Coker et al., 2008).

Table 4. Effect of crediting nitrogen fertilizer rate according to pre-plant, residual NO_3 at incremental soil depths on corn yield throughout the Upper Gulf Coast of Texas. 2008-2012.

Site-Year	Grain Yield				
	According to Crop Goal	Soil NO_3-N to 15 cm	Soil NO_3-N to 30 cm	Soil NO_3-N to 61 cm	Control[†]
	---kg/ha---				
Colorado 2008[‡]	8077 a[§]	8151 a	7679 a	7920 a	5221 b
Wharton 2009	3658	3171	3269	3096	2771
Colorado 2009	4487	4917	4244	4156	4399
Calhoun 2009	4042	4035	4428	4762	4232
Calhoun 2010	7912	-[¶]	7732	7688	7183
Colorado 2010	9579 a	10205 a	9272 a	10203 a	8028 b
Victoria 2010	8926 a	-	9039 a	8494 a	4264 b
Wharton 2010	8965 a	8658 a	-	8994 a	4787 b
Calhoun 2011	7264 a	7525 a	7414 a	7641 a	5935 b
Colorado 2011	6177	-	6811	6382	6785
Victoria 2011	6046	-	6338	5809	6164
Wharton 2011	4791	-	4760	4819	4157
Victoria 2012	6755	6961	6040	6690	6321

[†]No additional nitrogen added.
[‡]Study received approximately 5.1 cm irrigation in late July followed by the same watering during mid-August 2008.
[§]Within rows, means followed by different letters were significantly different according to the ANOVA F Test and Differences of Least Squares Means *t* test (P≤0.05).
[¶]Amount of residual N at interval soil depth was not sufficient to establish a treatment.

Site-year by rate of applied N interaction for grain test weight of corn was highly significant (Table 5).

Table 5. Type 3 tests of main effects related to test weight of corn and crediting nitrogen fertilizer rates according to pre-plant, residual NO_3-N at incremental soil depths along the Upper Gulf Coast of Texas. 2008-2012.

Type 3 Tests of Main Effects				
Effect	Num DF	Den DF	F Value	Pr > F
Site-year	12	47	40.1	0.0001
Treatment	4	179	3.9	0.0045
Site-year X Treatment	42	179	2.7	0.0001

For all site-years, corn test weights from plots with N fertilizer rates reduced according to residual NO_3-N to 61 cm were not different from those where N fertilizer was applied according to crop goal (Table 6). Excepting Wharton 2009, grain test weights in control plots were not different or statistically lower compared to plots that received N fertilizer.

Table 6. Effect of crediting nitrogen fertilizer rate according to pre-plant, residual NO_3 at incremental soil depths on corn test weight. South-Central and Central Texas. 2008.

Site-Year	Grain Test Weights				
	According to Crop Goal	Soil NO_3-N to 15 cm	Soil NO_3-N to 30 cm	Soil NO_3-N to 60 cm	Control[†]
	---kg/m³---				
Colorado 2008[‡]	775 a[§]	781 a	775 a	770 a	730 b
Wharton 2009[§]	675 b	685 ab	688 a	685 ab	696 a
Colorado 2009	680	713	680	698	687
Calhoun 2009	744	739	765	732	773
Calhoun 2010	768	-[¶]	766	772	765
Colorado 2010	739	740	740	739	737
Victoria 2010	745 a	-	745 a	741 a	688 b
Wharton 2010	730 a	725 a	-	730 a	704 b
Calhoun 2011	716	718	711	714	705
Colorado 2011	656	-	671	672	671
Victoria 2011	725	-	755	739	716
Wharton 2011	673	-	676	673	678
Victoria 2012	685	686	679	688	689

[†]No additional nitrogen added.
[‡]Study received approximately 5.1 cm irrigation in late July followed by the same watering during mid-August 2008.
[§]Within rows, means followed by different letters were significantly different according to the ANOVA F Test and Differences of Least Squares Means *t* test (P≤0.05).
[¶]Amount of residual N at interval soil depth was not sufficient to establish a treatment.

Summary

- ✓Reducing N fertilizer applications for corn based on residual soil NO_3-N to 15, 30 or 60 cm had no effect on grain yield and little effect on test weight across 13 environments with highly-variable rainfall.
- ✓Crediting N fertilizer could save an estimated average of $14.70/ha for corn production in Texas and has been adopted on 94,497 ha of cropland thus far for an estimated $25 million reduction in the cost of fertilizer.
- ✓Improved management of deep profile, residual N can improve production economics for corn grown in the Upper Gulf Coast of Texas and minimize potential environmental impacts.

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