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# Can Manure Replace the Need for Starter Nitrogen Fertilizer?

## 3-Year Summary

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## Background

Initial studies at a Western New York State dairy farm showed that for corn fields with a recent manure history, starter nitrogen (N) fertilizer could be eliminated without losing yield or reducing forage quality. Eliminating starter N on corn fields with a manure history has the potential to deliver significant savings of time and money to dairy producers. In 2009, we initiated a 3-yr project to test the need for starter N fertilizer across a range of New York State soil types and growing conditions. The objective of this study was to assess differences in yield and forage quality between corn that receives starter N fertilizer and corn that does not, on fields with varying manure history. Here we report the 3-year summary for sites completed without external challenges (weed control, bird damage, planter issues, harvest challenges, etc.). The final dataset included 22 trials, distributed throughout New York State.

## Materials and Methods

Each trial included four replications or more of two treatments: 30 lbs N/acre in the starter versus no N in the starter. In 2009, seven trials were completed, including three trials at commercial farms and four at the Aurora Research Farm (sites 1 through 7). In 2010, starter N response trials were established at ten commercial farm locations and repeated at the Aurora Research Farm (sites 8–21). In 2011, an additional seven sites were established on commercial farms. Across all trial years, a total of seven trials were lost due to planter issues, excessive moisture interfering with planting and/or harvest, bird or deer damage, weed pressure, excessive variability, or uncertainty about the actual treatment allocation. All other trials (21 sites) are included in this summary.

## Results

Eleven sites had an ISNT-N level classified as "deficient in soil N supply potential" (>7% below the critical value), five sites were "marginal in soil N supply potential" (within 7% of the critical value) while five sites were "optimal in soil N supply potential" (ISNT-N >7% above the critical value).

Across all three years, of the fields with <u>optimal soil N supply potential</u> (sites 19, 20, 21, 23, and 25), the manure application alone was sufficient to meet the N needs of the crop; none of these three locations showed a yield increase with starter N use (Table 1). The CSNTs (Table 2) confirmed N was not limiting yield at these sites, and for two locations (20 and 21) showed sidedress application rates can be reduced if not eliminated. Used in this way, the data suggest that the ISNT can help identify fields that will not benefit from starter or sidedress N.

Of the five sites that were classified by the ISNT as marginal in soil N supply potential, all received manure and only one (site 31) responded to starter N. The CSNTs were classified as optimal (sites 13, 31, and 35) or excess (sites 3 and 14), indicating that the fields received sufficient or more than sufficient N (Table 2). However, the lowest CSNT was measured for the site that had the yield response to starter N, suggesting an adjustment in CSNT interpretation is needed (inclusion of a 250–750 ppm "Marginal" range). We conclude for these five locations that manure application can replace starter and sidedress N for soils with a marginal soil N supply potential, as long as sufficient N is added with the manure. The results of site 31 also suggest that in some years a response to N can be expected where CSNTs are <750 ppm.

The sites classified as deficient in soil N supply potential (i.e., soil N alone is not expected to supply sufficient N for the corn crop that year) included the trials at Aurora with either no manure history (sites 6 and 11), or with limited manure history (sites 4, 5, 7 in 2009, and 9, 10, 12 in 2010) plus three on-farm locations (sites 8, 15, and 16). The results at sites 6 and 11 (significantly higher yields in 2010 with starter N and a similar though not statistically significant trend in 2009) suggest that starter N is needed for fields that do not have an optimal soil N supply as measured by the ISNT and are managed without manure. The results at site 11 also suggest that a response to N can be expected if CSNTs are <750 ppm (high producing year on deficient ISNT soil), consistent with the results of site 31.

Table 1. Stand density, percent moisture, and corn yield as influenced by application of 30 lbs of starter N/acre at planting in 2009 (sites 3–7), 2010 (sites 8–21), and 2011 (sites 23–35). Sites in grey shading showed a significant yield increase with use of starter N.

| Site | Treatment | Density pl/acre | MC % | Corn yield ton/acre | Corn yield bu/acre | Manure history and ISNT** rating |
|---|---|---|---|---|---|---|
| 4 | Starter | 28,579 * | 18.2 a | . | 112 a | ISNT=D. Manure aerator-incorporated in spring at ~8,000 gal/acre (5 yrs). |
| | No Starter | 28,579 * | 17.4 a | . | 109 a | |
| 5 | Starter | 29,513 * | 18.3 a | . | 119 a | ISNT=D. Manure chisel-incorporated in spring at ~8,000 gal/acre (5 yrs). |
| | No Starter | 29,513 * | 17.6 a | . | 105 b | |
| 6 | Starter | 29,394 * | 18.1 a | . | 144 a | ISNT=D. No manure history. Sidedressed. |
| | No Starter | 29,394 * | 19.0 a | . | 126 a | |
| 7 | Starter | 28,885 * | 18.5 a | . | 103 a | ISNT=D. Manure surface applied in spring at ~8,000 gal/acre (5 yrs). |
| | No Starter | 28,885 * | 18.2 a | . | 91 a | |
| 9 | Starter | 27,885 a | 16.6 b | . | 150 a | ISNT=D. Manure aerator-incorporated at ~8,000 gal/acre (6 yrs). |
| | No Starter | 24,640 b | 17.2 a | . | 138 b | |
| 10 | Starter | 29,124 a | 16.6 a | . | 160 a | ISNT=D. Manure chisel-incorporated at ~8,000 gal/acre (6 yrs). |
| | No Starter | 27,863 a | 16.9 a | . | 151 a | |
| 11 | Starter | 27,576 a | 16.9 b | . | 173 a | ISNT=D. No manure history. Sidedressed. |
| | No Starter | 24,107 b | 17.3 a | . | 147 b | |
| 12 | Starter | 27,683 a | 16.7 a | . | 141 a | ISNT=D. Manure surface applied at ~8,000 gal/acre (6 yrs). |
| | No Starter | 26,208 a | 17.0 a | . | 125 b | |
| 8 | Starter | 25,706 a | 67.1 a | 19.2 a | . | ISNT=D. Manure chisel-incorporated at 5,000 gal/acre each spring. |
| | No Starter | 25,626 a | 67.0 a | 20.0 a | . | |

| Site | Treatment | Density pl/acre | MC % | Corn yield ton/acre | Corn yield bu/acre | Manure history and ISNT** rating |
|---|---|---|---|---|---|---|
| 16 | Starter | 29,442 a | 68.3 a | 18.0 a | . | ISNT=D. Manure surface applied 12,000 gal/acre per year. |
| | No Starter | 29,186 a | 67.7 a | 19.1 a | . | |
| 15 | Starter | 37,897 a | 60.1 a | 24.7 a | . | ISNT=D. Manure chisel-incorporated at 4,000 gal/acre 2010; 20 ton/acre before. Sidedressed. |
| | No Starter | 37,571 a | 61.2 a | 24.9 a | . | |
| 13 | Starter | 32,390 a | 65.0 a | 19.1 a | . | ISNT=M. Manure incorporated 4,000 gal/acre in 2008 (1st yr corn); 10,000 gal/acre in 2009. |
| | No Starter | 31,097 a | 65.8 a | 20.0 a | . | |
| 3 | Starter | 25,134 a | 67.3 a | 25.4 a | . | ISNT=M. Manure additions in winter plus 6,000 gal/acre before planting. |
| | No Starter | 25,014 a | 65.6 a | 24.9 a | . | |
| 14 | Starter | 37,952 a | 59.6 a | 21.2 a | . | ISNT=M. Manure surface applied winter and spring at 8,000-9,000 gal/acre. |
| | No Starter | 37,952 a | 57.9 a | 20.6 a | . | |
| 31 | Starter | 31,690 a | 58.5 a | 21.2 a | | ISNT=M. Manure chiseled within 1 d at 6,000 gal/acre (3 yrs). |
| | No Starter | 31.255 a | 58.9 a | 17.2 b | | |
| 35 | Starter | 31,336 a | 59.0 a | 17.5 a | . | ISNT=M. Manure injected at 6,700 gal/acre in October and 7,400 gal/acre in April. Fall+spring application before that. |
| | No Starter | 31,363 a | 59.5 a | 17.0 a | . | |
| 25 | Starter | 33,051 a | 49.4 a | 25.1 a | . | ISNT=O. Manure injected at 11,000 gal/acre in May. |
| | No Starter | 32,997 a | 58.7 a | 24.5 a | . | |
| 23 | Starter | 31,309 b | 65.3 a | 22.8 a | . | ISNT=O. Manure surface applied at 25 ton/acre in January each of past 3 yrs. |
| | No Starter | 32,289 a | 65.9 a | 24.1 a | . | |
| 19 | Starter | 30,492 a | 49.8 a | 30.3 a | . | ISNT=O. Manure injected at 11,400 gal/acre 2010; no manure 2009; 7,400 gal/acre 2008. |
| | No Starter | 30,982 a | 50.1 a | 29.5 a | . | |
| 20 | Starter | 30,546 a | 67.9 a | 20.0 a | . | ISNT=O. Manure chisel-incorporated at 2,000 gal/acre 2009, 2010; surface applied 6,000 gal/acre June/August 2008. Sidedressed. |
| | No Starter | 33,106 a | 66.5 a | 21.1 a | . | |
| 21 | Starter | 31,908 a | 67.9 a | 23.8 a | . | ISNT=O. Manure surface applied at 17 ton/acre December 2009; 16,000 gal/acre 2008; 5 ton/acre 2007. Sidedressed. |
| | No Starter | 31,581 a | 68.9 a | 23.6 a | . | |

*Only one stand density (mean of reps) available for combined starter/no starter at this site, no statistical analysis possible. ** Illinois Soil Nitrogen Test – (D, M, O) indicates the soil N supply was deficient (D, yellow), marginal (M, orange), or optimal (O, green) for corn. MC = moisture content at harvest.

At the other 3 sites at the Aurora Research Farm (4, 5, 7 in 2009; 9, 10, 12 in 2010), liquid manure had been applied at a rate of ~8,000 gallons/year over the past 5/6 years. Manure application increased ISNTs over time (compare values to sites 6 and 11), but after 5 to 6 years of manure application, the ISNT of these sites was still classified as deficient. Of these six site*years, three showed a significant yield increase with starter N addition, while a similar trend was seen for the other three sites (Table 1). These same sites exhibited deficient CSNTs (Table 2), suggesting that the specific manure history was not enough to increase soil N supply to levels high enough to supply the N needed by the crop and that the current year manure applications were also insufficient to meet N needs of the crop. Under these conditions, the starter N application was needed.

Of the remaining three on-farm sites with low soil N supply potential, two sites had CSNTs in the optimal range (without starter). A lack of a yield response to starter N illustrated that for these locations, the current year manure supplied sufficient N and starter N was not needed. The very high CSNT of site 15 (>5000 ppm) suggests a reduction in sidedress N application was possible without an impact on yield or quality.

Table 2. Illinois soil nitrogen test (ISNT) ratio (ISNT/Critical ISNT) and rating (L=low, M=marginal, O=optimal), soil nitrate ($NO_3^-$) (0–8 and 0–12 inch depths), presidedress nitrate test (PSNT), and corn stalk nitrate test (CSNT*) as influenced by starter N fertilizer (0 versus 30 lbs N/acre) in corn trials in 2009 (Sites 3–7), 2010 (Sites 8–21), and 2011 (sites 23–35). Sites in grey shading showed a significant change in N indicators with use of starter N.

| | | | At Sidedress Time | | | At Harvest | | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | ISNT | Treatment | Nitrate-N | PSNT | | Nitrate-N | Nitrate-N | CSNT | |
| | Ratio | | 0–8 inch | 0–12 inch | | 0–8 inch | 0–12 inch | | |
| | | | lbs/acre | ppm | | lbs/acre | ppm | ppm | |
| 4 | 0.91 | Starter | 11 b | 7 a | Deficient | 23 b | 5 a | 94 a | Deficient |
| | L | No Starter | 17 a | 8 a | Deficient | 27 a | 7 a | 90 a | Deficient |
| 5 | 0.90 | Starter | 18 a | 12 a | Deficient | 22 b | 6 a | 94 a | Deficient |
| | L | No Starter | 21 a | 9 a | Deficient | 28 a | 7 a | 105 a | Deficient |
| 6 | 0.88 | Starter | 4 b | 6 a | Deficient | 16 a | 4 a | 160 a | Deficient* |
| | L | No Starter | 11 a | 4 a | Deficient | 18 a | 5 a | 208 a | Deficient* |
| 7 | 0.90 | Starter | 14 a | 9 a | Deficient | 20 a | 5 a | 104 a | Deficient |
| | L | No Starter | 14 a | 7 b | Deficient | 25 a | 6 a | 94 a | Deficient |
| 9 | 0.88 | Starter | 67 a | 28 a | Sufficient | 21 a | 15 a | 182 a | Deficient |
| | L | No Starter | 74 a | 28 a | Sufficient | 20 a | 17 a | 99 a | Deficient |
| 10 | 0.86 | Starter | 63 a | 31 a | Sufficient | 22 a | 18 a | 80 a | Deficient |
| | L | No Starter | 67 a | 26 a | Sufficient | 21 a | 15 a | 89 a | Deficient |
| 11 | 0.82 | Starter | 36 a | 14 a | Deficient | 18 a | 16 a | 827 a | Optimal* |
| | L | No Starter | 36 a | 13 a | Deficient | 18 a | 14 a | 669 a | Marginal* |
| 12 | 0.85 | Starter | 57 a | 24 a | Borderline | 21 a | 15 a | 129 a | Deficient |
| | L | No Starter | 64 a | 25 a | Sufficient | 22 a | 15 a | 83 a | Deficient |
| 8 | 0.84 | Starter | 84 a | 57 a | Sufficient | 13 a | 7 a | 1,661 a | Optimal |
| | L | No Starter | 79 a | 54 a | Sufficient | 10 a | 5 b | 463 b | Marginal |
| 16 | 0.81 | Starter | 66 a | 33 a | Sufficient | 40 a | 33 a | 2,552 a | Excess |
| | L | No Starter | 66 a | 31 a | Sufficient | 31 a | 25 a | 1,174 a | Optimal |
| 15 | 0.81 | Starter | 130 a | 52 a | Sufficient | 158 a | 44 a | 7,838 a | Excess* |
| | L | No Starter | 142 a | 45 a | Sufficient | 131 a | 53 a | 5,938 a | Excess* |
| 13 | 1.01 | Starter | 96 a | 31 a | Sufficient | 20 a | 10 a | 1,225 a | Optimal |
| | M | No Starter | 76 a | 33 a | Sufficient | 24 a | 9 a | 818 a | Optimal |
| 3 | 1.07 | Starter | 60 a | 34 a | Sufficient | 63 a | 27 a | 5,154 a | Excess |
| | M | No Starter | 52 a | 30 a | Sufficient | 47 a | 27 a | 5,017 a | Excess |
| 14 | 1.05 | Starter | 124 a | 55 a | Sufficient | 42 a | 18 a | 10,135 a | Excess |
| | M | No Starter | 117 a | 53 a | Sufficient | 25 b | 11 a | 9,164 a | Excess |

| | | | At Sidedress Time | | | At Harvest | | | |
|---|---|---|---|---|---|---|---|---|---|
| Site | ISNT | Treatment | Nitrate-N | PSNT | | Nitrate-N | Nitrate-N | CSNT | |
| | Ratio | | 0–8 inch | 0–12 inch | | 0–8 inch | 0–12 inch | | |
| | | | lbs/acre | ppm | | lbs/acre | ppm | ppm | |
| 31 | 0.97 | Starter | . | 19 a | Deficient | . | . | 704 a | Marginal |
| | M | No Starter | . | 20 a | Deficient | . | . | 762 a | Optimal |
| 35 | 1.07 | Starter | . | 21 a | Borderline | . | . | 2,129 a | Excess* |
| | M | No Starter | . | 19 a | Deficient | . | . | 1,308 a | Optimal* |
| 25 | 1.17 | Starter | . | 20 a | Deficient | . | . | 2,970 a | Excess* |
| | O | No Starter | . | 21 a | Borderline | . | . | 1,353 b | Optimal* |
| 23 | 1.35 | Starter | . | 48 a | Sufficient | . | . | 3.449 a | Excess |
| | O | No Starter | . | 44 a | Sufficient | . | . | 5,872 a | Excess |
| 19 | 1.10 | Starter | 80 a | 29 a | Sufficient | 30 a | 14 a | 4,817 a | Excess |
| | O | No Starter | 81 a | 33 a | Sufficient | 32 a | 16 a | 4,164 a | Excess |
| 20 | 1.13 | Starter | 54 a | 25 a | Sufficient | 38 a | 16 a | 4,484 a | Excess* |
| | O | No Starter | 57 a | 27 a | Sufficient | 38 a | 16 a | 4,599 a | Excess* |
| 21 | 1.12 | Starter | 42 a | 24 a | Borderline | 67 a | 24 a | 9,326 a | Excess* |
| | O | No Starter | 50 a | 23 a | Borderline | 90 a | 33 a | 10,051 a | Excess* |

*Sidedressed in addition to receiving manure (sites 15, 20, 21, 25, 35) or sidedressed with no manure history (6, 11).
** CSNT interpretation: <250 ppm is deficient; 250-750 ppm is marginal; 750-2000 ppm is optimal; >2000 ppm is excess.

Of the silage trials, two locations showed a significant increase in crude protein with starter N addition (sites 3 and 21) while at one site, crude protein declined with starter N addition (site 25). Soluble protein increased at two locations, although the difference was very small (an increase of 0.3 and 0.1% in soluble protein at sites 3 and 16, respectively) and decreased at one site (site 25). Only one site showed a change in NDF (decrease, site 21). At one site, NDF digestibility increased with starter N addition (site 23) while at two additional sites, NDF decreased with starter N addition (sites 31 and 35). Lignin and starch were not impacted at any of the silage trials. Elimination of starter N did not result in significant differences in milk per acre estimates except for at one site where starter use decreased milk per ton (site 25, results not shown). Milk-per-acre estimates were only impacted at one site (increase at site 31, consistent with the yield increase upon starter N use).

Sites 6 and 11 (the only deficient ISNT sites without a manure history) illustrate that starter N will be needed even if sidedress N is applied. This scenario applies to cash grain operations without manure histories. Under those conditions, the best management practice is to use starter N (20-30 lbs N/acre) and sidedress to meet crop N needs. Omission of starter N is not recommended for fields without a manure history (deficient ISNT-N).

Sites that were classified as sufficient in ISNT-N included sites 19–25 (5 sites). None of these five sites showed a yield response to starter N addition. We conclude that if the ISNT is classified as sufficient, manure can be used to replace starter N.

Manured sites that were sidedressed (sites 15, 20, 21, 25, and 35) all had CSNTs that were optimal or excessive. Starter N use did not increase yield at any of these locations. Optimal or excessive CSNTs at each of these five locations suggest that sidedress N could have been eliminated or application rates reduced at these locations. These results suggest that starter N can be omitted for sites with a manure history even if the ISNT is deficient or marginal, as long as sufficient N from manure and other sources (rotations, soil N, sidedress N) is available.

Table 3. Crude protein, soluble protein, neutral detergent fiber (NDF), digestible NDF (dNDF), lignin, and starch as influenced by 30 lbs/acre of starter N fertilizer. In grey background are sites where starter N increased quality parameters with a P value of 0.05 (95% certainty level).

| Site | Treatment | Crude protein | Soluble protein | NDF | dNDF | Lignin | Starch |
|---|---|---|---|---|---|---|---|
| | | ------------% of dry matter----------- | | | % NDF | ---% of dry matter--- | |
| 8 | Starter | 8.0 a | 1.6 a | 46.4 a | 67.6 a | 3.5 a | 29.3 a |
| | No Starter | 7.9 a | 1.6 a | 43.8 a | 66.5 a | 3.3 a | 31.4 a |
| 16 | Starter | 8.3 a | 2.0 a | 39.3 a | 70.2 a | 2.8 a | 34.5 a |
| | No Starter | 7.8 a | 1.9 b | 37.5 a | 70.2 a | 2.7 a | 37.2 a |
| 15 | Starter | 8.3 a | 2.2 a | 47.0 a | 61.2 a | 3.6 a | 28.7 a |
| | No Starter | 8.3 a | 2.4 a | 46.1 a | 60.6 a | 3.5 a | 30.0 a |
| 13 | Starter | 7.8 a | 1.8 a | 40.5 a | 69.8 a | 2.8 a | 34.6 a |
| | No Starter | 7.9 a | 2.0 a | 39.6 a | 67.3 a | 2.7 a | 35.6 a |
| 3 | Starter | 8.3 a | 2.4 a | 42.2 a | 65.2 a | 3.2 a | 33.6 a |
| | No Starter | 7.3 b | 2.1 b | 42.5 a | 64.1 a | 3.0 a | 34.7 a |
| 14 | Starter | 7.8 a | 2.1 a | 40.0 a | 64.3 a | 3.1 a | 40.4 a |
| | No Starter | 7.7 a | 2.2 a | 41.1 a | 64.7 a | 3.1 a | 38.6 a |
| 31 | Starter | 6.3 a | 1.3 a | 42.6 a | 60.8 a | 3.1 a | 38.0 a |
| | No Starter | 5.8 a | 1.1 a | 44.4 a | 63.2 a | 2.9 a | 36.2 a |
| 35 | Starter | 9.1 a | 2.2 a | 41.4 a | 79.5 b | 2.3 a | 34.9 a |
| | No Starter | 8.9 a | 2.2 a | 41.6 a | 80.6 a | 2.3 a | 34.8 a |
| 25 | Starter | 7.7 a | 1.9 b | 40.1 a | 56.7 a | 3.2 a | 39.8 a |
| | No Starter | 8.0 a | 2.0 a | 38.8 a | 58.2 a | 3.1 a | 40.9 a |
| 23 | Starter | 8.8 a | 2.4 a | 41.3 a | 63.8 a | 3.2 a | 31.7 a |
| | No Starter | 9.0 a | 2.4 a | 41.3 a | 62.5 b | 3.3 a | 31.4 a |
| 19 | Starter | 8.1 a | 1.7 a | 36.4 a | 74.8 a | 2.4 a | 43.6 a |
| | No Starter | 8.1 a | 1.8 a | 34.2 a | 72.1 a | 2.4 a | 46.1 a |
| 20 | Starter | 7.9 a | 2.1 a | 46.1 a | 64.6 a | 3.5 a | 30.8 a |
| | No Starter | 7.6 a | 2.0 a | 46.0 a | 63.1 a | 3.3 a | 31.7 a |
| 21 | Starter | 9.2 a | 2.5 a | 35.9 b | 77.5 a | 2.4 a | 37.9 a |
| | No Starter | 8.9 b | 2.5 a | 39.6 a | 77.0 a | 2.5 a | 34.1 a |

Sites that had a manure history but were classified as deficient in N based on the CSNT included sites 4–5, 7, 9–10 and 12 (6 sites). Of these sites (all Aurora Research Farm sites with some but limited manure application history), sites 5, 9, and 12 showed higher yields when starter N had been applied than where corn was planted without a starter, with similar trends at sites 4, 7, and 10 (all Aurora Research Farm sites). The ISNT for each of these Aurora Research Farm sites was classified as deficient, suggesting additional N was needed. These results indicate a response to starter N is likely if ISNT-N is deficient and additional N applied is insufficient.

The tool available to determine whether or not the overall N addition was sufficient is the CSNT. The yield results of sites 11 and 31 (locations with an average CSNT between 250 and 750 ppm plus a significant yield difference upon use of starter N), suggest that a new interpretation should be added for 2$^{nd}$ or higher year corn: "Marginal" (250–750 ppm), where a response to starter N could be expected in wet years.

## Main Conclusions

- Starter N should be used for fields with no manure history and no current year manure applications (deficient ISNT-N).
- If the ISNT-N is classified as optimal, manure can be used to replace starter N without a yield or quality decline.
- Manure can replace starter N for sites deficient or marginal in ISNT-N as well, but only if sufficient N from manure and other sources (cover crops, soil N, sidedress N) is available (CSNTs between 750 and 2000 ppm); a yield response to starter N would have been likely if the ISNT-N was deficient and additional N applied was insufficient as well.
- A new interpretation should be added for the CSNT for 2$^{nd}$ or higher year corn: "Marginal" (250–750 ppm), where a response to starter N could be expected in some years. To reduce risk, it is recommended that farms strive for CSNTs between 750 and 2000 ppm, using 8-inch stalks taken between 6 and 14 inches above the ground.
- We recommend producers analyze 2$^{nd}$ or higher year corn fields for both ISNT-N and CSNT, to identify sites where a starter N application can be omitted.

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## For Further Information

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