INCREASING ROOT MASS AND YIELD IN CORN THROUGH THE USE OF FERTILIZER ADDITIVES

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INTRODUCTION

Corn growers in the southeastern US have increased corn yield by increasing plant population and the use of starter fertilizer. In 2009, corn yields approaching 400 bu acre^{-1} were recorded in North Carolina with more than 200 growers reporting yields of 225 bu acre^{-1} or more. Research at North Carolina State University has shown that plant populations of 30,000 to 34,000 plants acre^{-1} or greater are needed to achieve maximum yield (unpublished data) and some growers have reported maximizing yield at populations over 45,000 plants acre^{-1}. As plant population increases so does the crop demand for early nutrition. Research has shown that increased plant population leads to poor stalk strength and a reduction in root depth and mass (Heiniger, R.W., K. Gurganus, A. Meijer, and C.R. Crozier. 2005. Impact of Plant Population and Fertility on Corn Yield and Root Volume. *In* 2005. Agronomy Abstracts. ASA, Madison WI). The solution to this problem is the use of starter fertilizer with the proper balance of nitrogen (N), phosphorus (P) and potassium (K). Starter fertilizer can increase root mass and stalk diameter by encouraging early growth. Furthermore, because ear size is critical to the success of high population corn systems, good early growth is essential to obtain maximum ear size and yield. While research has shown positive results from the use of starter fertilizers on early plant growth more work needs to be done to improve the efficiency of these fertilizer materials. In particular, large amounts of N applied at planting are susceptible to leaching or denitrification in wet soils. Likewise, in fields where the pH is high following cotton or tobacco P often is fixed in forms unavailable to the plant.

Several new fertilizer additives have been introduced that have the potential to improve the efficiency of starter fertilizer. Additives such as Avail® and Nutrisphere® use a charged polymer to prevent P from bonding to cations such as Ca or Mg (Avail®) or, in the case of Nutrisphere®, use the charged polymer to bind the urease enzyme. These materials could greatly enhance the efficiency of starter fertilizer applied on corn in the southeast resulting in larger root systems, better stalk strength, improved stress tolerance and increased yield. The objectives of this project were: 1) to examine the impact of the fertilizer additives Avail® and Nutrisphere® on root development, stalk strength, and yield in high population corn systems, and 2) to determine optimum rates of fertilizer using the additives Avail® and Nutrisphere®.

MATERIALS AND METHODS

Sixteen replicated research trails were conducted in 2007, 2008, and 2009 at locations in Pamlico, Pasquotank, Perquimans, Currituck, Guilford, Beaufort, Forsythe, Bertie, Hyde, and

Davidson Counties on wide range of soil types (Table 1) with a range of soil properties. These trials tested two fertilizer additives Avail® or Nutrisphere® marketed by Specialty Fertilizer Products, Inc. At some locations these materials were tested in a combined study; while at other locations the products were tested alone.

2007 and 2008 Methods

Methods and treatments used in 2007 and 2008 have been described in detail in a previous report published in 2009. To summarize, the experimental design for the starter materials tests in both years was a split plot with four replications. In 2007, the main plot treatments consisted of a no-starter check which was compared to fluid fertilizers 10-27-0, 10-27-0 plus Avail, 12-12-4, 12-12-4 with Avail, and 17-17-0 which were applied at four applications rates: 5, 10, 20, and 40 gal acre^{-1} in a 2 x 2 band (not all fluid fertilizers were used at all locations). In 2008 the main plots consisted of a Bt hybrid and its isoline. Subplots consisted of a no starter check which was compared to fluid fertilizers fertilizers 0-0-27, 17-17-0, 12-12-4, 10-27-0, 10-27-0 + Avail, and 30-0-0. These fluid fertilizers were applied at planting in a 2 x 2 band at a single rate of 20 gal acre^{-1}.

In addition to the starter materials tests experiments were conducted in 2007 and 2008 that examined the use of nitrogen (N) materials at planting. The main plot treatments were 30% UAN and 30% UAN with Nutrisphere. Each of these materials was applied using four application rates: 10, 20, 40, and 80 gallons acre^{-1} which were broadcast shortly following planting. At some of the locations (Davidson08, Forsythe08, and Guilford08) the starter and N materials tests were combined. Starter materials were the main plot treatments with 12-12-4, 12-12-4 + Avail, or no starter fertilizer applied in a 2 x 2 band at a rate of 20 gal acre^{-1}. At layby either 30% UAN, 30% UAN plus Nutrisphere or no N was applied to the plots at two rates of 40 and 50 gal acre^{-1}.

Table 1. Soil and crop management information for starter materials research trials conducted from 2007 through 2009.

Location	Soil Series	Planting Date	Hybrid	Seed Rate	Row Width
Pamlico 07	Wasda L. muck	Mar 28, 2007	DKC69-71	35 000	30”
Currituck 07	Pasquo. Silt L.	Apr. 3, 2007	Pioneer 31G98	33 000	30”
Perquimans 07	Roanoke F. Sand	Apr. 22, 2007	Terral TV21BR40	32 700	36”
Guilford 07	Dragston S. Loam	Apr. 20, 2007	Pioneer 31G98	33 000	30”
Davidson 07	Kirksey C Loam	May 1, 2007	Pioneer 31G98	33 000	30”
Pasquotank 08	Bladen S. Loam	Apr. 17, 2008	Pioneer 33M53/57	33 000	30”
Beaufort 08	Cape Fear S. Loam	Apr. 25, 2008	Pioneer 33M53/57	33 000	30”
Davidson 08	Kirksey C. Loam	May 2, 2008	Syngenta NK68-B8	33 000	30”
Forsythe 08	Hiwassie C. Loam	May 2, 2008	DKC61-69	33 000	30”
Guilford 08	Dragston S. Loam	May 3, 2008	DKC61-69	33 000	30”
Bertie 08	Goldsboro Sandy L.	Apr. 15, 2008	DKC61-69	33 000	36”
Pamlico 08	Yonges L. Fine Sand	Apr. 11, 2008	Pioneer 31G96	33 000	30”
Pamlico 09	Yonges L. Fine Sand	Apr. 8, 2009	Pioneer 31P44	33 000	30”
Hyde 09	Ponzer muck	Apr. 9, 2009	Pioneer 33M57	33 000	30”
Beaufort 09	Roanoke F. Sandy L.	Apr. 21, 2009	Pioneer 31P42	33 000	30”

2009 Methods

One starter fertilizer materials study was conducted in Hyde County in 2009. Hyde09 was located near Swan Quarter, NC on a Ponzer muck soil type (Loamy, mixed, dysic, thermic

Terric Medisaprists) with soil test P and K values of 95 and 148 ppm, respectively (Table 1). The site was planted in soybeans in 2008. A Randomized Complete Block Design (RCBD) was used with four replicated blocks. Treatments consisted of six starter materials plus one untreated control. The starter materials used were: 0-0-27, 30% UAN, 12-12-4, 10-27-0, 10-27-0 + Avail™, and an organic acid starter product by UAP called Black Label™. They were applied at planting in a 2x2 band at 20 gal acre^{-1}. On May 26, 30% UAN was applied to all plots with drop nozzles between each row. On June 22 (VT), root dimensions, stalk diameter, and plant height were measured in each plot. At harvest grain yield, moisture, and test weight were measured on the center two rows of each plot using a K2 Gleaner combine equipped with a HarvestMaster grain gauge. The grain weight from each plot was adjusted to 15.5% moisture before calculating yield. Statistical comparisons were made using both ANOVA and MIXED models. Individual means were compared using the least significant difference procedure.

Nitrogen additives were tested at two sites in 2009: Pamlico09 and Bertie09 (Table 1). The experimental design was a split-split plot with three replications. Main plot treatments consisted of either 30% UAN, or 30% UAN plus Nutrisphere. Subplot treatments were two dates of application either at-planting (21 April) or at-layby (27 May). Sub-subplots consisted of five rates of N fertilizer: 0, 16.7, 50.2, 66.9, and 83.7 gal acre^{-1}. No starter fertilizer was applied to either of these locations in 2009. Whole plant tissue samples were collected at growth stages V5 and R1 (Pamlico09 only) and stalk nitrate samples were collected at harvest.

Common Methods

In the starter materials tests at all locations except Davidson08, Forsythe08, and Guilford08, 30% UAN was applied at layby at rates adjusted within each starter treatment to provide a total of 180 lbs of N acre^{-1}. Bicep applied at planting and Roundup and atrazine applied at layby provided excellent weed control. Insects and diseases (with the exception of the Pamlico07 location) were not a factor. Root and stalk measurements were taken at five locations, Pamlico07, Currituck07, Beaufort08, Pasquotank08, and Hyde09 prior to R1. Five consecutive plants from the outside row of each plot were excavated by digging a 12-in deep trench on each side of the plant and carefully removing the root ball from the soil. At the same time stalk diameter was measured at the internode below the ear leaf. The root ball was then separated from the plant by clipping above the highest brace root. Roots were washed to remove soil and the depth and the width at the widest point was measured. The root ball was then dried and weighed. All plots were harvested in September using a Gleaner K2 combine with a Harvestmaster system that recorded plot weight, moisture, and test weight. All data were analyzed using PROC ANOVA in SAS (SAS Institute, Cary, NC). Mean separations were done using Fisher's protected LSD or with contrast statements.

RESULTS AND DISCUSSION

Root and Stalk Measurements

When the data were combined across locations there were significant location by starter interactions for root mass, root depth, and stalk diameter. Within locations there were significant differences among the starter treatments in within all three of these plant properties, but no differences at any location for maximum root diameter. In most cases these significant differences were between one or more of the starter materials and the no-starter treatment (data not shown). In 2007, all of the starter materials resulted in root mass and stalk diameters that

were greater than the measurements taken in the no-starter check. In 2008, 10-27-0 and 17-17-0 had larger root mass and stalk diameter than the no-starter check at Pasquotank08 but only the 10-27-0 with Avail had more root mass than the no-starter check at the Beaufort08 location. In 2009, there were no significant differences among the starter treatments and the untreated check for any of the plant or root properties measured.

Comparisons between the same starter material with and without Avail found significant differences in root mass in 2007 at both locations and differences in stalk diameter at Pamlico07, Beaufort08 and Pasquotank08 locations (Table 2). There were no significant differences between the same starter material with and without Avail in any of the other root or plant properties measured. In 2009, no differences were found between the 10-27-0 with or without Avail in any of the plant or root properties measured.

Table 2. Measured root and stalk properties from starter treatments with (Yes) and without (No) Avail. Letters in the same row within each root or stalk property indicate significant differences at p = 0.05.

Location - Year	Root Properties						Stalk Properties	
	Depth (in)		Width (in)		Mass (oz)		Diameter (in)	
	No	Yes	No	Yes	No	Yes	No	Yes
Pamlico – 07	5.3	6.0	5.8	6.1	7.5a	8.7b	0.95a	1.0b
Currituck – 07	3.6	3.7	5.0	5.0	9.0a	11.2b	0.93	0.95
Beaufort – 08	2.6	2.6	4.0	4.3	2.6	2.8	0.74a	0.78b
Pasquotank - 08	3.7	3.8	5.8	5.6	4.7	3.8	0.79a	0.83b
Hyde – 09	6.9	7.1	5.2	5.4	3.1	3.2	0.95	0.95

Starter Materials Tests - Yield Comparisons

When the data were combined across locations there was a significant location by starter interaction and starter main effect on yield and grain moisture and a significant starter effect on test weight. At most locations starter fertilizer significantly increased grain yield, moisture, and test weight when compared to the untreated check. However, the best starter material differed by location. In 2009, there were no significant differences among the untreated check, 10-27-0, 10-27-0 with Avail, or 30-0-0 for yield, grain moisture, or test weight, but starter treatments of 0-0-27, 12-12-4, and BlackLabel did result in lower yield compared to 10-27-0 or 10-27-0 with Avail (Fig. 1).

Comparison of Starter Materials with and without Avail

Table 3 shows the impact of starter materials with or without Avail on corn yield across the eleven site-years tested. In seven of the eleven there were no significant differences in grain yield between the starter without Avail and the same material with Avail. In four of the eleven, Pamilico07, Currituck07, Guilford07, and Guilford08 there were significant differences where the use of Avail increased corn yield. Of these four two of the sites had low P soil test values at the start of the study and one had a medium P soil test value. Only the second year of testing at the Guilford site did we find a response even though the P soil test value was high. In most cases when P soil test values were medium or high there were no advantages to using the fertilizer additive Avail. This is shown in 2009 at the Hyde location where there was no difference in yield between the use of 10-27-0 with or without Avail.

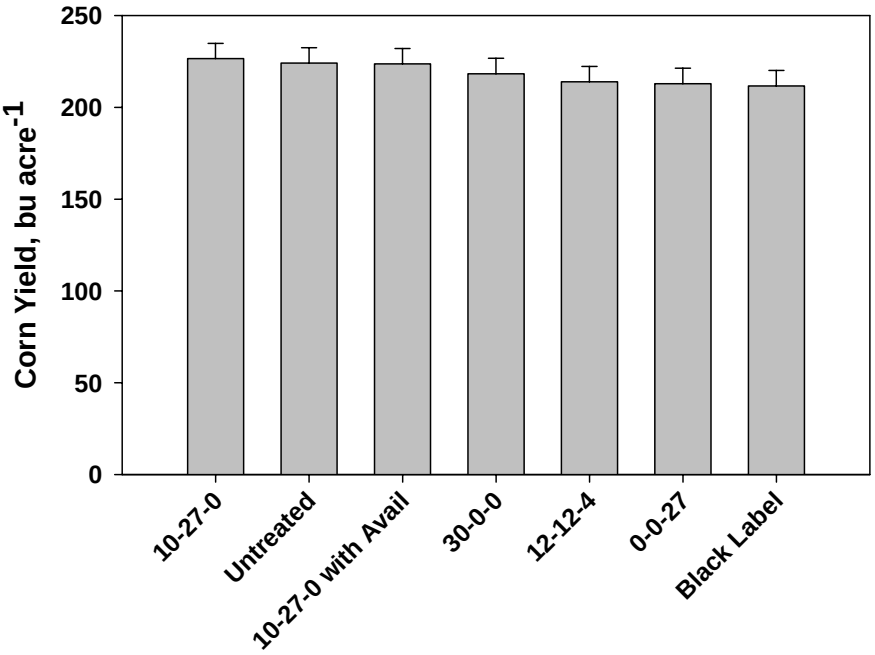

Figure 2. Corn yield response to starter fertilizer treatments in Hyde County in 2009. Anything between the top of the yield bar to the top of the error bar would not be considered statistically different at p < 0.10.

N Materials Tests - Yield Comparisons

Differences in study design among the locations eliminates the possibility of combining results. Table 4 shows a comparison of maximum yields measured at each site for both 30% UAN and 30% UAN with Nutrisphere. Overall there were small differences in maximum yield between the two treatments. In four of the twelve comparisons these differences were significant. Probably the most compelling case occurred in Forsythe County in 2008. At this location the use of Nutrisphere increased yield with or without the use of a starter fertilizer. At locations where a range of N fertilizer rates were applied the use of a quadratic response function made it possible to calculate the economic optimum N rate. When economic optimum N rates are considered the addition of Nutrisphere often resulted in less N required to optimize yield compared to the use of 30% UAN alone (Table 4). The only situations where this was not the case occurred when N was applied as a sidedress application at both sites in 2009. Evidently, the N in the Nutrisphere-N application was not as available relative to crop need when the application occurred later in the growing season.

Comparison of Nitrogen Sources with and without Avail in 2009

Analysis of yield data from two trials testing the use of the fertilizer additive Nutrisphere in 2009 only found an application by N rate interaction at the Beaufort09 location and an N rate main effect at the Pamlico09 location. While comparisons at both locations indicated small yield advantages to the use of the Nutrisphere additive these differences were not large enough to overcome the variability in these tests.

Table 3. Yield results from ten locations across two years comparing treatments with no starter, starter (10-27-0, 12-12-4, or 17-17-0) without Avail, and the same starter treatment with Avail. Rows highlighted in bold indicate locations where the use of Avail resulted in a significant yield increase compared to the use of the same starter material without Avail at p=0.05.

		Corn Yield (bu acre^{-1})		
Location - Year	Soil P Level	No Starter	Starter only	Same Starter with Avail
Pamilico -07	**Med**	**185.1a**	**191.0a**	**200.7b**
Currituck – 07	Med	190.8	198.6	199.4
Beaufort – 08	High	128.0	122.7	127.5
Pasquotank - 08	High	165.3	153.7	160.0
Perquimans – 07	**Low**	**131.3a**	**155.0b**	**167.8c**
Guilford – 07	**Low**	**143.3a**	**142.2a**	**160.9b**
Davidson – 07	Med	123.7	151.0	133.5
Davidson - 08	High	161.3	164.6	164.0
Forsythe – 08	Med	105.6	110.4	120.3
Guilford - 08	**High**	**106.6a**	**107.0a**	**121.8b**
Hyde - 09	High	224.1a	226.5a	223.7a

Table 4. Maximum yield and economic optimum N rate for N materials test at eight locations. Rows highlighted in bold indicate locations where the use of Nutrisphere resulted in a significant (p = 0.05) yield increase between at least one of the N rate treatments compared to 30% UAN alone.

	30% UAN		UAN + Nutrisphere	
Location - Year	Maximum Yield	Economic Optimum N rate	Maximum Yield	Economic Optimum N Rate
Pamilico -07	**209.7**	**187**	**219.1**	**135**
Currituck – 07	**176.5**	**147**	**191.1**	**109**
Pamlico – 08	**165.9**	**230**	**169.8**	**180**
Bertie - 08	64.6	0	87.8	0
Davidson – 07	151.0	n/a	136.0	n/a
Davidson - 08	179.1	n/a	163.2	n/a
Forsythe – 08	**125.4**	**n/a**	**142.1**	**n/a**
Guilford - 08	127.7	n/a	128.3	n/a
Pamlico – 09 (Plant)	206.1	294	214.6	281
Pamlico – 09 (Sidedress)	203.4	247	207.9	262
Beaufort – 09 (Plant)	214.0	234	224.5	196
Beaufort – 09 (Sidedress)	223.6	202	233.0	234