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

R.W. Heiniger
Crop Science Department
North Carolina State University
Raleigh, North Carolina 27695
Ron_Heiniger@ncsu.edu
(252) 793-4428 ext. 154
(252) 793-5142

INTRODUCTION

Dramatic increases in corn yield in the southeast US over the past two years have been the result of growers adopting high population corn systems. Research in North Carolina has shown that plant populations of 30,000 to 34,000 plants per acre or greater are needed to reach maximum yield (unpublished data). However, high plant populations are often accompanied by 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). Furthermore, because ear size is determined by V6, good early growth is essential to obtain maximum ear size and yield. Fortunately, recent research has shown that there are solutions to these problems (manuscript in preparation). This research shows that starter fertilizer with nitrogen (N), and phosphorus (P) can significantly increase stalk diameter and root mass. While this research has shown positive results from the use of starter fertilizers more work needs to be done to improve the efficiency of these fertilizer materials in enhancing root development. 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.

Comparitive research done at Kansas State University has shown that fertilizer additives such as Avail® and Nutrisphere® can be used to address these problems and improve yield. These materials 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, 2) to determine optimum rates of fertilizer using the additives Avail® and Nutrisphere® , and 3) to identify the effects of soil factors (pH, temperature, soil moisture) on the efficacy of fertilizer additives in increasing root mass and corn yield.

MATERIALS AND METHODS

Twelve research trails were conducted in 2007 and 2008 at locations in Pamlico, Pasquotank, Perquimans, Currituck, Guilford, Beaufort, Forsythe, Bertie, 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 Methods

At the Pamlico07 and Currituck07 locations main treatments in the starter fertilizer test were no-starter check, 10-27-0, 10-27-0 with Avail, 17-17-0, 17-17-0 deep band (Pamlico07 only). Each of these starter materials were applied using four application rates: 5, 10, 20, and 40 gal acre^{-1} in a 2 x 2 band with the exception of the 17-17-0 which was applied in a deep band 8 in below and 2 in to the side of the seed. In the nitrogen (N) materials test the main 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} applied in a broadcast application shortly following planting. The purpose for making the application at this time was to insure that adequate N was available for early plant growth while recognizing that the possible slow release of N using the Nutrisphere material may delay N availability. In these plots, 17-17-0 was applied in a 2 x 2 band at a rate of 10 gal acre^{-1}.

At the Davidson07 location the main treatments in the starter test were no-starter check, 17-17-0, 17-17-0 with Avail, 3-18-18, and 0-0-27. The 17-17-0 and 17-17-0 with Avail were applied at 10 and 20 gal acre^{-1} in a 2 X 2 band, while the 3-18-18 and 0-0-27 were applied at 10 gal acre^{-1} in furrow. The N materials test consisted of four rates of 30% UAN with Nutrisphere added (10, 20, 40, and 80 gal acre^{-1}). However, the lack of space dictated that the 30% UAN treatment without Nutrisphere could only be applied at a single rate of 40 gal acre^{-1}. Both of these treatments were applied shortly after planting. 17-17-0 was applied to these plots in a 2 x 2 band at a rate of 10 gal acre^{-1}. At the Perquimans07 and Guilford07 locations the main treatments were a no-starter check, 12-12-4 and 12-12-4 with Avail. At Perquimans07 the starter materials were applied at 20 gal acre^{-1} in a 2 x 2 band, while at Guilford07 they were applied at 5, 10, 20, and 40 gal acre^{-1} in a 2 x 2 band. No N materials were tested at the Perquimans07 and Guilford07 locations.

Table 1. Soil and crop management information for starter materials research trials in 2007 and 2008.

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.	April 15, 2008	DKC61-69	33 000	36”
Pamlico 08	Yonges L. Fine Sand	April 11, 2008	Pioneer 31G96	33 000	30”

2008 Methods

Starter materials tests were conducted in Pasquotank08 and Beaufort08 locations where main treatments were hybrids Pioneer 33M53 and 33M57. Both hybrids share a common genetic background with the exception that Pioneer 33M57 is a Bt variant. Subplot treatments

were different starter fertilizers (0-0-27, 17-17-0, 12-12-4, 10-27-0, 10-27-0 + Avail, 30-0-0) and a no-starter check. These fertilizer blends were applied at a single rate of 20 gal acre^{-1} in a 2 x 2 band.

At the Davidson08, Forsythe08, and Guilford08 locations 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} to each of ten plots. 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}. At Pamilco08 and Bertie08 locations only N materials were tested. Main plot treatments consisted of either 30% UAN, 30% or UAN plus Nutrisphere. Subplot treatments were five rates of N fertilizer: 0, 16.7, 50.2, 66.9, and 83.7 gal acre^{-1}. Starter fertilizer in the form of 10-27-0 was applied at a rate of 10 gal acre^{-1} in a 2 x 2 band at planting.

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 four locations, Pamlico07, Currituck07, Beaufort08, and Pasquotank08, 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. 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

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. There were significant differences among the starter treatments in within all three of these plant properties. In most cases the key differences were between one or more of the starter materials and the no-starter treatment. 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 (Fig. 1). 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 (Table 2).

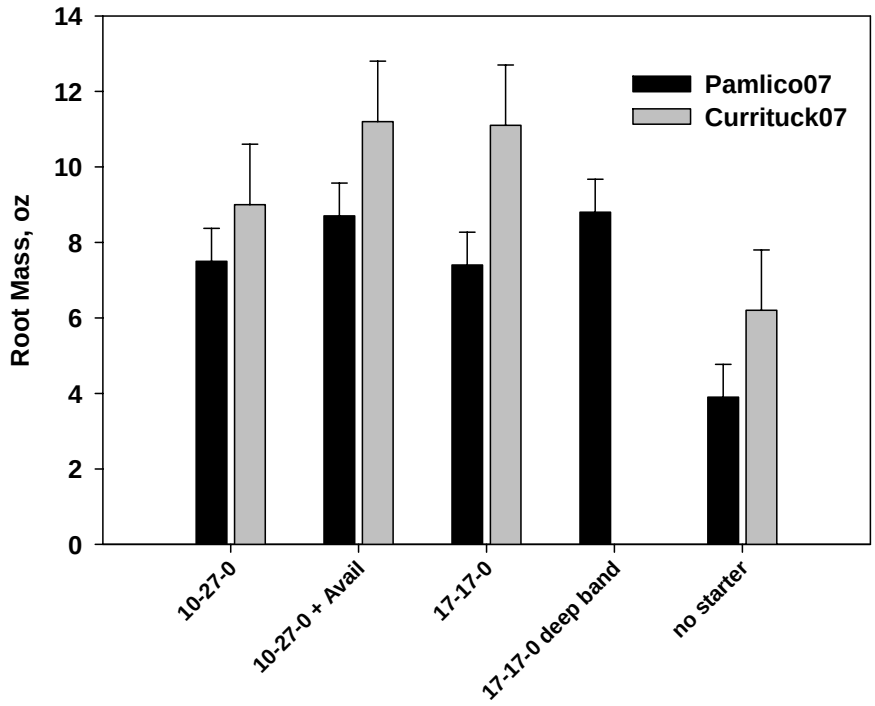

Figure 1. Root mass measured from plots where the highest rate of starter material was applied. Error bars indicate the LSD (p=0.05) for determining differences within a location.

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.

Table 2. Measured root and stalk properties from starter treatments with (Yes) and without (No) Avail. Numbers in bold indicate significant differences.

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	**7.5**	**8.7**	**0.95**	**1.0**
Currituck – 07	3.6	3.7	5.0	5.0	**9.0**	**11.2**	0.93	0.95
Beaufort – 08	2.6	2.6	4.0	4.3	2.6	2.8	**0.74**	**0.78**
Pasquotank - 08	3.7	3.8	5.8	5.6	4.7	3.8	**0.79**	**0.83**

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 with or without avail increased grain yield, moisture, and test weight significantly when compared to the untreated check. While there were significant differences among starter materials, the best material differed by location.

Pamlico07 and Currituck07

The key differences among starter treatments occurred at the Pamlico07 location where the 10-27-0 plus Avail resulted in a significantly higher grain yield compared to the other treatments. Yield was increased by 10 bu acre^{-1} when Avail was added to 10-27-0 at the Pamlico07 location (Table 3). The impact of the Avail may have been enhanced by the cool, wet conditions at this site. At the Currituck07 location differences among treatments were small and not significant with only a 3 bu acre^{-1} increase in the Avail treatment compared to 10-27-0 without Avail.

Davidson07

The only significant differences at the Davidson07 location occurred among the control treatment (no starter applied) and the high rates of 17-17-0 (data not shown). There were no differences among treatments with or without Avail. While the two starter materials with potassium did not improve yield, they did reduce the amount of stalk lodging observed in the plots. The use of the starter materials that were applied in furrow did impact the rate of plant emergence and this probably resulted in the lack of yield response observed with these materials.

Perquimans07 and Guilford07

At both of these locations a significant yield increase was observed between the plots receiving 12-12-4 and those where Avail was added to the 12-12-4 (Table 3). The 11 to 14 bu acre^{-1} yield increases observed at these locations were similar in magnitude to the yield increase found at Pamlico07. Both of these locations had low soil test indexes for phosphorus (P index less than 37) and high pH (> 6.4) and the starter material used had less P compared to most of the materials used at the other locations. The use of Avail at these locations may have increased the amount of P available to the crop.

Beaufort08, Pasquotank08, Davidson08, Forsythe08, and Guilford08

There were no significant differences in grain yield among any of the starter treatments at either Beaufort08 or Pasquotank08 locations (Table 3). Early growth and development favored treatments receiving some P in the starter fertilizer, but dry weather during late June damaged treatments which promoted earlier silking and rainfall on 7 July favored late development. There were no significant differences among the treatments with 12-12-4, 12-12-4 with Avail, and the no-starter check at the Davidson location. A soil test at this site indicated very high levels of P and K. While yield was increased by using Avail at both the Forsythe and Guilford locations only the Guilford location had a significant increase in grain yield associated with the use of Avail. At both of these locations the use of starter fertilizer resulted in significant yield increases compared to the no-starter check.

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. 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 yield using a corn price of $5.00 bu^{-1} and N fertilizer price of $0.80 per lb of N.

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**	**185.1**	**191.0**	**200.7**
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**	**131.3**	**155.0**	**167.8**
Guilford – 07	**Low**	**143.3**	**142.2**	**160.9**
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**	**106.6**	**107.0**	**121.8**

Pamlico07and Currituck07

There were a significant N rate effects on yield at these locations that differed based on whether or not Nutrisphere was added to the 30% UAN solution. When Nutrisphere was added 20, 40, and 80 gal of solution produced similar yields but all were higher than the lowest rate of 10 gal acre^{-1}. With 30% UAN alone the two lowest rates of N solution did not differ but had significantly lower yields than the two higher rates. Even though 30% UAN plus Nutrisphere produced numerically greater yield at each N rate, analysis of the data only found significant differences between the two materials at the 20 gal acre^{-1} application rate. However, when the yield response to added N was analyzed using a quadratic response function and a corn price to N price ratio of 7.2 the addition of Nutrisphere reduced the optimum N rate from 178 lbs of N acre^{-1} (30% UAN alone) to 126 lbs of N acre^{-1} (UAN plus Nutrisphere) at Pamlico07 and 106 lbs of N acre^{-1} for 30% UAN plus Nutrisphere vs 155 lbs of N acre^{-1} for 30% UAN at Currituck07.

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

Pamlico08

Contrast statements found a significant differences among N fertilizer rates within each main N fertilizer treatment. Within the 30% UAN treatment the highest rate of 83.7 gal acre^{-1} has significantly greater yield than the lowest three rates (Figure 3). Within the 30% UAN plus Nutrisphere treatment the three highest rates (50.2, 66.9, and 83.7 gal acre^{-1}) had significantly greater yield than the lower two rates (0 and 16.7 gal acre^{-1}). Between the two fertilizer treatments there were significant differences in yield when 50.2 or 66.9 gal acre^{-1} were applied with the 30% UAN plus Nutrisphere having the higher yield. This analysis showed that when Nutrisphere was added the economically optimum fertilizer rate was 50.2 gal acre^{-1}; while when 30% UAN was used alone the optimum rate was 66.9 gal acre^{-1}.

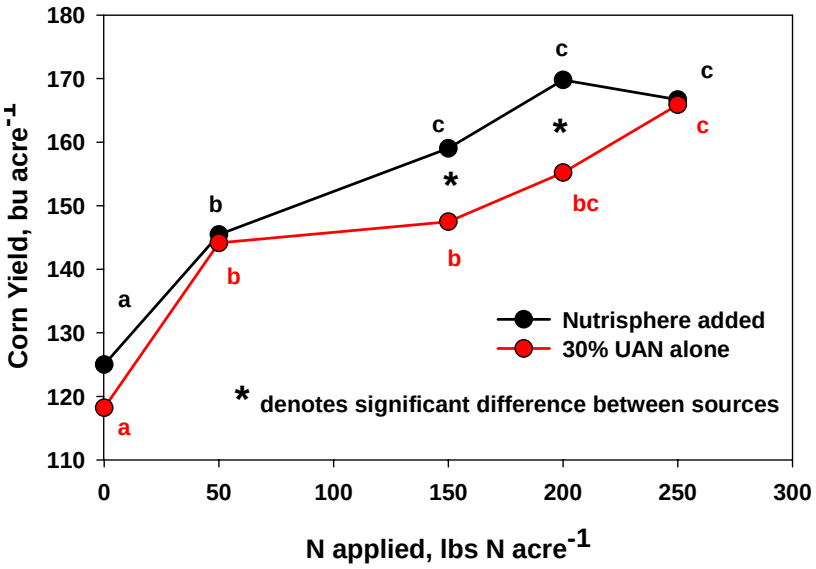

Figure 3. Corn yield response to N fertilizer treatments at Pamlico08 location. Letters that are the same color as the line represent significant differences among fertilizer rate; while stars indicate significant differences among fertilizer treatments within the same rate at p < 0.05.

Forsythe08

Contrast statements found a significant difference in yield between fertilizer treatments. 30% UAN plus Nutrisphere increased yield compared to 30% UAN alone regardless of the starter fertilizer treatment used (Table 4). However, the highest yield was achieved when both Avail and Nutrisphere were used.

Davidson07, Davidson08, Bertie08, and Guilford08

There were no significant differences in yield between the 30% UAN treatment and 30% UAN plus Nutrisphere nor were there any significant differences among the rates of N fertilizer used at these sites. Davidson07 and Bertie08 both experienced extreme drought resulting in very low yields. Davidson08 and Guilford08 were locations where there was a large amount of residual N remaining from previous fertilization of a crop that was abandoned.

CONCLUSIONS

1. **Is there a benefit to using starter fertilizer on corn?** These tests support previous work that shows a benefit to using starter fertilizer on corn. In most of these studies there was a significant yield increase from at least one of the starter materials compared with the no-starter check (Table 3) At the four sites tested in 2007 and 2008 there were consistent increases in root mass, root depth, and stalk diameter when some form of starter fertilizer was used. The starter benefit at Guilford07 and Guilford08 only occurred when Avail was added.

2. **What blend of starter fertilizer results in the best yield?** No starter material resulted in a consistent advantage across all locations in both years. At some locations an equal blend of N and P resulted in the best yield (17-17-0 or 12-12-4 being good examples). At others the use of 30% UAN as a starter material improved yield. Dry weather at the two sites which had a wide range of starter products and blends reduced yield resulting in poor comparisons. Further work is needed to help answer this question.

3. **Did the addition of Avail to starter fertilizer improve plant properties and yield?** Avail did increase stalk diameter and root mass at several locations, particularly in environments where yield levels were high. At some locations Avail added to starter fertilizer did increase yield by as much as 14 bu acre^{-1}. Unfortunately, when all ten site-years are considered together there is not a consistent yield advantage to using Avail as a fertilizer additive. It appears that Avail was effective under certain conditions such as wet, cool soils, low soil P levels, or high pH. Growers should consider their soil and environmental conditions when deciding whether or not to apply Avail.

4. **Is there any benefit from using Nutrisphere?** The difference in corn yield response to increasing rates of fertilizer between 30% UAN and 30% UAN with Nutrisphere indicates that there is indeed a benefit to using Nutrisphere. In three out of four tests plots treated with 30% UAN with Nutrisphere reached optimum yield at a lower rate of added N than did plots treated with 30% UAN alone (Table 4). In these studies fertilizer rates could have been reduced by 49 to 50 lbs of N acre^{-1}. Given the cost of UAN solution this is a substantial benefit. In summary, while similar corn yields could be achieved by using 30% UAN with or without Nutrisphere, adding Nutrisphere to N applied at planting reduced the amount of solution needed to achieve optimum corn yield.