NC STATE UNIVERSITY

Impact of Uniform Emergence on Corn Growth and Yield

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INTRODUCTION

In discussions of the reasons for their success corn yield contest winners often mention the need for uniform emergence (all plants emerging at the same time). Previous research has shown that variability in plant emergence can reduce plant height, leaf area index, dry matter accumulation and yield (Weidong et al., 2004; Glenn and Daynard, 1974; Nafziger et al., 1991; Ford and Hicks, 1992; Lawless et al., 2012). Weidong et al. (2004) found that a 2-leaf stage delay (12 d) in plant emergence reduced yield by 4% and a 4-leaf stage delay reduced yield by 8%. Nafziger et al. (1991) also found that similar delays in emergence decreased corn yield but that only delays of > 2 wk were large enough to justify replanting. Elmore and Abendroth, 2006 summarized relevant research in this area (Fig. 1) showing the range of yield loss measured from a 6 to 21 d delay in plant emergence.

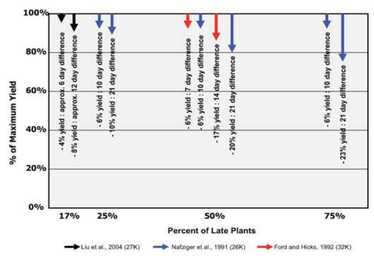

Figure 1. Compilation of research results showing percent yield loss when a certain percentage of the stand (x axis) is late compared to the rest of the field. Arrow colors represent which research report they are from. Populations are embedded within parentheses of the references (26 to 32K where K is 1,000 plants per acre). (Elmore and Abendroth, 2006)

Unfortunately, all of these studies relied on changing planting dates of individual seeds to introduce variability in plant emergence. This approach makes it difficult to mimic short delays in emergence (24 to 48 hrs or less), it may not adequately mimic the impact of delayed emergence and it makes it difficult to assess management factors that influence the variability in emergence experienced in the field. To overcome these problems a method of observing and marking emerging plants was developed that could be used to assess the impact of variability in plant emergence over a short time period on ear characteristics. In 2015 ear characteristics measured on plants marked that emerged over a period of 24 to 48 hrs indicated that even a short delay in emergence can result in fewer rows of kernels, fewer kernels row^{-1} and less grain weight ear^{-1} (Table 1) (Heiniger and Boerema, 2015).

METHODS

This study was conducted at two sites in eastern North Carolina (Hyde and Pasquotank County) on two very different soil types (Table 2). The experimental design was a split-split-split plot with three replications.

Main Plots – Planting Date: 18 Apr (Hyde) or 19 Apr and May 11
Subplot Treatments - Seeding Depth: 381 or 635 mm
Sub-subplot Treatments - Pioneer '1319' or Pioneer '1311' planted with each of four fertilizer seed treatments.

1. 3-18-18 applied in-furrow at a rate of 46.8 L ha^{-1}
2. InVigor8 (Genesis Ag, LLC., Kansas City, Mo.)(0-37-37 applied to the seed at 0.01 g kg^{-1} seed)
3. Teprosyn (Helena Chemical Co., Collierville, TN) (9-15-0 + 18% Zn applied to the seed at 0.008 L kg^{-1} seed).
4. No Seed Treatment

Individual plots were 4 rows wide by 9.1 m long. Planting date, seeding rate, and row spacing for each site are shown in Table 2. At V7 468 L ha^{-1} of 30% UAN was applied to achieve a rate of 1.79 t of N ha^{-1}. Standard pre- and post-emergence weed control practices were used resulting in 99% or greater weed control.

Starting two days after planting, field observations were made daily at the same time of day on a 4.6-m section randomly selected and marked from the second row of each plot. When the spike of a corn plant was first observed emerging from the soil it was marked with a small, colored wooden stake and numbered based on the day it was observed. After all the plants in each 4.6-m section had emerged counts were made to determine the number of plants emerging within each daily time period and the total number of plants emerged. At harvest ears from three to five plants that had emerged on the first day emergence was observed in each plot and ears from three to five plants that emerged 24 to 48 hrs later were randomly selected and bagged and the third and fourth rows of each plot were then harvested using a plot combine with a Harvestmaster™ grain gage which measured grain weight, moisture, and test weight. Analysis of ear characteristics (row number, kernels row^{-1} and grain weight) has not been completed at this time.

Table 2. Soil characteristics and planting management.

Site	Soil Type	Planting Dates	Seeding Population	Row Spacing
		----	seeds ha^{-1}	- cm -
Hyde County	Hydeland silt Loam (Fine silty, mixed, thermic Typic Umbraqualfs)	18 April and 11 May	74 100	76 cm
Pasquotank County	Bayboro loam (Fine, mixed, semiactive, thermic Umbric Paleaquults)	19 April and 11 May	74 100	76 cm

Statistical Procedures

The number of plants in each plot that emerged on the first day that spikes were observed and those that emerged 24 and 48 hrs later were divided by the final stand count for each plot and multiplied by 100 to calculate percent emergence for each category (first emerged, 24 hr delay, or 48 hr delay). Final stand counts, percent emergence in each of these three categories, and plot grain yield ha^{-1} were analyzed separately by location using a split split split plot design with Proc Mixed (SAS Institute, 2009). When significant differences were found among planting date, seeding depth, hybrid, and seed treatment Fischer's protected LSD was used to separate means.

RESULTS

Factors that Impacted Emergence

At the first planting date both locations received 2 to 3 cm of rainfall within 3 to 4 d. Soil temperatures ranged from 62 to 70° F for the first week after planting. At the second planting date both locations received excessive rainfall (>12 cm) within the first three days. Soil temperatures at each location were above 70° F for the first seven days. Final stand counts at both locations indicated that over 90% of the seeds emerged within 14 d of planting and were affected by planting date (Tables 3 and 4) with 94% of the seeds emerging on average at the first planting date and 90 to 91% emerging at the second planting date. There were also hybrid and hybrid by treatment effects on final stand counts (data not shown).

At the Hyde location there were significant three-way interactions among planting date, seeding depth, and treatment and planting date, hybrid, and treatment for percentage of plants emerging on the day of first observation of spikes and for percentage of plants emerging 24 and 48 hr later (Table 3). The 3-18-18 fertilizer treatment at the 381 mm seeding depth planted on 18 Apr had the lowest first day emergence when compared across dates and seeding depths (Fig. 2). However, when the corn was planted on 11 May the 3-8-18 treatment did not differ from the other treatments in first day emergence. When compared across planting dates and hybrids (Fig 3) the 3-18-18 and InVigor8 treatments applied to Pioneer 1311 had significantly lower first day emergence at the first planting date and were at least numerically lower at the second planting date. While the same treatments when applied to Pioneer 1319 did not significantly reduce first day emergence at either planting date.

At both locations there were significant main effects ($p < 0.05$) of planting date and seeding depth for the percentage of plants emerging at first observation of spiking and consequently the percentage of plants emerging either 24 or 48 hrs later (Tables 3 and 4). There were also significant main effects of hybrid and treatment for percent first day emergence at the Hyde location; while at the Pasquotank location the hybrid and treatments effects were significant at the $p < 0.1$ level. Percent emergence on the first day spikes were observed was better at the later planting in Hyde County; while it was better at the first planting date in Pasquotank County (Table 5). Pasquotank County was planted using no-till practices and the excessive rain along with residue impacted emergence. At both sites the deeper seeding depth increased the number of plants emerging on the first day spikes were found and the Pioneer 1319 hybrid had better first day emergence. When compared to the untreated check the use of seed treatments or in-furrow fertilizer did not statistically improve the percentage of plants emerging on the first day spikes were found.

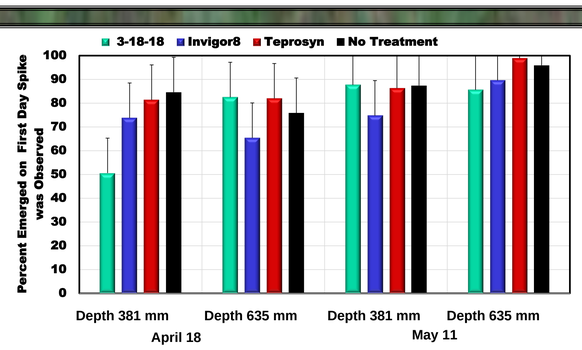

Figure 2. Percent emergence for seed or fertilizer treatments when corn was seeded at two planting depths on two dates at the Hyde County location. Error bars show differences based on Fischer's protected LSD at $p < 0.05$.

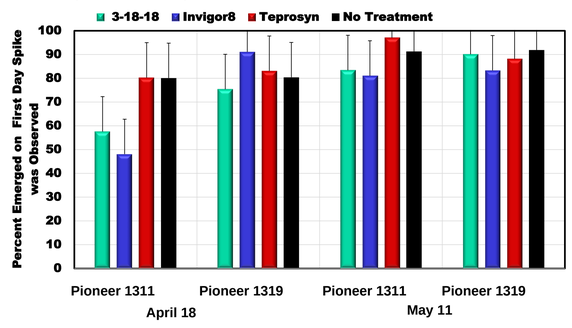

Figure 3. Percent emergence for seed or fertilizer treatments applied to two hybrids seeded on two planting dates at the Hyde County location. Error bars show differences based on Fischer's protected LSD at $p < 0.05$.

Table 1. Comparison of corn ear measurements between ears from plants that emerged at the first observation of spiking and those from plants that emerged 24 to 48 hr later from field studies at two locations in 2015. Different letters in the same column within the same location indicate significance at $p < 0.05$.

Location	Time of Emergence	Row Number Ear^{-1}	Kernels Row^{-1}	Grain Weight Ear^{-1}
Beaufort	First Observed Spikes	15.3 a	40.5 a	192.0 a
	24 to 48 hr delay	14.6 b	36.6 b	161.0 b
Camden	First Observed Spikes	15.4 a	37.8 a	195.6 a
	24 to 48 hr delay	15.4 a	35.4 b	171.5 b

Analysis of Variance - Emergence and Yield – Hyde Co.

Table 3. Analysis of variance for stand counts, emergence over three observations, and grain yield as influenced by location, seeding depth, hybrid, and seed or fertilizer treatment.

Source of Variation	d.f.	Stand Count	% First Emerged	% 24 hr Emerged Delay	% 48 hr Emerged Delay	Grain Yield
			---------- P< F ----------			
Planting Date (Date)	1	0.0024	<0.0001	0.0012	<0.0001	0.7013
Seeding Depth (SD)	1	0.8871	0.0204	0.0816	0.0011	<0.0001
Date x SD	1	0.5336	0.3795	0.0187	0.0004	0.0363
Hybrid	1	0.0089	0.0029	0.0605	0.0810	0.0194
Date x Hybrid	1	0.8591	0.0034	0.0150	0.2655	0.2136
SD x Hybrid	1	0.7604	0.5964	0.3710	0.7252	0.9131
Date x SD x Hybrid	1	0.1689	0.3950	0.1531	0.1146	0.2954
Treatment (Trmt)	3	0.7353	0.0026	0.0092	0.1291	0.0265
Date x Trmt	3	0.7611	0.5486	0.8347	0.9715	0.0001
SD x Treatment	3	0.7378	0.2104	0.7501	0.5049	0.0161
Date x SD x Trmt	3	0.1839	0.0008	0.0129	0.0708	0.0059
Hybrid X Trmt	3	0.4766	0.0032	0.0330	0.0019	0.0024
Date x Hybrid x Trmt	3	0.8145	0.0441	0.0113	0.0399	0.0277
SD x Hybrid x Treatment	3	0.2663	0.8891	0.1591	0.6025	0.0642
Date x SD x Hybrid x Trmt	3	0.9929	0.5272	0.5814	0.0182	<0.0001

Analysis of Variance - Emergence and Yield – Pasquotank Co.

Table 4. Analysis of variance for stand counts, emergence over three observations, and grain yield as influenced by location, seeding depth, hybrid, and seed or fertilizer treatment.

Source of Variation	d.f.	Stand Count	% First Emerged	% 24 hr Emerged Delay	% 48 hr Emerged Delay	Grain Yield
			---------- P< F ----------			
Planting Date (Date)	1	0.0083	0.0012	0.1059	<0.0001	0.0076
Seeding Depth (SD)	1	0.7065	0.0115	0.0023	0.4246	0.0013
Date x SD	1	0.6130	0.5252	0.6171	0.0042	0.3263
Hybrid	1	0.8593	0.0872	0.9867	<0.0001	0.1639
Date x Hybrid	1	0.1154	0.0184	0.0006	0.0228	0.7452
SD x Hybrid	1	0.6586	0.8466	0.9135	0.7988	0.3676
Date x SD x Hybrid	1	0.6586	0.1678	0.0563	0.3069	0.7933
Treatment (Trmt)	3	0.3333	0.0815	0.1477	0.2666	0.1724
Date x Trmt	3	0.0455	0.4667	0.1881	0.5576	0.8098
SD x Treatment	3	0.8381	0.3444	0.3315	0.5920	0.6813
Date x SD x Trmt	3	0.3093	0.5984	0.3730	0.5534	0.9644
Hybrid X Trmt	3	0.1601	0.6061	0.5638	0.1982	0.9876
Date x Hybrid x Trmt	3	0.3039	0.4858	0.6884	0.4015	0.4597
SD x Hybrid x Treatment	3	0.3081	0.1415	0.2032	0.2377	0.7179
Date x SD x Hybrid x Trmt	3	0.4623	0.3847	0.4882	0.6580	0.4386

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Table 5. Comparison of percent emerged seedlings on the first day spikes are observed and resulting corn yield between planting dates, seeding depth, hybrids, and four seed or fertilizer treatments at two locations in North Carolina. Different letters in the same column indicate significance at $p < 0.05$.

	Hyde County			Pasquotank County		
		Emerged First Day	Yield		Emerged First Day	Yield
		... % ...	Mt ha^{-1}		... % ...	Mt ha^{-1}
Planting Date	18 Apr	74.5 b	11.61	19 Apr	73.8 a	14.68 a
	11 May	88.3 a	11.56	11 May	61.2 b	14.08 b
	LSD ($p < 0.05$)	5.2	0.27	LSD ($p < 0.05$)	7.4	0.43
Seeding Depth	381 mm	78.3 b	11.22 b	381 mm	62.7 b	14.01 b
	635 mm	84.5 a	11.95 a	635 mm	72.3 a	14.74 a
	LSD ($p < 0.05$)	5.2	0.27	LSD ($p < 0.05$)	7.4	0.43
Hybrid	P 1311	77.4 b	11.43 b	P 1311	64.3	14.53
	P 1319	85.4 a	11.75 a	P 1319	70.7	14.22
	LSD ($p < 0.05$)	5.2	0.27	LSD ($p < 0.05$)	7.4	0.43
Treatment	3-18-18	76.6 b	11.52 ab	3-18-18	69.3	14.18
	InVigor8	75.9 b	11.36 b	InVigor8	59.2	14.79
	Teprosyn	87.2 a	11.53 ab	Teprosyn	72.1	14.20
	No Treatment	85.9 a	11.93 a	No Treatment	69.3	14.34
	LSD ($p < 0.05$)	7.4	0.41	LSD ($p < 0.05$)	10.5	0.61

RESULTS and CONCLUSIONS

Yield and Its Relationship to the Percent of plants that Emerge on the First Day Spikes are Observed

In Hyde County analysis of variance for yield found a significant four-way interaction among planting date, seeding depth, hybrid, and treatment along with significant main effects for planting date, seeding depth, hybrid, and treatment (Table 4). Figures 3 and 4 show that the four-way interaction was largely the result of differences in yield among seed treatments that changed across dates, seeding depths, and hybrids. In general, at the 18 April planting date the 3-18-18 or untreated check often had the highest yield; while at the 11 May planting date there were fewer significant differences among the treatments. Yield differences between the seeding depths and hybrids were consistent across dates allowing for the consideration of main effects.

At the Hyde County location there were significant main effects of seeding depth, hybrid, and treatment on corn yield (Table 3); while at the Pasquotank County location only planting date and seeding depth had significant effects on yield (Table 4). In Pasquotank County planting on 19 April resulted in a higher yield compared with 11 May (Table 5). This is consistent with the impact of the excessive rainfall on stand counts and percent of plants that emerged on the first day that spikes were found. At both locations seeding at 635 mm resulted in greater yield compared with seeding at 381 mm and Pioneer 1319 had a greater yield compared with Pioneer 1311. Again, these differences were consistent with differences found in percent of plants emerging on the first day spikes were found. In Hyde County none of the seed or fertilizer treatments improved yield when compared to the untreated check.

Regression analysis of the impact of the percent of plants emerging 24 hrs after first observance of spiking indicated that for each percent increase in plants delayed by 24 hrs there is a 0.017 t ha^{-1} decrease in grain yield (0.3 bu acre^{-1}). This is similar to the yield loss found in previous years (Heiniger and Boerema, 2015). This study shows that even a short delay in emergence can impact plant development and yield.

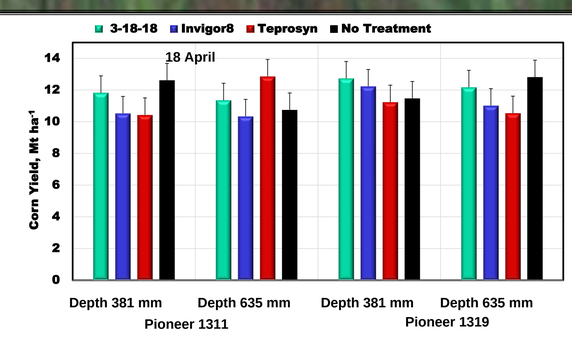

Figure 3. Percent emergence for three seed or fertilizer treatments applied to two hybrids seeded at two planting depths averaged over two locations. Error bars show differences based on Fischer's protected LSD at $p < 0.05$.

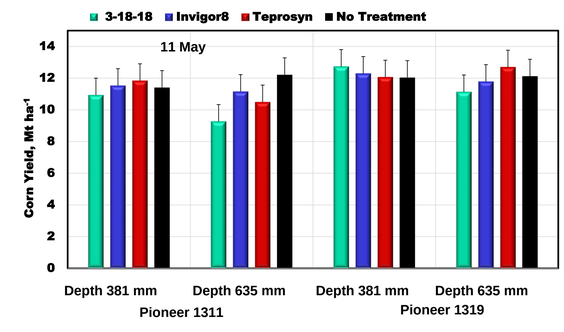

Figure 4. Percent emergence for three seed or fertilizer treatments seeded at two planting depths at two locations averaged over two corn hybrids. Error bars show differences based on Fischer's protected LSD at $p < 0.05$.

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