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A Method to Evaluate Seeder Performance

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***Abstract*— Evaluating in field seeder performance is challenging and sometimes requires destructive methods. An alternative method for evaluating seeder performance based on nonlinear regression was developed. This method yields parameters that describe seeder performance, such as emergence rate, initial emergence data, and emergence percent. These parameters are easy to explain to the practitioner. The proposed method was compared to a widely used method to assess emergence rate. Results assessing emergence percent were comparable between the two methods. There were differences between the emergence rate index and emergence rate determined from the proposed method. These differences were expected since the emergence rate index encompasses more information than simply the rate of emergence.**

***Index Terms*—emergence percent, emergence rate, linear-plateau regression, precision seeder**

I. INTRODUCTION

Establishing uniform crop stands has long been a goal for growers. Selecting, adjusting, and operating a seeder is paramount for success. However, evaluating seeder performance can be a tedious task with many hours spent counting seedlings and measuring plant spacing. When evaluating seeder performance, consideration of the relevant items regarding crop stand establishment is critical. Creating a seed/soil environment that promotes complete germination and emergence is the primary goal. Instead of quantifying the seed/soil environment, we typically measure the plant's response as a proxy. Spatially and temporally uniform emergence is desirable. Spatial uniformity of the stand is of most interest for row crops such as corn and sunflower. Reference [1] indicates several indices describing spatial distribution of plants within the row and has become a benchmark for assessing spatial uniformity of plant stands.

Temporal uniformity of emergence can best be assessed by emergence percentage and rate of emergence. If the number of seeds planted is known, the emergence percentage is a simple calculation. However, with many seed metering devices the exact seed drop can only be estimated. Furthermore, an effort to count seeds in the planted row requires that seeds be uncovered leading to the potential introduction of error by 'replanting' the seeds after counting. This invasive approach is undesirable when attempting to assess the true performance of the seeder. Determining the emergence rate requires counting plants as they emerge. A high emergence rate means that seeds germinate and plants come out of the ground in a short period of time. The two desirable traits are initial emergence (first plants) soon after seeds are planted and final emergence (last plants) soon after the first plants have emerged.

Reference [2] used four indices (speed of emergence, mean emergence date, emergence rate index, and relative emergence) to evaluate seedling emergence in a greenhouse experiment. They counted emerged seedlings three times per day. The relative emergence (RE) they discuss is the decimal equivalent to emergence percent used by other researchers. They fit a logistic growth model to the RE data using nonlinear regression where RE is a function of time (t) (1).

$$RE_t = \frac{1}{1+e^{(a+b\cdot t)}} \tag{1}$$

Speed of emergence (SE) was measured by [3], [4], and [5] by counting emerged plants at specified intervals after emergence. Whereas [3] proposed this method as an aid to evaluate seedling vigor, he did not offer details on sampling intervals. However, [4] and [5] counted emerged plants in their plots 4, 7, and 10 days after initial emergence and weekly after the tenth day. The speed of emergence was determined by dividing the number of plants within 0.5 m of the row counted on a day by the number of days since planting. These values were summed and divided by the sampling area (2).

$$SE = \frac{\sum_{i=1}^{x} \frac{N_i}{d_i}}{A} \tag{2}$$

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where:

SE is the speed of emergence per unit area per day

N_i is the number of newly emerged seedlings counted at the day d_i, and,

A is the area

Reference [6] counted emerged corn plants 14, 18, and 22 days after planting (DAP) to determine the effect of previous soil management practices on no-till corn emergence. They made no attempt to calculate an emergence rate and noted that emergence was 92 percent complete at 14 DAP. Emergence at 22 DAP was considered complete and used to calculate emergence percent.

Reference [7] used a rate of emergence to assess the effect of tillage systems on sugarbeet emergence. Rate of emergence was defined as the percent of plants emerged divided by the number of days since planting. They conducted stand counts at three times, once when emergence was about 30 percent (based on seeds planted), again when emergence was about 60 percent, and lastly at the 4-6 true leaf stage to assess final stand. The rate of emergence at the second interval encompassed the data from the first interval, but they did not make comparisons between the two observation times.

Reference [8] counted plants daily to determine emergence rate of corn for different tillage systems and starter fertilizer treatments. They defined emergence rate as the number of days necessary to achieve 50% emergence.

Reference [9] presented an emergence rate index (ERI) to assess seeder performance (3). The ERI is based on the number of seeds planted and daily counts of the number of emerged plants.

$$ERI = \sum_{n=1}^{x} \frac{EMG_n - EMG_{n-1}}{DAP_n} \tag{3}$$

where:

EMG is the percent of plants emerged

DAP is days after planting

n is the day of the observation

Units for the ERI are percent per day and a greater ERI indicates faster emergence. The ERI does discount plants that take longer to emerge. However ERI is more weighted toward initial emergence than temporal uniformity of emergence. Consider an example where the first plant emerges on the fifth day after planting and emergence continues uniformly until the ninth day after planting, thus, taking five days for complete emergence. An alternative would be if the first plant emerges on the seventh day and emergence continues uniformly until the ninth day after planting. Now three days are required for complete emergence. If the emergence percentage is the same for the two examples, the former would have a greater ERI. If you skip a day counting, the plants that emerged on that day will get discounted to the day when you counted.

Many valid methods are available for assessing seedling emergence. While the previous mentioned methods all assess emergence rate effectively, they are not without limitations. From a seedling emergence perspective, the items of interest are the percentage of planted seeds that emerge, the date after planting when emergence begins, and the date when emergence is complete. The objective of this study was to develop a new method for evaluating plant emergence as a means of assessing seeder performance and compare this new method to a commonly used method.

II. PROCEDURES

Data used in this study were gathered as a part of other experiments. These experiments included various planter setups or operational conditions while planting corn. The different treatments were expected to have varying emergence conditions. The first initially reported in [10] was conducted at two sites with six treatments. The site (TP02) near Topeka, KS had three replications. Stand counts were taken daily 7-12 DAP and then 14 DAP. The site (PH02) near Powhattan, KS had four replications and stand counts were taken daily 7-15 DAP and again 18 DAP. The third data set (TR13) was collected in 2013 at Tribune, KS. This study had 10 treatments replicated four times resulting in 40 observations. At all three locations, stand counts were taken from sections of plots 4.5 m (15 ft) in length in the center two rows of each treatment. After the first plant had emerged, the number of emerged plants (visible coleoptiles) was counted in the sub plots. Stand counts were taken regularly as often as possible until emergence was deemed complete. A final stand count was taken a few days after complete emergence. The two rows within a plot were considered repetitive measures.

The ERI proposed by [5] was calculated for each repetition within plots and averaged for the plot. This method of calculating ERI was chosen as the benchmark because of its use by many researchers ([10], [11], [12], [13]). Emergence percent (EP) was calculated for each observation by dividing the stand count for a given day by the theoretical seed drop for the plot. An average EP was calculated across all observations (rows) for each plot based on the final stand counts.

For regression analysis, emergence data from the center two rows of each row crop plot were considered one observation and the data were pooled. All zero EP values were deleted from the data sets before regression. The zero values create a greater intercept which in turn predicts an earlier initial emergence. Emergence percentage was regressed as a function of days after planting (DAP) to fit a linear plateau (equation 4) using the PROC NLIN function in [14]. Emergence percentage (EP_M), day after planting of initial emergence (DAP_{IE}), emergence rate (ER_M), and day after planting of complete emergence (DAP_{CE}) were calculated from the regression coefficients of the equation (4). These parameters are shown graphically in figure 1. The DAP_{CE} is the inflection point of the linear plateau determined from the regression. Emergence percent is simply the plateau of the regression and can be determined from the second part of (4) using DAP_{CE}. The DAP_{IE} was calculated from the regression by setting EP equal to zero and solving for DAP. Emergence rate (percent/day) is simply the slope coefficient, b, from the regression.

$$\begin{aligned} EP &= a + b \cdot DAP \ \text{ if } \ DAP \le DAP_{CE} \\ EP &= a + b \cdot DAP_{CE} \ \text{ if } \ DAP > DAP_{CE} \end{aligned} \tag{4}$$

where,

EP is emergence percent

DAP is days after planting

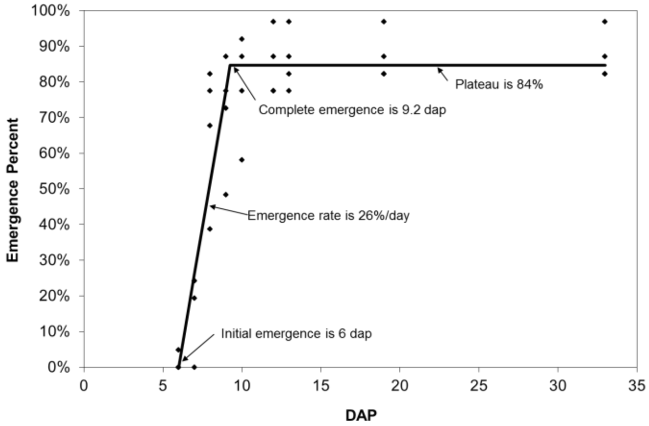

Fig. 1. Emergence percent plotted versus days after planting for one treatment within a field shown with the linear plateau regression.

DAP_{CE} is days after planting when emergence is complete

a and b are regression coefficients

III. RESULTS

The linear plateau regression analysis yields four items of interest, DAP_{IE}, DAP_{CE}, ER_M, and EP_M. Note that DAP values determined from regression are not integers. As well, the emergence values, rate and percent, are determined from regression and are not calculated.

Tables 1-3 show the correlation between the six items of interest for the corn emergence data for the three sites. The correlations are consistent at all three sites. Note that EP and EP_M are highly correlated (Fig. 2). This relationship is expected since they are simply two means to arrive at the same result. The ERI value calculated based on [9] is highly correlated with EP and EP_M. Again, this relationship is not surprising since EP is embedded in the calculation of ERI. The ERI is negatively correlated with DAP_{CE}. The negative correlation with DAP_{CE} makes sense because of the time component embedded in the ERI calculation. If complete emergence requires more time, the ERI will be lower regardless of when the first plant emerges.

TABLE 1

CORRELATIONS FOR TP02

	ERI	EP	ER_M	DAP_{CE}	DAP_{IE}	EP_M
ERI	1.000					
EP	0.937	1.000				
ER_M	0.614	0.632	1.000			
DAP_{CE}	-0.664	-0.533	-0.860	1.000		
DAP_{IE}	0.063	0.265	0.686	-0.275	1.000	
EP_M	0.930	0.968	0.548	-0.445	0.188	1.000

TABLE 2

CORRELATIONS FOR PH02

	ERI	EP	ER_M	DAP_{CE}	DAP_{IE}	EP_M
ERI	1.000					
EP	0.924	1.000				
ER_M	0.519	0.534	1.000			
DAP_{CE}	-0.503	-0.429	-0.914	1.000		
DAP_{IE}	0.089	0.213	0.718	-0.629	1.000	
EP_M	0.891	0.980	0.466	-0.354	0.192	1.000

TABLE 3

CORRELATIONS FOR TR13

	ERI	EP	ER_M	DAP_{CE}	DAP_{IE}	EP_M
ERI	1.000					
EP	0.858	1.000				
ER_M	0.617	0.635	1.000			
DAP_{CE}	-0.758	-0.352	-0.533	1.000		
DAP_{IE}	-0.512	-0.057	0.127	0.737	1.000	
EP_M	0.877	0.989	0.651	-0.386	-0.094	1.000

The ERI is positively correlated with ER_M though not to the same degree as emergence percentages. Though both are measuring emergence rate, ER_M is not as highly correlated with EP as ERI, because EP is not embedded in the calculation as in the calculation of ERI.

Comparing EP determined from regression and averaging actual data provided the most straight forward comparison. The two emergence values (EP and EP_M) were highly correlated even with the regression forced through the origin (Fig. 2). The slight under prediction of emergence percentage for TP02 and TR13 were likely due to the inflection point where the data plateaus. Describing this transition is probably more quadratic than linear. The logistic model used by [2] would likely capture this trend. However, discerning the practical values of interest, initial emergence and days to complete emergence, would be more challenging with this

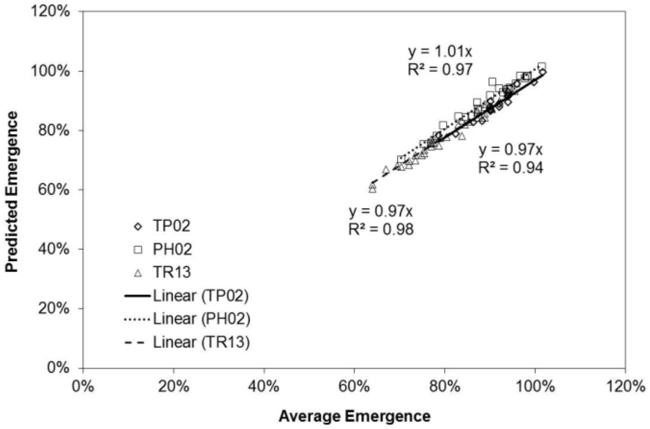

Fig. 2. Predicted emergence percentage (EP_M) from the linear plateau regression plotted as a function of average emergence percentage (EP) for the three data sets.

model.

The relationship between ERI and ER_M was not as strong as that for the two estimates of emergence percent (Fig. 3). The average ERI for the TP02 data was 10.5%/day whereas the average ER_M was 28.3%/day. The average ERI for the PH02 data was 10.1%/day while the average ER_M was 19.5%/day. For TP02 and PH02 the average ERI was similar, but the ER_M was almost nine percentage points different. The difference can be explained with the other information from the linear-plateau regression. The average DAP_{IE} at TP02 was 6.6 while the average DAP_{IE} at PH02 was 6.1. Thus the corn at PH02 started coming up about a half day earlier than TP02. However, emergence was complete at TP02 (9.9 days) before PH02 (11.3 days), so it took about 3.2 days for corn to emerge at TP02 and 5.2 days at PH02. The ERI calculation is weighted for early emergence, so the PH02 gained an initial advantage. However, because complete emergence was later, that advantage was lost. The proposed linear-plateau regression method better described the entire emergence process.

The ERI for the TR13 data set was really low relative to the ER_M. This result is because the average DAP_{IE} for this data set was 21. Though the soil temperature was adequate when the crop was planted, the temperature turned cold and the seed was in the ground a long time before it emerged. The range of emergence averaged 7.5 days across all treatments with an average ER_M of 11%/day. While the ERI certainly describes the emergence process in this case, it combines all the information related to emergence into a single value.

IV. CONCLUSION

The following conclusions can be drawn based on the results of this study.

- The method presented here proved effective in describing plant emergence in simple terms that are easily understood by researchers and crop producers alike. The outputs of this method, initial emergence date, emergence rate, complete emergence date, and emergence percent are meaningful to users and can be used to evaluate seeder performance.
- The predicted emergence percent (EP_M) was slightly less than the observed value (EP) for two data sets and similar for one. The under prediction was likely due to the oversimplification of plant emergence with a linear function.
- Emergence rate (ER) was slightly correlated with emergence rate index (ERI) proposed by [5]. The differences were attributed to separating the initial emergence date (DAP_{IE}) and ER with the proposed method whereas these items are embedded in the ERI calculation.
- To ensure a high probability of success when using linear plateau regression to describe plant emergence, the two critical times to measure stand counts are close to initial and complete emergence.

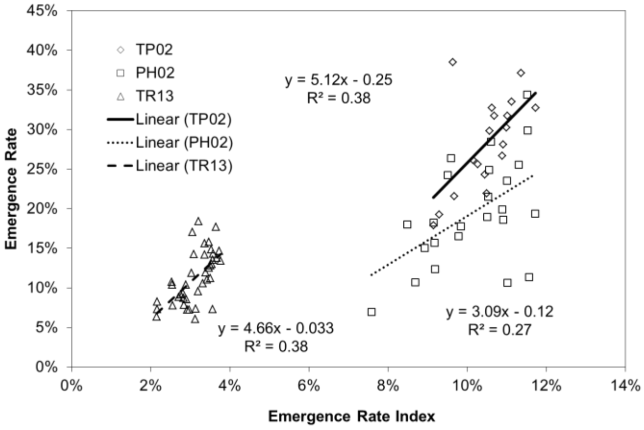

Fig. 3. Emergence rate (ER_M) from the linear plateau regression plotted as a function of emergence rate index (ERI) for the three data sets.

REFERENCES

[1] S. D. Kachman and J. A. Smith, "Alternative measures of accuracy in plant spacing for planters using single seed metering," *Trans. ASAE* Vol. 38, No. 2, pp.379-387, 1995.

[2] H. M. Nasr and F. Selles, "Seedling emergence as influenced by aggregate size, bulk density, and penetration resistance of the seedbed," Soil & Tillage Research Vol. 34, pp.61-76, 1995

[3] J. D. Maguire, "Speed of germination - aid in selection and evaluation for seedling emergence and vigor," *Crop Sci*., Vol. 2, pp. 175-176, 1962.

[4] S. Tessier, K. E. Saxton, R. I. Papendick, and G. M. Hyde, "Zero-tillage furrow opener effects on seed environment and wheat emergence," Soil & Tillage Research, Vol. 21, pp. 347-360, 1991.

[5] Y. Chen, F. V. Monero, D. Lobb, S. Tessier, and C. Cavers, "Effects of six tillage methods on residue incorporation and crop performance in a heavy clay soil," *Trans. ASAE* Vol. 47, No. 4, pp. 1003-1010, 2004.

[6] E. Perfect and N. B. McLaughlin, "Soil management effects on planting and emergence of no-till corn," *Trans. ASAE* Vol. 39, No. 5, pp. 1611-1615, 1996.

[7] J. A. Smith, R. G. Wilson, G. D. Binford, and C. D. Yonts, "Tillage systems for improved emergence and yield for sugarbeets," *Applied Eng. Agric.* Vol. 18, No. 6, pp. 667–672, 2002.

[8] J. A. Vetsch and G. W. Randall, "Corn production as affected by tillage system and starter fertilizer," *Agron. J.* Vol. 94, pp. 532-540, 2002.

[9] D. C. Erbach, "Tillage for continuous corn and corn-soybean rotation," *Trans. ASAE* Vol. 25, No, 4, pp. 906-911, 918, 1982.

[10] S. A. Staggenborg, R. K. Taylor, and L. D. Maddux, "Effect of planter speed and seed firmers on corn stand establishment," *Applied Eng. Agric.* Vol. 20, No. 5, pp. 573-580, 2004.

[11] H.M. Hanna, B.L. Steward, and L. Aldinger, "Soil loading effects of planter depth-gauge wheels on early corn growth." *Applied Eng. Agric.* Vol. 26, No. 4, pp. 551-556, 2010.

[12] M. Iqbal, S. J. Marley, D. C. Erbach, and T. C. Kaspar, "An evaluation of seed furrow smearing," *Trans. ASAE* Vol. 41, No. 5, pp. 1243-1248, 1998.

[13] M. A. Licht. and M. Al-Kaisi, "Corn response, nitrogen uptake, and water use in strip-tillage compared with no-tillage and chisel plow," *Agron. J.* Vol. 97, pp. 705-710, 2005.

[14] SAS 9.3 for Windows. 2010. SAS Institute Inc., Cary, NC, USA.

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