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Effect of Different Row Spacings and Seeders on Yield and Speed of Emergence for Corn

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ABSTRACT Corn yield and speed of emergence are important performance indicators for seeders. A field study was conducted investigating the effects of row spacing as well as two different seeders on speed of emergence and yield. Row spacings that were compared included 7.5 inch, 15 inch, 30 inch and paired rows (7.5 inch pairs, 30 inches on centre). The two seeders compared were a twin row Monosem planter and a Salford 522 air drill. Seeding depth and seeded population were intended to be held constant while emergence and yield were investigated. Measurements taken included furrow profile data, seeding depth, emerged population, speed of emergence, and yield. The planter had a wider and shallower average furrow profile than the air drill, leading to seeding depths of 44.8 mm and 52.4 mm, respectively. The planter also had much more uniform seeding depth. Emerged population was found to be 10.2 plants/m^2 for the planter and 8.8 plants/m^2 for air drill plots. The speed of emergence for planter plots was 2.5 plants/day/m^2 compared to 1.6 plants/day/m^2 for air drill plots. Yield for the planter and air drill plots was 11032 kg/ha and 10458 kg/ha, respectively. The 15 inch and 7.5 inch plots had higher yields than the 30 inch and paired row plots. Yield had a linear relationship with speed of emergence with an R^2 of 0.38. The precise seed placement of the planter was shown to improve yield compared to the air drill.

Keywords: Corn, Emergence, Yield, Spacing, Depth, Air drill, Planter

INTRODUCTION There are many questions concerning the sustainability of food and fuel production for a growing global population in the coming decades. One commodity that contributes to the global food and fuel supply is corn. This grain and many of its extracts are used to produce countless different food products on the market today as well as feed for animals such as pigs and poultry. Corn is also widely used to produce biofuels as alternatives to fossil fuels. Because of the growing demand for corn as well as the unavailability of new arable land, crop yields must increase. There are several ways to raise crop yields including plant genetics, chemicals, and fertilizers. Another method of increasing yields is to place seeds more accurately to increase germination and more efficiently use nutrients and water in the soil (Allen 2012). This study looked at that particular aspect of increasing corn yield.

Seed placement is described in multiple ways. These include seeding depth, row spacing, and in-row spacing (Liu et al. 2005). Seeding depth is important in ensuring that the seeds are deep enough to have access to water while being shallow enough to emerge to the soil surface after germination. In this experiment, the seeding depth was ideally held constant while row spacing was a variable being investigated. Row spacing and in-row spacing are vital in ensuring the seeds have sufficient access to nutrients and water while competing with weeds (Teasdale 1998). Different row spacings have been shown to affect grain yield (Lyon et al. 2009). Large row spacing such as skip row have been shown to improve yield in areas with low amounts of precipitation (Lyon et al. 2009). Population was also ideally kept constant, since yields are known to increase (Raymond et al. 2009) and decrease (Blumenthal et al. 2003; Shanahan et al. 2004) with population, depending on the soil moisture levels and other factors.

Different seeders and openers have varying levels of accuracy when comparing seeding depth, population control, and consistency of in-row spacing (Doan et al. 2005). Seeders provide differing furrow profiles and compaction levels leading to diverse results (Chen et al. 2004). A critical factor for high speed of emergence is uniform seed depth (Choudhary et al. 1985). In this experiment, dissimilar seeders are a variable being investigated for speed of emergence and yield, with similar methods to Chen et al. (2005).

The literature is in agreement that seeding depth, row spacing and population are critical factors in determining crop yield. Yield is also thought to be positively correlated with speed of emergence. Speed of emergence is connected to uniform seed depth. However, little research has been done in these regards. The objectives of this study were to (1) compare the effects of different row spacings and seeders on speed of corn emergence, plant population, seeding depth and yield, and (2) determine the best-case spacing and seeder for south-central Manitoba.

MATERIALS AND METHODS

FIELD AND EQUIPMENT DESCRIPTION Corn spacing and seeder tests were carried out on a field west of Portage la Prairie, Manitoba. The soil in the field varied from a Burnside silt loam to an Almasippi sandy loam. The corn seed variety was Pioneer 7332. Corn was planted using a twin row Monosem planter as well as a Salford 522 plot air drill. The Monosem planter rows were 8 inch spaced twin rows (each row 4 inches off centre), 30 inches on centre as shown in Figure 1 with disc openers. The Salford air drill rows were spaced at 7.5 inches as shown in Figure 2. The air also had disc openers.

Figure 1. Twin row Monosem planter.

Figure 2. Salford 522 air drill.

EXPERIMENTAL DESIGN A completely randomized experiment was conducted with four different row spacings and two different seeding implements: the planter and air drill described above. The four different spacings used were 7.5 inches, 15 inches, 30 inches, and paired rows (7.5 inch pairs, 30 inches centre to centre). Altogether there were eight treatments. Each treatment was replicated five times. Thus, there were 40 plots on the field in a completely randomized order. Each plot was 50 feet wide; five passes with the planter or four passes with the air drill. Prior to seeding, each implement was adjusted for all spacings in an attempt to seed the same population for all the plots. The seeders were also adjusted for depth in an attempt to keep the depth at 2 inches for both planter and air drill. All of the plots except the Planter 7.5 inch plots were planted on May 8th and 9th. The Planter 7.5 inch plots were planted on May 10th and 11th due to rain and time constraints. For the Planter 15 inch and Planter 7.5 inch plots, the planter drove over the same pass twice to achieve the desired spacing. This could have affected the results by increasing localized compaction on these plots more than on others. A Global Positioning System (GPS) was used to ensure the row were straight and evenly spaced.

MEASUREMENTS BEFORE SEEDING On May 4th, the plots were marked and flagged in preparation for seeding. Residue cover measurements were taken using the Rope Method. A 40-foot rope was used with a tick to mark every foot. The rope was placed diagonally and residue under the ticks was summed up.

Representative measurements of the soil were taken on May 7th, the day prior to seeding. Soil core samples were taken and oven dried to calculate the moisture content. Bulk density was also calculated from the soil cores. Soil resistance was measured using a Geotester Pocket Penetrometer (Model No. HM-502, Italy). Soil shear strength was measured using a Vane Shear meter (Geotechnics, Auckland, NZ). Representative furrow profiles were traced on May 9th using a soil profiler to be analyzed.

MEASUREMENTS AFTER SEEDING After first emergence of the corn, the first plant count was done. On each plot 10 locations were randomly flagged as in Figure 3. Each location had 5 marked rows, 4 feet long, where the plants were counted. Counts were done 4, 7, 10, and 17 days after emergence, which corresponded to May 24th, 27th, 30th, and June 6th, respectively. Speed of emergence was calculated using equation (1), popularized by Tessier et al. (1991):

$$S_E = \frac{\sum\left(\frac{N_i}{d_i}\right)}{L * s} \tag{1}$$

Where:

S_E = speed of crop emergence (plants/d/m^2),

N_i = number of newly emerged seedlings counted per day d_i,

L = length of row counted (m), and

s = row spacing (m).

The formula produces a higher result with increased populations due to more plants emerging. The equation also has a higher output if the emergence is more uniform.

The last count was taken as the final plant stand or population for each plot. This meant that only emerged plants counted towards the population count. On June 6th, seeding depth was also measured as shown in Figure 4. A single plant was dug up from each marked row and measured in millimetres from the centre of the seed to where the color started on the stem. This section is known as the mesocotyl.

Figure 3. An example of a plant count location.

Figure 4. Seeding depth measurement where D is seeding depth

The corn was harvested on October 27th and 28th using a John Deere S680 combine equipped with a 31 foot MDD-100 Mainero corn header. Unlike many corn headers, the versatility of this model allowed it to be able to take in corn from any row spacing. Before harvesting the plots, each end of the field was squared using GPS to ensure that each plot was the same length. The average plot length was found to be 2040 feet. The settings on the combine which included air speed and concave speed, among others, were set prior to the plot harvest on a separate field of corn. These settings were left unchanged throughout the course of the plot harvest.

Because the plots were 50 feet wide, one pass was taken with the combine down the middle of each plot. After such a pass, the corn was weighed on a Meridian 400SLD seed tender and then emptied onto a semi-trailer. A sample bag was also taken at that time to measure corn moisture content and bushel weight for each plot. After the corn from the plots had been harvested and weighed, the strips that were left in between plots were harvested.

DATA ANALYSIS The analysis of data was done using Statistical Analysis System (SAS) software. Using this program, various means and standard deviations were calculated. Analysis of variation (ANOVA) was used to find whether seeder, spacing, or their interaction were the cause of the differences between sets of data. The software was also used to compare means using Duncan multiple range tests to indicate statistically significant differences between results.

RESULTS AND DISCUSSION

BACKGROUND INFORMATION Data collected prior to seeding included residue cover, soil resistance, shear strength, moisture content, and bulk density. Furrow profile data comparing planter to air drill was taken during seeding. These data collection methods are outlined above. The residue cover was calculated to be 12.7% of the soil surface. Soil resistance was found to have an average of 1.59 kg/cm^2. The shear strength of the soil was found using the largest vane and had an average of 53.5 kPa. The average moisture content of the soil on the day prior to seeding was found to be 15.8% w.b., while the average bulk density on the same day was 1472 kg/m^3. The temperature of the soil on the first day of seeding was 19 °C.

When comparing the furrow profile data, there were several concepts to consider. First, the soil disturbance was quantified by soil throw (L) and roughness (h). Soil throw described the distance between the mounds left by the implement while roughness was the height of the mounds. Following this was the quantification of the profile itself using opening width (w), cutting depth (d), and furrow cross sectional area (A). Table 1 shows the compared values of the air drill profile to that of the planter.

Table 1. Furrow profile comparison between air drill and planter.

Seeder	L (mm)	H (mm)	w (mm)	D (mm)	A (mm^2)
Air Drill	116	24	71	40	1287
Planter	143	21	99	25	1509

From the L and h values it can be seen that the planter threw soil further and more evenly than the air drill. This could result in more consistent seeding depths for the planter, unless the soil was thrown far enough to have an impact on neighboring rows. When looking at the furrow profiles, it can be seen that the planter profiles had wider openings, shallower depths and larger average cross sectional areas than the air drill furrows. These variables could factor into the accuracy of the seed placement and depth.

SEEDING DEPTH Seeding depth and its uniformity has a great effect on the speed of emergence, and thus on the yield of a crop. This is due to seeds having a certain amount of energy stored for attempting to reach the soil surface. If placed too deep in the soil, the seed will be unable to reach the surface. Seeds also need moisture to start germinating. If placed too shallow, the seed may be unable to find sufficient moisture for this process.

When comparing the seeders, the average seeding depth for the planter was 44.8 mm compared to 52.4 mm for the air drill. These are statistically significant as shown in Figure 5a. This difference occurred in spite of the attempt to set the planter and air drill to the same depth. This discrepancy may have allowed the corn seeded with the planter to emerge faster since it had less distance to grow to the soil surface. When analyzing the furrow profile data, it can be seen that the cutting depth was deeper for the air drill. This is the probable cause for the deeper seeding depth.

When comparing spacings, it can be seen on Figure 5b that there are no great discrepancies between the variable spacings. The 15 inch plots showed a deeper depth at 50.6 mm compared with 48.1 mm for 30 inch, 47.8 for 7.5 inch, and 47.4 for pair row. This difference could have been due to experimental error. Seeding depth was not significantly influenced by spacing.

The uniformity of seeding depth is also imperative for high yielding crops. Uniform depth ensures a more uniform plant stand and growth. Higher uniformity allows a majority of plants to reach maturity and ripen in a smaller window, leading to higher yields. The planter was much more uniform in seeding depth, with uniformity calculated as the standard deviation of the seeding depths. The planter had a uniformity of 6.4, which was significantly lower compared to 15.0 for the air drill. This may have allowed the planter plots to grow more uniformly and produce higher yields. The uniformity for spacings all ranged from 12.6 to 16.2, or within reasonable error.

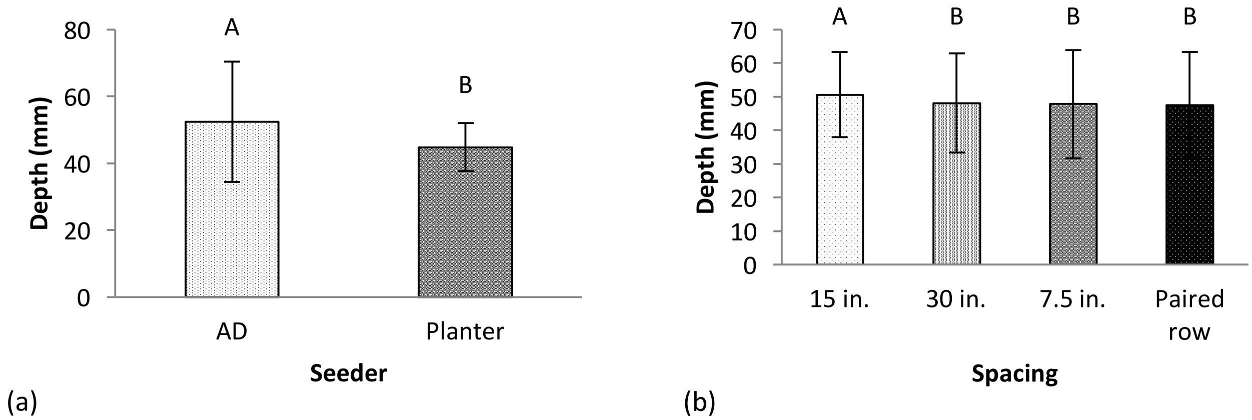

Figure 5. Effects of seeder (a) and row spacing (b) on seeding depth (error bars represent uniformity as standard deviation; different letters indicate significant difference at $p<0.05$).

PLANT POPULATION Population is a variable that can have an effect on the speed of emergence as well as yield. Lower populations could allow plants freedom from competition with each other. This would be advantageous in years and locales where resources such as water and nutrients are scarce. Higher populations could produce higher yields in years and settings where water and nutrients are in excess. In this experiment, attempts were made to keep the population constant from plot to plot. However, this was not quite attainable due to the limitations of the planter settings. It is important to note that population measured for this paper was the emerged population.

When comparing between seeders, the average population for the planter was 10.2 plants/m^2 compared to 8.8 plants/m^2 for the air drill. This translated to a 16% difference. As noted above, this difference could have been caused by non-ideal placement of seed by the air drill resulting in poor germination, causing a lower emerged population.

Among planter plots, the 7.5 inch plots had the highest average population at 10.5 plants/m^2. This was due to the inability of the planter to be set any lower. The other populations ranged from 9.1 plants/m^2 for 15 and 30 inch plots to 9.4 plants/m^2 for the paired row plots. This difference in the 7.5 inch plots was caused by the planter 7.5 plots and was also the biggest cause of the greater planter population measured. This discrepancy could have caused differences in the yield of the crop. Other than this outlier caused by experimental error, spacing had no effect on population.

SPEED OF EMERGENCE Another important variable to compare is speed of emergence of the seedlings, as it can help predict yield differences. The earlier the crop emerges, the more sunlight it can absorb to begin growing and competing with weeds. This is especially true for corn, a crop that has high demands for sunlight. High speed of emergence could be the result of increased population. Higher speed of emergence also signifies more uniform development of the crop, which could lead to a higher yield, as discussed in the seeding depth section.

When comparing the seeders, the average speed of emergence for the planter was 2.5 plants/day/m^2 compared to 1.6 plants/day/m^2 for the air drill, as shown in Figure 6a. This was statistically significant and translated to a 56% difference in speed of emergence. Part of this large difference was due to the higher population of planter 7.5 plots which in turn elevated the speed of emergence. However, when the planter 7.5 plots were omitted, the planter had a speed of emergence of 2.4 plants/day/m^2, which was still much higher than that of the air drill. It is likely that the higher speed of emergence was caused at least in part by the shallower and more uniform seeding depth of the planter. These factors likely allowed the corn seeded by the planter to emerge faster and more uniformly.

Among planter plots, the 7.5 inch plots were found to have the quickest average speed of emergence as shown in Figure 6b. Among air drill plots, there were no statistical discrepancies between the different plot types. When the speed of emergence for the planter 7.5 plots were ignored, no statistically significant differences between spacings were present.

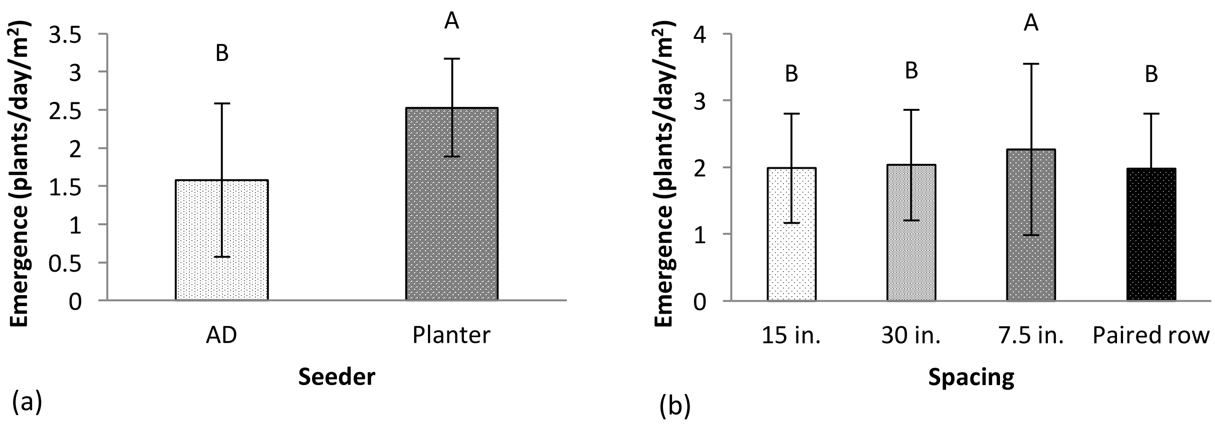

Figure 6. Effects of seeder (a) and row spacing (b) on speed of emergence (error bars indicate standard deviation of the replicates; different letters indicate significant difference at $p<0.05$).

CORN YIELD For grain crops, yield is typically the most important measurable to consider when comparing between treatments. This is because yield directly relates to the profitability of the crop, while other measurable variables such as speed of emergence and seeding depth may not translate into profit.

When comparing effects of the seeders, average yield for the planter was 11032 kg/ha compared to 10458 kg/ha for the air drill. This difference was statistically significant as shown in Figure 7a. This translated to a 5.5% difference in yield. The planter also had more uniform and predictable yield with a standard deviation of 350 kg/ha compared to the air drill standard deviation of 502 kg/ha. The planter had shallower and more uniform depth, which may have caused faster and more uniform speed of emergence as outline above, leading to higher yields than the air drill.

When comparing effects of spacing only, yield was found to be the highest for 15 inch plots at 11129 kg/ha. The 7.5 inch plots were not statistically different than this at 10911 kg/ha. The 30 inch and paired row plots were significantly lower at 10320 kg/ha and 10548 kg/ha, respectively. These differences are displayed on Figure 7b as Duncan groupings A and B.

These results could have been influenced by the high volume of precipitation this season. Increased precipitation could have allowed closely spaced plants to thrive due to reduced competition for moisture. However, if this was the only cause of differing results, paired row plots should have thrived as well. The 15 and 7.5 inch plots likely had the most evenly spaced plants. This could have caused higher yields as plants could have avoided competing with each other. The 7.5 inch results could have been influenced by the higher population discussed in previous sections. The 15 and 7.5 inch plots could also have been influenced by the extra compaction due to the double passes made by the planter, although the expected result of compaction would be lower rather than higher yield.

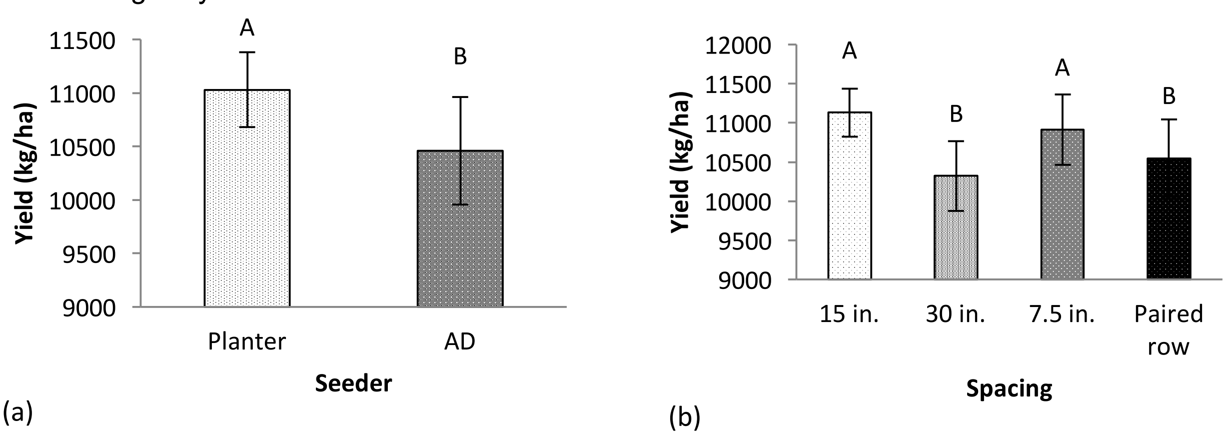

Figure 7. Effects of seeder (a) and row spacing (b) on yield (error bars indicate standard deviation of the replicates; different letters indicate significant difference at p<0.05).

The yield was found to have a relationship with the average speed of emergence for each plot. This is displayed on Figure 8, with the linear relationship shown. This linear trend had an R^2 value of 0.38, meaning 38% of the variation in yield could be attributed to variation in speed of emergence. The relationship established demonstrates that uniform and quick speed of emergence affects the yield of the crop.

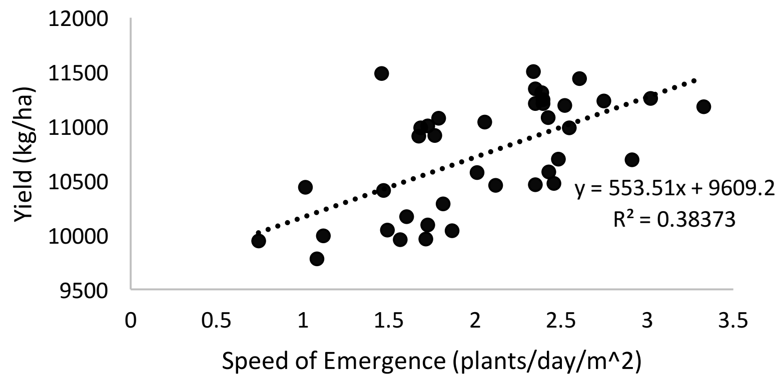

Figure 8. Relationship of yield to speed of emergence

CONCLUSION The objectives of this study were to (1) compare the effects of different row spacings and seeders on speed of corn emergence, plant population, seeding depth and yield, and (2) determine the best-case spacing and seeder for south-central Manitoba. Planter plots yielded 11032 kg/ha while air drill plots yielded 10458 kg/ha. The 15 inch plots and 7.5 inch plots yielded 11129 kg/ha and 10911 kg/ha, respectively, compared to the 30 inch and paired row plots yielding 10320 kg/ha and 10548 kg/ha, respectively. Yield was positively correlated with speed of emergence. Speed of emergence, plant population, and seeding depth were all shown to be affected by seeders and spacings.

To conclude, the planter provided more consistent seeding depth than the air drill, leading to faster speed of emergence, which induced a higher yielding crop. Also, 15 inch and 7.5 inch spacing produced higher yields than 30 inch and paired rows. The best-case spacing and seeder for south-central Manitoba in a year with similar environmental conditions would be a planter spaced at 15 inches. One limitation of this study was that the population and seeding depth were not successfully held constant. With this study being conducted over one year only, there were limitations in drawing conclusions. It would be of particular interest to investigate the results of this study over several years to account for variation in precipitation and climate. Differing populations and seeding depths should also be investigated as variables in the future.

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