EFFECT OF DOWNFORCE ON THE PERFORMANCE OF NO-TILL DISC FURROW OPENERS FOR CLAY-LOAM AND LOAMY SOILS

VERTIKALIOS SPAUDIMO JĖGOS ĮTAKA TIESIOGINĖS SĖJOS DISKINIŲ NORAGĖLIŲ DARBUI PRIEMOLIO IR MOLIO DIRVOSE

1) Davut Karayel, 2) Egidijus Šarauskis

1) Akdeniz University, Faculty of Agriculture, Agricultural Mach. Dept., 07070 Antalya–Turkey, e-mail: dkarayel@akdeniz.edu.tr
2) Aleksandras Stulginskis University, Department of Agricultural Machinery, Lithuania, e-mail: egidijus.sarauskis@asu.lt

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Seed placement uniformity and failure to establish a uniform plant stand are critical problems associated with no-tillage production of maize (Zea mays L.) following wheat (Triticum aestivum). The objective of this research was to evaluate the effect of different downforces (680, 880, 1150 and 1400 N) on performance of disc furrow openers and determine the optimum downforce for modified precision seeder equipped with single or double disc-type openers. The study was conducted in two different field conditions (field I and field II). The soil of field I and II were clay-loam and loamy, respectively.

Seed spacing uniformity, sowing depth uniformity, mean emergence time and percentage of emergence were determined. Sowing depth and seed spacing uniformity, mean emergence time and percentage of emergence of both furrow openers were increased as a result of increasing downforce for both fields. The downforce of modified conventional precision seeder should be greater than 880 N for more precise no-till sowing using with single and double disc furrow openers for clay-loam and loamy soils.

Seeder, no-till sowing, downforce, furrow opener, seed placement, maize.

Introduction

Conservation tillage is defined to be any tillage/sowing system which leaves at least 30% of the field covered with crop residue after sowing has been completed. The continuous development of conservation tillage technologies has led to studies on the performance of no-till seeders. No-till sowing requires a seeder that will effectively penetrate untilled soil and place the seed at the optimum depth for rapid plant emergence. The furrow openers are the only components of any machine which actually break the soil surface. In no-tillage sowing, they are required to perform all of the functions necessary to physically prepare a seedbed and sow the seed.
The types of furrow openers used vary with soil and operating conditions. The common types of furrow openers used for minimum and no tillage systems are single and double disc-type openers. Furrow openers for no-till seeding require an effective downforce to cut through surface residues and penetrate hard soil to a specific depth. This force typically ranges between 700 and 2300 N (Schaaf et al., 1979) depending on the field conditions encountered. Maintaining a constant force on openers while seeding will help to achieve a uniform seeding depth under a uniform soil condition. Constant seeding depth is important to achieve uniform seedling emergence (Choudhary et al., 1985; Gratton et al., 2003).

Janelle et al. (1993) studied seed placement of two double disc openers under three different downforces (669, 1338, and 2007 N). They reported that the smallest downforce resulted in insufficient seeding depth and consequently poor crop emergence. Increasing downforce generally increases seeding depth. Gratton et al. (2003) studied on the development of a mathematical optimization approach for the design of a no-till opener downforce system. Two design alternatives, a spring-loaded single linkage and spring-loaded parallel linkage, were considered for the replacement of a hydraulically loaded downforce system. The prototype spring-loaded parallel linkage was tested in laboratory and in field conditions. Compared to the hydraulically loaded parallel linkage, the spring system resulted in approximately 50% smaller changes in downforce.

Tajudin and Balasubramanium (1995) evaluated hoe, shoe, wedge, single-disc and double-disc furrow openers used in bullock drawn seeder. Each furrow opener was tested with vertical forces of 0, 78.5, 157 and 245 N by adding dead weights. A performance index was developed to compare the furrow openers. Single-disc furrow openers gave the best performance index mainly due to lower unit draught, i.e. draught per unit area of furrow. Wedge-type openers required the maximum power. Double-disc openers had lower unit draught but the performance index of the opener was affected due to poor penetration.

Many studies have been conducted on seeding depth (Ozmerzi et al., 2002), opener types and designs (Choudhary et al., 1985; Karayel and Ozmerzi, 2005), press wheel configurations (Morrison and Gerik, 1985), and drill types (Tessier et al., 1991). However, little work has been done on determination optimum downforce for different furrow opener design. The objective of this research was to evaluate the effect of downforce on the performance of disc furrow openers and determine if the downforce of a commercial modified precision seeder performing cutting, penetration, and furrow closure is enough under no-tillage conditions in clay loam and loamy soils. A modified conventional precision seeder equipped with single and double disc furrow openers was used for no-till sowing of maize. Because no-tillage is a relatively new technique, new and different equipment has to be purchased or hired. The price of the no-till seeders is the main limitation to no-tillage in Turkey. Modifying the conventional seeders commonly used in Turkey may be key factor in the shift to no-till sowing.
Materials and methods

The study was conducted in July 2006 at the Research and Application Land of Akdeniz University in two different field conditions (field I and field II) with previous wheat crop residue. The soil of field I, composed of 2% sand, 56% silt, and 42% clay, was classified as clay-loam. The soil of field II, composed of 28% sand, 46% silt, and 26% clay, was classified as loamy. The wheat was harvested by a combine harvester leaving relatively uniform stubble. The average residue mass before sowing operation was 1.7 and 1.6 t ha\(^{-1}\) for field I and II, respectively. Moisture content of the soil for the top 50 mm before sowing was 21.8 and 22.1% for field I and II, respectively. Maize (\textit{Zea mays L.}) seed of 235 g 1000\(^{-1}\) seeds was used for all treatments.

Four downforces (680, 880, 1150 and 1400 N) for each furrow opener (single and double disc) were considered as treatment. Plot dimensions were 5 by 25 m and the measurements taken in each plot were: the distance between seedlings, depth of seed placement and number of seeds emerged per day.

A precision vacuum seeder was modified to allow simultaneous mounting of two different furrow openers. The seeder was a general-purpose seeder designed for row crops such as maize and soybean (Figure 1). A seed plate operated in a vertical plane and required a vacuum of 3.5 to 8.0 kPa to select a seed. Air suction from the holes of the seed plate caused the seed to stick to holes 4 mm in diameter. Seed was released from the rotating plate by blocking air suction over the opener, which had no seed tube. Each sowing unit was independently mounted on a parallelogram by joint springs and was composed of a furrow opener followed by a presswheel, which closed and compacted the seed furrow. The seed metering system was adjusted for a nominal seed spacing of 204 mm in the row and a nominal depth of 50 mm. The seeder was operated at a speed of 5 km h\(^{-1}\).

The downforce of seeder unit for performing cutting, penetration, and furrow closure was 680, 880, 1150 and 1400 N obtained by either adjustment of compression spring length or additions of 270 and 520 N ballast weights.

\textbf{Fig. 1.} The modified precision vacuum seeder for no-till sowing: 1 – seed hopper; 2 – compression spring; 3 – Wavy-edged disc; 4 – furrow opener; 5 – presswheel

\textbf{1 pav.} Patobulinta vakuuminė tiesioginės sėjamosi: 1 – sėkladėžė; 2 – spaudimo įtaisas; 3 – banguotas-karpytas diskas; 4 – noragėlis; 5 – prispaudimo volelis
Single and double disc-type furrow openers were used in the study because disc openers are becoming more popular where minimum and no-tillage systems are used and there is a greater amount of residue left on the surface. The single and double disc-type furrow openers were designed and fabricated from highcarbon steel plates 3.5 mm thick (Figure 2). Each furrow opener assembly comprised a vertical shank and an axle to which the furrow opener was mounted via a bearing. The furrow opener shank assembly was designed in such a way that the furrow opener could easily float, avoid side force and follow the direction of machine travel. A wavy-edged disc was 400 mm in diameter mounted in front of furrow opener. The distance between the centres of each wavy-edged disc to the following furrow opener was set at 450 mm.

![Fig. 2. Furrow openers as used in the experiment: (a) single disc-type opener; (b) double disc-type opener](image)

After sowing, horizontal and vertical seed distribution patterns, mean emergence times (MET), and percentage of emergence (PE) were compared. The distance between the nearest neighbouring seedlings was measured in the horizontal plane. Seedling spacings were measured in the field 17 days after sowing between about 30 seedlings for each treatment. Mean and coefficient of variation (CV) were calculated from the seed spacing's.

The depths of the seeds to the soil surface were measured in the vertical plane. Mean sowing depth and coefficient of variation were determined by measuring the mesocotyl length of 30 maize and soybean seedlings to the nearest 1.0 mm for each replication.

Seedling counts were made in 25 m of row per treatment every day during the emergence period. From these counts, mean emergence time and percentage of emergence were calculated as (Karayel and Ozmerzi, 2002):

\[
MET = \frac{N_1T_1 + N_2T_2 + \ldots + N_nT_n}{N_1 + N_2 + \ldots + N_n}
\]

(1)

\[
PE = \frac{S_n}{n}
\]

(2)
where $N_{1...n}$ – is the number of seedlings emerging since the time of previous count; $T_{1...n}$ – is the number of days after sowing; $S_{te}$ – is the number of total emerged seedlings per meter; $n$ – is the number of seed sown per meter; $MET$ – is the mean emergence time, in day and $PE$ is the percentage of emergence.

A split-plot experiment was selected for the experiment. Each treatment was replicated three times. Analysis of variance was determined using the SAS package (Carry, N.C.) to examine the effects of treatments. Duncan’s multiple-range tests were used to identify significantly different means within dependent variables at $P \leq 0.05$.

**Results**

Performance of single and double disc-type openers was analyzed related to the sowing uniformity of horizontal and vertical seed distribution pattern, mean emergence time and percentage of emergence. Seed spacing, sowing depth, mean emergence time and percentage of emergence were combined for analysis of variance to determine the significant difference in the variability among the parameters. The results of the analysis show that the seed spacing were not significantly influenced by down force or furrow openers for both fields.

Comparison of data on overall average coefficient of variation of seed spacing as affected by down force and furrow opener treatments shows the highest coefficient of variation for the down force of 680 N for both furrow openers and fields (Table 1). Coefficient of variation (CV) of seed spacing is a measure of the variability in spacing’s between plants after accounting for variability due to both multiples and skips. A practical upper limit for coefficient of variation is 29%. Smaller values of coefficient of variation indicate better performance than larger values (Kachman and Smith, 1995). The range of coefficient of variation of seed spacing of all down forces experienced in this study was 22.8–18.1 for field I and 22.9-17.0% for field II which is well below 29% and therefore is acceptable.

**Table 1.** The sowing uniformity of horizontal distribution patterns for different downforces and furrow openers.

<table>
<thead>
<tr>
<th>Down force (N)</th>
<th>Field I</th>
<th>Field II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single disc-type opener</td>
<td>Double disc-type opener</td>
</tr>
<tr>
<td></td>
<td>Mean seed spacing (mm)</td>
<td>CV of seed spacing (%)</td>
</tr>
<tr>
<td>680</td>
<td>201</td>
<td>21.9</td>
</tr>
<tr>
<td>880</td>
<td>199</td>
<td>21.2</td>
</tr>
<tr>
<td>1150</td>
<td>200</td>
<td>19.1</td>
</tr>
<tr>
<td>1400</td>
<td>197</td>
<td>18.4</td>
</tr>
</tbody>
</table>

**I lentelė.** Sėklu įterpimo horizontalaus pasiskirstymo tolygumas priklausomai nuo noragėlių konstrukcijos ir juos veikiančių vertikalių spaudimo įėgų.
Analysis of combined data showed significant differences in mean sowing depth occurring among down forces and furrow openers. Table 2 shows the influence of the down forces and furrow openers on uniformity of sowing depth. The mean sowing depth has increased and coefficient of variation of depth has decreased as a result of increasing down force for both furrow openers and fields. The actual mean sowing depths are nearly equal to nominal sowing depth of 50 mm for down forces of 1150 and 1400 N. The mean sowing depth of double disc-type opener is generally higher than single disc-type opener for all down forces. While the best uniform sowing depth was obtained for plots sown by the double disc-type opener at the down force of 1400 N, the worst results are obtained for plots sown by the single disc-type opener at the down force of 680 N. Because of the lower coefficient of variation of sowing depth, sowing depth uniformity of the double disc-type opener is generally better than single disc-type opener.

**Table 2.** The sowing uniformity of vertical distribution patterns for different downforces and furrow openers.

<table>
<thead>
<tr>
<th>Down force (N)</th>
<th>Field I</th>
<th>Field II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single disc-type opener</td>
<td>Double disc-type opener</td>
</tr>
<tr>
<td></td>
<td>Mean sowing depth (mm)</td>
<td>CV of sowing depth (%)</td>
</tr>
<tr>
<td>680</td>
<td>32 d</td>
<td>27.7</td>
</tr>
<tr>
<td>880</td>
<td>38 c</td>
<td>20.2</td>
</tr>
<tr>
<td>1150</td>
<td>48 b</td>
<td>15.1</td>
</tr>
<tr>
<td>1400</td>
<td>51 a</td>
<td>14.6</td>
</tr>
</tbody>
</table>

*: Means followed by same letter within a column are not significantly different at probability P=0.05, by Duncan’s multiple range test.

The negative effect of the smaller down forces of 680 and 880 N on the coefficient of variation of sowing depth is evident for both furrow openers and fields. Our results support reports from Morrison and Gerik (1985), Janelle et al. (1993) and Gratton et al. (2003) who reported the negative effect of decreasing down force on uniformity of sowing depth. According to Table 3, down force of 680 N resulted in the least mean emergence time, the reason might be lower sowing depth in soil at the lower down force. The analysis of combined data showed a significant difference in percentage of emergence due to down force (P<0.05). The percentage of emergence was not significantly influenced by furrow openers. The data on the final percentage of emergence has increased as a result of increasing down force for both furrow openers and fields.
Table 3. Mean emergence time (MET) and percentage of emergence (PE) for different downforces and furrow openers.

| Downforce (N) | Field I | | Field II | | |
| | Single disc-type opener | Double disc-type opener | | Single disc-type opener | Double disc-type opener |
| | MET (days) | PE (%) | MET (days) | PE (%) | MET (days) | PE (%) |
| 680 | 7.1 c | 67.1 c | 7.2 c | 68.2 c | 7.0 c | 66.7 c |
| 880 | 8.1 b | 70.9 b | 8.3 b | 71.7 b | 8.0 b | 69.9 b |
| 1150 | 8.7 a | 74.7 a | 8.9 a | 74.9 a | 8.5 a | 73.8 a |
| 1400 | 8.8 a | 75.1 a | 9.1 a | 76.2 a | 8.7 a | 74.5 a |

*: Means followed by same letter within a column are not significantly different at probability P=0.05, by Duncan’s multiple range test.

Due to the best uniform sowing depth, percentage of emergence of downforces of 1150 and 1400 N was the highest. Our results support reports from Heege (1993), Ozmerzi et al. (2002), Karayel (2005) and Ozmerzi and Karayel (2006) who found the negative effect of high variation in sowing depth on percentage of emergence. It can be concluded that the position of the seed in the soil effects mean emergence time and percentage of emergence of plants. The maximum downforce of modified precision vacuum seeder used for this research was 880 N at the maximum spring load, with the seed hopper full of maize seeds and without ballast weights. As a result of these tests, the downforce of modified precision vacuum seeder should be greater than 880 N for more precise no-till sowing using with single and double disc furrow openers for clay-loam and loamy soil conditions.

Conclusion

The following conclusions were made on the basis of this research. Decreasing the downforce of modified precision vacuum seeder resulted in a higher coefficient of variation of seed spacing and sowing depth for both furrow openers and fields. The range of coefficient of variation of seed spacing of all downforces experienced in this study was well below 29% and therefore is acceptable. The negative effect of the smaller downforces of 680 and 880 N on the coefficient of variation of sowing depth is evident for both furrow openers and fields. Due to the best uniform sowing depth, percentage of emergence of downforces of 1150 and 1400 N was the highest. Downforce of modified precision vacuum seeder should be greater than 880 N for more precise no-till sowing using with single and double disc furrow openers for clay-loam and loamy soil conditions.
Acknowledgements

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Santrauka

Sėklų įterpimo tolygumas ir netinkamas pasėlio formavimas yra pagrindinės problemas sėjant kukurūzus (Zea mays L.) į kviečių (Triticum aestivum) ražieną.

Tyrimais nustatyta sėklų paskleidimo tolygumas, sėklų įterpimo tolygumas, vidutinis sėklų sudarymo laikas ir sėklų sudarymas. Didinant noragėlių veikiančią vertikalą spaudimo jėgą, abiejose dirvose nustatytas sėjos gylio ir sėklų paskleidimo tolygumo bei vidutinio sėklų sudarymo laiko ir sėklų sudarymo gerėjimas. Viendiskiais ir dvidiskiais noragėliais tiesiogiai sėjant priemolio ir molio dirvose geresi sėjos kokybės rodikliai gaunami, kai vertikali spaudimo jėga didesnė negu 880 N.

Sėjamoji, tiesioginė sėja, vertikali spaudimo jėga, noragėlis, sėklų įterpimas, kukurūzai.

Д. Карелил, Э. Шараускис

ВЛИЯНИЕ ВЕРТИКАЛЬНО ДЕЙСТВУЮЩЕЙ СИЛЫ НАЖИМА НА ДИСКОВЫЕ СОШНИКИ ПРИ ПРЯМОМ ПОСЕВЕ В СУГЛИНИСТЫХ И ГЛИНЕВЫХ ПОЧВАХ

Резюме

При прямого посева кукурузы (Zea mays L.) в стерию пшеницы (Triticum aestivum) существуют основные проблемы равномерность внесения семян и качество формирования посева. Цель исследований – определить влияние вертикальной силы прижима разной величины (680, 880, 1150 и 1400 Н) на качество работы дисковых сошников, обосновать ее оптимальную величину для усовершенствованной сеялки одно-, двухдисковыми сошниками. Исследование проведены в двух различных полевых условиях (почва I и почва II). Почва I – суглинок, II – глина.

Исследованиями определено равномерность распределения и внесения семян, среднее время появления всходов и всхожесть посева. В обоих случаях определено улучшение равномерности распределения и внесения семян, средней временно появления всходов и всхожести посева при увеличении вертикальной силы прижима дисковых сошников. Наилучшие результаты в обоих полевых условиях достигаются при вертикальной силы прижима одно-, двухдисковых сошников прямого посева выше 880 Н.

Сеялка, прямой посев, вертикальная сила прижима, сошник, внесение семян, кукурузы.