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RESEARCH ARTICLE

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Disturbance of Ultisol soil based on interactions between furrow openers and coulters for the no-tillage system

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Abstract

The present study evaluated the effect of different associations between coulters and fertilizer furrow openers on soil disturbance, furrow depth and width, according to forward speed. The study was conducted on a farm in Santa Maria (Brazil/RS), in soil classified as sandy loam Ultisol. The experiment consisted of 24 combinations of treatments with three replications in a 2×3×4 factorial experiment. The combinations were formed by the interaction of the factors including: two types of furrow openers (hoe and double-disc), three types of coulters (no-coulter, smooth and offset fluted) and four levels of forward speed (1.11, 1.67, 2.22 and 2.78 m/s). Soil elevation and soil disturbance area profiles were obtained with the use of a micro profilometer, and disturbance values were calculated with the aid of computer software program Auto Cad. The disturbance area was not affected by speed; it was greater when using the hoe opener, and in association with the offset fluted coulter. Speed was inversely proportional to the depth of the furrows made by the hoe opener. Furthermore, the hoe caused the greatest furrow width (0.26 m) in comparison with the double-disc (0.24 m). The use of different coulters associated with furrow openers increased this variable (0.23 m for the no-coulter condition, 0.25 m with smooth and 0.26 m with offset fluted). The use of coulters combined with furrow openers reduces soil swelling, in approximately 8% for the smooth and 20% for the offset fluted.

Additional key words: agricultural engineering; elevated soil area; hoe furrow opener; mismatched double discs; row crop planter; soil disturbance area.

Abbreviations used: ANOVA (analysis of variance); Da (soil disturbance area); Dv (soil disturbance volume); Ea (Soil elevated area); EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária); FWA (front wheel assist); HFO (hoe furrow opener); IS (inter-row spacing); Mfd (maximum furrow depth); MFO (mismatched double-disc furrow opener); Mfw (maximum furrow width); NC (no-coulter condition); OC (offset fluted coulter); SC (smooth coulter); Ss (swelling).

Authors' contributions: Conceived and designed the experiments: TRF and ASA. Performed the experiments: TRF, ASA, ODCM, AAV and DPC. Analyzed the data: TRF. Contributed reagents/materials/analysis tools: TRF, ASA, CB, ODCM and DPC. Wrote the paper: TRF and ODCM.

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Introduction

The penetration and movement of a tool into the soil is an action that can be described by a composite behavior, since the soil is usually disturbed by some combination of cutting, shearing, compaction and flow, as the device is forced into the soil (Portella, 1983).

The phenomena arising from the performance of soil tools can be divided into two actions: vertical soil displacement and soil disturbance area. To determine these actions, three profiles should be studied: natural soil surface, soil surface elevation, and internal profile of disturbed soil. The soil disturbance area is the area between the natural profile and the bottom of the furrow, while the elevation area is the one between the original profile and the soil surface after its disturbance. The evaluation of the area between the profiles can be determined by means of graphical representations; the different representations of their areas can be surveyed by means of planimetric techniques and/or computer software programs, as recommended by Conte *et al*. (2009), Santos *et al*. (2010), Hasimu & Chen (2014) and Francetto *et al*. (2015).

Another important feature that results from the elevation area is swelling, which represents the increase in soil volume after the use of tools (Brandelero *et al*., 2014), due to the increase in the voids between solid particles.

Soil disturbance depends on working depth, length and width of the tool, as stated by Spoor & Godwin (1978) and Chen *et al*. (2013), besides soil moisture and density. According to Collares *et al*. (2006) and Mazurana *et al*. (2011), this action results in reduced soil density and mechanical resistance, and increased macroporosity (Marcolan *et al*., 2007; Rosa *et al*., 2008; Nunes *et al*., 2015), which provides reduction of critical soil density according to Logsdon & Karlen (2004), basic conditions for the proper development and productivity of agricultural crops, as evidenced by Debiasi *et al*. (2010). Veiga *et al*. (2007) explain that soil disturbance at the sowing row decreases soil resistance to penetration up to twelve centimeters when using a hoe furrow opener, and there is no formation of compacted layers with higher resistance to root penetration in the soil.

According to Jin *et al*. (2012) and Brandelero *et al*. (2014), different furrow opener devices have a direct effect on seeding quality, since they behave differently and provide different conditions. Furrow-opening tools for line seeders differ in coulters, used for vegetation cover management, and furrow openers, which can be fixed, as in the case of the hoe, or rotary, namely, double-discs. To characterize the performance of seeders' furrow-opening tools, Mion & Benez (2008) and Levien *et al*. (2011), while evaluating soil disturbance caused by different tools, showed that the hoe opener disturbs the soil to a larger extent, in comparison to double-discs. Modolo *et al*. (2012) also confirmed that the hoe causes more soil disturbance than the double-discs, and found values of 0.0045 m² for the former and 0.0037 m² for the latter. Moreover, Casão Júnior *et al*. (2000) found that the hoe reduces plant residue on the furrows, although this effect may also be associated with speed, which is also reflected in other types of furrow openers, as explained by Celik & Altikat (2012).

Coulters also produce different effects, and according to Silva *et al*. (2012), the offset fluted and smooth coulters generally increase disturbance of the seedbed soil, the effect of the former being more significant. Mion *et al*. (2009) corroborated this statement, since they found significant differences in soil disturbance by these mechanisms, with 0.0015 m² values for smooth coulters and 0.0041 m² for the offset fluted. However, Santos *et al*. (2010), while also analyzing different coulters, found higher disturbance area values for the smooth (0.0087 m²) in comparison with offset fluted coulters (0.0074 m²). These two studies focused on coulters alone, and did not associate them with other mechanisms.

Casão Júnior *et al*. (2000) and Silveira *et al*. (2011) evaluated the influence of operating speed on maize sowing with a row crop planter fitted with the hoe opener, and concluded that furrow depth was reduced by operating speed and that the soil disturbance area was increased with higher speed. Cepik *et al*. (2005), when evaluating the volume of soil disturbance by a row crop planter with five lines, fitted with hoe openers, according to the speed, found a mean value of 121.80 and 135.90 m³/ha, showing a 12% increase when sowing speed went from 1.25 m/s to 1.81 m/s. However, Bellé *et al*. (2014) and Gassen *et al*. (2014), when evaluating hoe openers for soil scarification, and Francetto *et al*. (2015), when analyzing furrowers of planters, found no influence of increased speed on soil mobilization.

The objective of this study was to evaluate the performance, in relation to the disturbance of the soil, of different associations of coulters and fertilizer furrow openers of a row crop planter for the no-tillage system, under different forward speeds, in a red Ultisol soil.

Material and methods

The experiment was conducted on a farm in the municipality of Santa Maria (Rio Grande do Sul). The geographical coordinates of the site are 29º54'08'' south latitude and 53º49'39'' west longitude, with an average altitude of 97 m asl. Soil cover was characterized by ryegrass (*Lolium multiflorum*), weeds and soybean (*Glycine max*) crop residues, with 287.20 g/m^2 dry matter, measured by oven-drying. Historically, there is alternation between soybean crops and grass for grazing activity in the area in the winter, under the no-tillage system.

The physical characterization of the soil was carried out by field sampling at the depth of 0 to 0.20 m, following the methodology proposed by EMBRAPA Solos (1997) for the determination of soil density and moisture content. There was an average value of 1.64 g/cm^3 in the first sampling, and 13.15% in the second. Soil texture was characterized with the use of the Vettori method: 17.59% clay, 28.44% silt and 53.97% sand; thus, the soil was considered to be a sandy loam. It was classified as red Ultisol by EMBRAPA Solos (2013). Soil penetration resistance was determined by using a

Falker PLG 1020 electronic penetrometer; a mean value of 1,220 kPa was found. The evaluation was conducted at depth from 0 to 0.40 m, with data being collected every 0.01 m deep.

The overall assessment set allowed the installation of associations between coulters and furrow openers, which characterized the treatments applied, consisting of a New Holland, TL75E Exitus 4×2-wheel drive farm tractor with front wheel assist (FWA), with shipping weight of 3,390 kg, used to pull a mobile tool holder structure characterized by a chassis structure, coupling, wheels and tool suspension systems for maneuvers (Fig. 1e). During the experiment, the differential lock was not activated and the FWA was turned off. Internal pressure of front tires (12.4-24) was 190.0 kPa and that of rear tires (18.4-30) was 180.0 kPa.

The furrow opener elements used were a hoe furrow opener (HFO) (Fig. 1a) and the mismatched double-disc (Fig. 1b) (MFO). Both furrow openers were manufactured in Brazil. The hoe had a 55º angle of attack, 20 mm tip thickness and 10 mm shank thickness. The double-discs have a diameter of 390 mm, 12º angle between the rotary planes of the discs, and 70 mm height for the point of contact. By adjusting the tool holder, the working depth was 0.12 m for the hoe opener and 0.07 m for the double-discs.

The cutting discs used were a smooth coulter (SC), shown in Fig. 1c, and a offset fluted with 20 waves (OC), shown in Fig. 1d, as well as a no-coulter condition (NC). The coulters both measured 460 mm in diameter and worked to a 50 mm cutting depth. The associations between furrow openers and cutting discs are shown in Fig. 2.

The treatments consisted of the interaction between the following factors: furrow opener mechanism (with 2 levels: HFO and MFO), type of coulter (with 3 levels: NC, SC and OC) and seeding speeds (with four levels: 1.11, 1.67, 2.22 and 2.78 m/s). The experiment used a randomized complete block design, consisting of 24 treatments with three replications each, in a 2×3×4 factorial arrangement, in a total area of 4,320 m². The plots measured 180 m², 3 m wide and 60 m long.

The effects of the coulters and furrow openers were determined in three stages, evaluating the natural soil


(a) (b) (c) (d)

(e)

Figure 1. Furrow openers, coulters and motor-mechanic set: Hoe furrow opener (a), mismatched double-disc furrow opener (b), smooth coulter (c), offset fluted coulter (d) and set tractor and mobile tools holder (e).

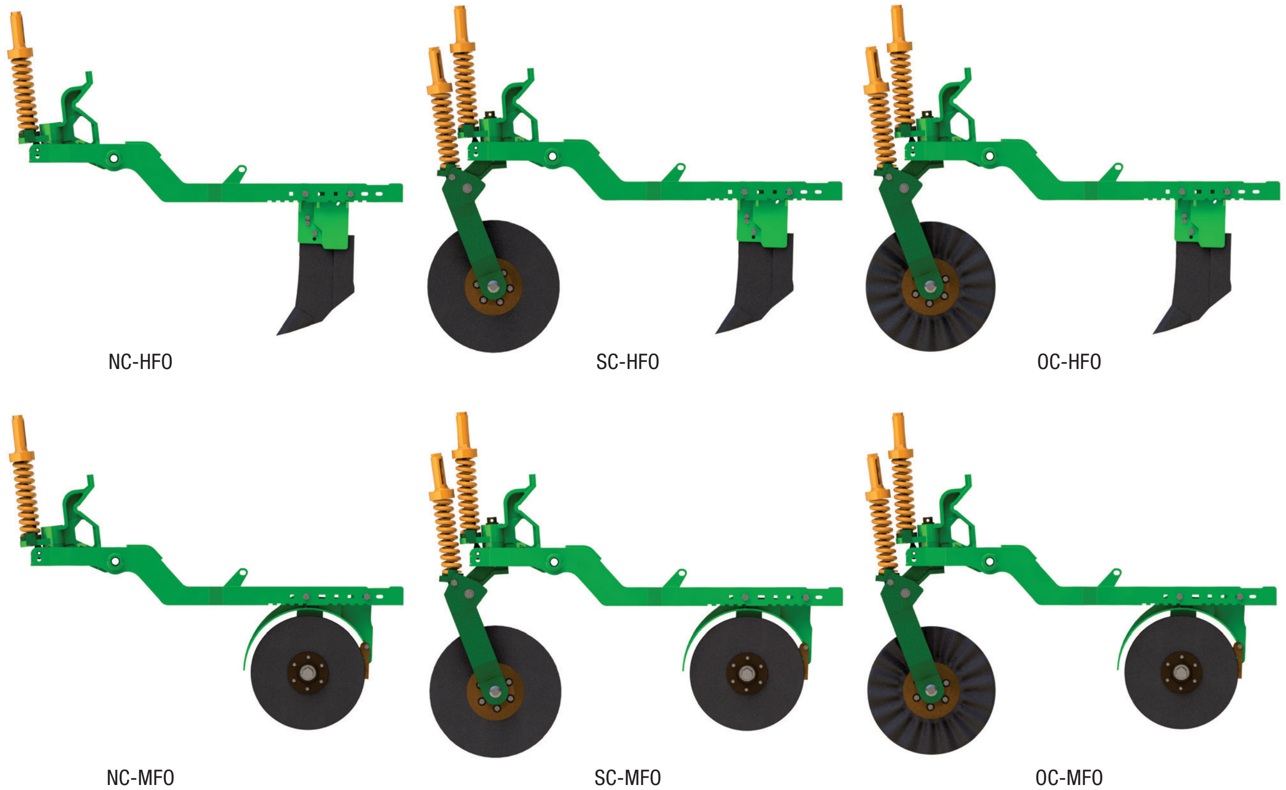

Figure 2. Associations of coulters (NC, no-coulter condition; SC, smooth coulter; OC, offset fluted coulter) and furrow openers (HFO, hoe furrow opener; MFO, double-disc furrow opener).

profile (1), the elevation profile (2) and the soil disturbance profile (3). The first was performed before the passage of the equipment, the second and the third after its passage, at the same location, thus obtaining the geometric shape of the furrow. A micro-profilometer has been used; it was successively placed at the same point in each stage, marked by stakes, along the passage line of tools, demarcating in A2 millimeter paper. When evaluating the natural soil profile (1), the evaluation point was marked in order to reposition the equipment after the passage of the tools. After the verification of the elevation profile (2), the soil was removed manually until the depth where the tool was used, carefully avoiding changes to the profile of subsurface disturbed soil, then the disturbance profile (3) was obtained.

Subsequently, the graphs of the profiles were photographed, with the camera kept in stationary position (position x, y and z). After this, the images were loaded into the Auto Cad software to draw the contour lines of the profiles and, through the use of tools for the scanning of the area, to determine the area in square meters. The difference between the first and third measurements yielded the disturbance area (Da), whereas the discount of this value in the area of the second measurement indicated the elevated area (Ea). Furthermore, maximum depth (Mfd) and width (Mfw) were determined, as shown in Figure 3.

Soil disturbance volume (Dv) was determined by the equation:

$$\mathrm{Dv} = (\mathrm{Da} \times 10{,}000)/\mathrm{IS}$$

where Da refers to the disturbance area; the value 10,000 corresponds to the area of one hectare. Interrow spacing (IS) used for the calculations was 0.45 m; it is the spacing value usually used in soybean sowing.

The ratio between soil elevated area and disturbance area is the soil swelling (Ss); it was determined by the equation:

$$\mathrm{Ss} = (\mathrm{Ea}/\mathrm{Da}) \times 100$$

After their collection, the data underwent analysis of variance by using Tukey's analysis test at 5% error probability. Normality of errors was tested with the Kolmogorov-Smirnov test, and homogeneity of variances with Cochran's test. Analyses were performed using the software Assistat 7.7 beta 2016.

Results and discussion

Analysis of variance (ANOVA) of the variables, with their respective means, levels and results of the F-tests are shown in Table 1. Normality of data and homogeneity of variances were observed.

Table 1. Summary of statistical analysis of variance with means for factors, their levels and the results of the F-test

Factors	Variables[1]					
	Mfd (m)	**Mfw (m)**	**Da (m^2)**	**Ea (m^2)**	**Dv (m^3)**	**Ss (%)**
Furrow openers						
Hoe (HFO)	0.1139 a	0.2556 a	0.0126 a	0.0052 a	281.09 a	42.33 a
Double-disc (MFO)	0.0741 b	0.2357 b	0.0096 b	0.0028 b	212.78 b	30.26 b
Coulters						
No-coulter (NC)	0.0933 a	0.2307 b	0.0108 b	0.0049 a	240.04 b	45.25 a
Smooth coulter (SC)	0.0923 a	0.2560 a	0.0106 b	0.0040 ab	236.59 b	37.44 a
Offset fluted coulter (OC)	0.0963 a	0.2501 a	0.0119 a	0.0033 b	264.18 a	26.20 b
Speeds						
1.11 m/s	0.10043 a	0.2361 a	0.0106 a	0.0041 a	235.48 a	38.18 a
1.67 m/s	0.0967 ab	0.2464 a	0.0116 a	0.0040 a	257.62 a	33.79 a
2.22 m/s	0.0911 bc	0.2532 a	0.0112 a	0.0038 a	250.03 a	33.39 a
2.78 m/s	0.08760 c	0.2468 a	0.0110 a	0.0043 a	244.60 a	39.82 a
CV (%)	8.87	8.27	13.49	37.71	13.49	38.79
Standard deviation (SD)	0.0225	0.0253	0.00219	0.00191	48.42	16.03
Overall mean (OM)	0.0939	0.2456	0.0111	0.0040	246.94	36.29
F-test						
Furrow opener (F1)	411.15**	17.14**	75.70**	46.83**	75.70**	13.22**
Coulter (F2)	1.46 ns	10.20**	4.89*	6.77**	4.88*	11.09**
Speed (F3)	8.44**	2.19 ns	1.41 ns	0.36 ns	1.41 ns	0.93 ns
F1 × F2	1.48 ns	0.66 ns	0.47 ns	0.73 ns	0.47 ns	0.95 ns
F1 × F3	3.26*	0.74 ns	0.39 ns	0.04*	0.39 ns	0.25 ns
F2 × F3	1.18 ns	0.80 ns	0.62 ns	0.35ns	0.62 ns	0.51 ns
F1 × F2 × F3	1.66 ns	1.57 ns	1.42 ns	0.06**	1.42 ns	0.23 ns

[1] Maximum depth (Mfd); Maximum width (Mfw); Disturbance area (Da); Elevated area (Ea); Disturbed volume (Dv); Swelling (Ss). Means followed by the same letter in the column do not differ significantly by Tukey's test ($p < 0.05$). ** Significant at 1% probability ($p < 0.01$). *Significant at 5% probability ($p < 0.05$). ns: non-significant ($p \geq 0.05$).

Maximum furrow depth

Maximum depth responded to the effects of the type of furrow opener; there was an average of 0.12 m for the hoe and 0.07 m for the mismatched double-disc (Fig. 4a). The double-disc showed a shallower working depth, as reported by Palma *et al*. (2010) considering that they are bigger, and it is more difficult for them to penetrate the soil, as stressed by Seidi (2012). Similar results were also found by Koakoski *et al*. (2007) and Mion *et al*. (2009); according to the authors, such results are related to the fact that the hoe furrow opener reaches a greater depth due to the action of the tip, which causes a downward vector that tends to suck down the tip of the hoe.

There was no significant effect of the interaction between type of furrow opener and coulter; this suggests that the use or lack of use of coulters with both furrow openers has no influence on depth; a mean value of 0.09 m was found for all treatments.

The effects of speed were significant only when considered alone, or in interaction with the type of furrow opener, which indicates that coulter selection does not change maximum depth, even under the effect of increased speed. The average maximum depth of the two furrow openers was reduced with increasing speed, reaching 0.10 m in 1.11 m/s and 0.09 m at a speed of 2.78 m/s, when they were analyzed in combination. The interaction between furrow opener and speed had a significant effect on maximum depth only for the hoe opener, with values between 0.12 and 0.01 m for the first three levels (1.11, 1.67 and 2.22 m/s), with significant reduction under the effect of higher speed, when depth was 0.10 m. The mismatched double-disc yielded an average depth of 0.07 m for the tested speeds. Silveira *et al*. (2011), while evaluating furrow depth by a hoe during maize seeding, also identified reduction of this variable when increasing seeding speed. The authors stressed that this behavior is due to the fact that the hoe furrow opener tends to move closer to the surface at higher speeds, and the possible causes for this variation are penetration resistance, soil moisture and roughness.

Maximum furrow width

As expected, the furrow opener that worked at a greater depth created wider furrows, corroborating the

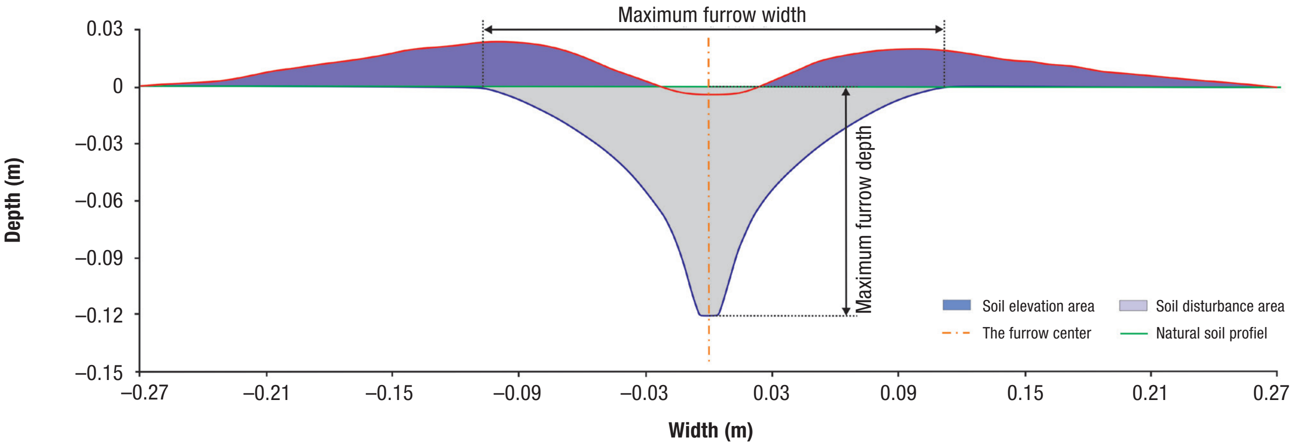

Figure 3. Graph illustrating the quantitative variables analyzed in the furrow.

results of Hasimu & Chen (2014). In addition to the significant effects of the furrow opener, the coulters also influenced maximum width (Fig. 4b). The hoe furrow opener showed the highest maximum furrow width (0.26 m), while the mismatched double-disc made a narrower furrow (0.24 m); the values were significantly different. The absence of coulter resulted in a width of 0.23 m, while the smooth and offset fluted coulters increased width to 0.26 m and 0.25 m for the first and second coulters, respectively, and there was no difference between them. By contrast, speed did not affect width, as it maintained an average of 0.25 m, and there was no statistical difference between the different speeds.

Soil disturbance area

It was observed an effect of the type of furrow opener on the soil disturbance area (Fig. 4c), where the hoe had the largest movement (0.0126 m²). In comparison, the mismatched double-disc moved 31.25% less than the hoe, with 0.0096 m². This was due to i) the greater working depth used for the hoe, as noted by Hasimu & Chen (2014), ii) the different action of the furrow opening mechanisms, and iii) the differences between the size of the elements, which affects cutting, shear and compaction that they cause to the soil. This result corroborates the findings of Herzog *et al.* (2004), Mion & Benez (2008) and Modolo *et al.* (2012), who also concluded that the hoe openers disturb the soil more than mismatched double-discs. However, the values were higher than those in the literature, mainly due to lower gravimetric moisture, which reduces the lubricating effect of water and therefore provides greater disturbance. Furthermore, the differences between the technical specifications of the furrow openers used in this experiment, and the contrasts between soil density, penetration resistance and other physical characteristics of the studied soils, may have caused different effects in the processes of cutting, shear, compaction and flow in soil behavior, as described by Portella (1983).

The cutting discs presented a statistically significant effect on soil disturbance, particularly the fluted coulters, which affect the sides of the furrows, as confirmed by larger width (0.25 m); it is thus evident that the coulters caused greater soil disturbance under the studied conditions. The use of smooth coulters reduced soil disturbance by 12.26% when compared with the offset fluted; there was no difference from the treatment without coulters. Mion *et al.* (2009) and Silva *et al.* (2012), while working with different coulters, also found statistical differences between soil disturbance caused by different types of coulters, and the offset fluted coulters also caused more disturbance than the smooth discs.

The use of different seeding speeds for the whole set did not affect the soil disturbance area, which averaged 0.01 m². This is indicative that this factor is not limiting for adequate disturbance in the furrow for no-tillage systems, thus suggesting the possibility of using speeds up to 2.78 m/s without reducing soil disturbance. These results are similar to those found by Bellé *et al.* (2014) and Gassen *et al.* (2014), while working with chisel plows in tillage systems, and by Francetto *et al.* (2015), while analyzing the performance of associations between cutting discs and furrow openers. This effect may be associated with the friable soil consistency at the time of the experiment, confirming the results found by Casão Junior *et al.* (2000), who observed no increase of the soil disturbance area only in this moisture condition.

Soil elevation area

The most disturbed area was by the hoe opener, around 12%, it was higher in the elevated area, which was 89.28% higher compared with the mismatched double-disc furrow opener. The hoe opener resulted in an increase of 0.0028 m^2, while the double-discs accounted for 0.0053 m^2 (Fig. 4d). This possibly occurred because the double-discs were arranged at a shallower depth and made narrower furrows, resulting in a smaller elevated soil area. Another reason may be the fact that culters have a cutting action rather than shearing when opening furrows.

There was no statistical difference between the elevated soil area by either the smooth coulter or the offset fluted coulter. However, there was a contrast when the offset fluted coulter was compared to the absence of coulter; the wavy coulter elevated the soil at least 48.48% less. This may be due to the higher fractionation of soil caused by this type of mechanism, as explained by Francetto *et al*. (2015), compared with the no-coulter condition, because of the larger contact area of this element with the ground, confirmed by greater furrow width.

The furrow opener and speed factors showed significant interaction, demonstrating that the elevated area by the hoe was notably higher at all speed levels, with values ranging between 0.0025 m^2 and 0.0032 m^2 for the double-discs, and from 0.0051 m^2 to 0.0055 m^2 for the hoe furrow opener. In addition to this double interaction, there was a significant interaction between hoe furrow openers, coulters and speed on elevated area, as shown in Table 2.

The use of coulters only showed statistical difference in soil elevation when the association between offset fluted and mismatched double-disc furrow opener was compared with the combination of hoe opener and no-coulter at seeding speeds of 2.22 and 2.78 m/s. Furthermore, there was a difference between double-disc and smooth coulter with the hoe opener without coulters at the speed of 1.11 m/s. In both situations, the use of the hoe furrow opener showed the highest soil elevation. In the other situations, no differences were evidenced between the mechanisms, especially at the speed of 1.67 m/s, where there was no difference in soil elevation for any combination of elements. The use of coulters associated with the hoe opener did not influence the elevated area, obtaining an average value of 0.0053 m^2. However, using the offset fluted with the double-disc opener reduced this variable by roughly 50%, when compared to the remaining treatments with this furrow opener, and by 67% for the furrows made by the hoe opener.

Disturbed soil volume

The effects of the hoe openers on the evaluated areas were reflected in the highest disturbed soil volume values; there was a soil volume of 68.31 m^3/ha higher than that of the mismatched double-disc furrow opener, representing an increase of 32.10% (Fig. 4e). This is due to the greater working depth of this mechanism, as evidenced by Herzog *et al*. (2004) and Conte *et al*. (2009), who evaluated the soil disturbance volume at two depths by a hoe opener. Regarding the effect of coulters, when the offset fluted coulter was used for both furrow openers, this accounted for the largest disturbance: 11.66% and 10.05% higher than the smooth coulter and the no-coulter condition, respectively. By contrast, the different seeding speeds caused no changes in disturbed soil volume.

Soil swelling

The hoe opener, in comparison to the double-disc, caused the most swelling: 42.33% compared with 30.26%, respectively (Fig. 4f). This difference represents an increase by 39.89% in soil volume. This result occurred because the hoe causes greater voids between soil particles than double-discs, because they perform a shearing rather than a cutting action on the soil.

Table 2. Interaction between furrow opener, coulter, and speed in the elevated soil area

Furrow opener-Coulter interaction[1]		**Seeding speed (m/s)**				**Mean (m^2)**
		1.11	**1.67**	**2.22**	**2.78**	
NC	HFO	0.0063 aA	0.0054 aA	0.0060 aA	0.0060 aA	0.0059
SC	HFO	0.0045 abA	0.0052 aA	0.0049 abA	0.0056 abA	0.0050
OC	HFO	0.0053 abA	0.0046 aA	0.0045 abA	0.0048 abA	0.0048
NC	MFO	0.0042 abA	0.0033 aA	0.0037 abA	0.0039 abA	0.0038
SC	MFO	0.0025 bA	0.0029 aA	0.0027 abA	0.0035 abA	0.0029
OC	MFO	0.0016 bA	0.0020 aA	0.0012 bA	0.0021 bA	0.0017
Mean (m^2)		0.0041	0.0039	0.0038	0.0043	

[1] Hoe furrow opener (HFO); Double-disc furrow opener (MFO); No-coulter condition (NC); Smooth coulter (SC); Offset fluted coulter (OC). Means followed by the same lower case letter in the column and capital letter on the line, do not differ significantly by Tukey's test ($p < 0.05$).

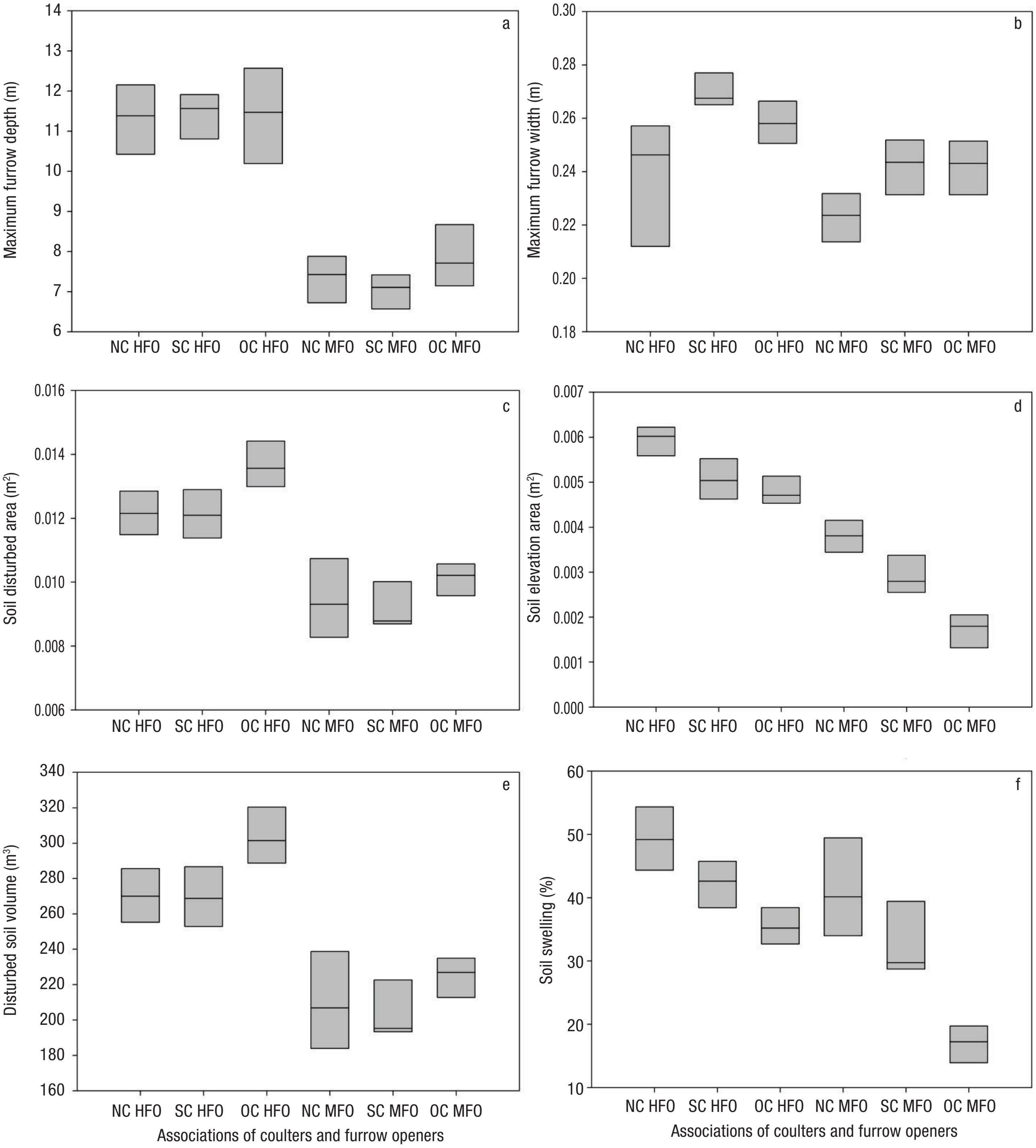

Figure 4. Performance of associations between coulter and furrow opener for soil disturbance variables at the different forward speeds. First line quartile, minimum value; second line quartile, median; third line quartile, maximum value. HFO, hoe furrow opener; MFO, double-disc furrow opener; NC, no-coulter condition; SC, smooth coulter; OC, offset fluted coulter.

There was no statistical difference between the use of the smooth coulter and combinations without this kind of mechanism, when the coulter factor was analyzed alone. On the other hand, they both showed contrast when compared with the use of the offset fluted coulter. Swelling was reduced by 42.90% and 72.71% for the smooth coulter and associations without cutting elements, respectively. It was due to higher disturbance area, where the aforementioned treatment had the highest value compared to the others, and to the lower elevated area provided by this type of structure; however, it is explained by the resulting higher maximum width. Consequently, this type of mechanism causes a more horizontal soil disruption than the smooth coulter and the association that used no-coulter. This situation is similar to the one observed by Brandelero *et al*. (2014) when evaluating hoe furrow openers, coulters, row cleaners and covering mechanisms in a no-till seeder. Furthermore, the use of coulters associated to furrow openers reduces swelling because they promote a cut in a section of the soil prior to the passage of the furrower, especially in association with the hoe, where it was observed an average decrease of 20%.

Soil swelling is due to the ratio between elevated and disturbed soil area, and neither of them is subject to changes resulting from the increase in seeding speed; this way, there were no statistical differences when the speed factor was evaluated; and it was verified a mean value of 36.29%.

As final conclusions, the soil disturbance area was not affected by speed; being greater when the hoe furrow opener was used. Among the combinations with coulters, the offset fluted favored the greatest disturbance and the lowest elevation and soil swelling. Furthermore, the use of coulters associated with furrow openers reduced swelling in approximately 8% for the smooth and 20% for the offset fluted coulter. The double-disc furrow opener had the least working depth, and there was no change to this variable when coulters were used in association with different furrow openers. Moreover, speed was inversely proportional to maximum depth for the furrows made by the hoe opener, with a 15% reduction. The hoe furrow opener showed the highest maximum furrow width. Additionally, the use of different coulters increases furrow width in approximately 10%, regardless of whether the edge of the coulter is smooth or fluted. By contrast, speed did not affect this variable.

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