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Evaluation of the effects of no-tillage openers on maize: a field study

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Abstract

The openers are the planter components that interact with soil and several researchers studied openers characteristics and behaviour in different conditions, but few explored the effects on crop emergence, growth and yield. The aim of this study is to evaluate and quantify any effects of openers on crop development and yield. The performance of three planters equipped with five different openers were compared on maize in a field test: double disc (DD), punch planter (PP), horizontal furrow with winged opener (HW), vertical furrow with winged opener (VW), vertical furrow with shank opener (SO). Seed spacing, depth, penetration resistance and plant emergences, root dry mass and yield were measured respectively on seeding slots and during crop development to evaluate openers effects. The results showed low variability in seed depth and spacing when DD and PP openers were used despite higher level of compaction on DD slot. High variability was found on maize plants when VW and HW openers were used. SO obtained relevantly lower yield in absolute value -35% (1.7 Mg ha^{-1}) compared to other openers. However, the high variability observed in the different replicates and plant adaptability to stress conditions could explain the absence of significant differences in crop yield.

Introduction

No-Tillage (NT) is one of the most widespread techniques adopted to mitigate soil degradation and increase soil fertility (Lal, 2013; Tamburini et al., 2020), involving the growing of herbaceous crops without soil disturbance due to tillage. The planting of seeds without tillage takes place with direct or sod seeding (Aikins et al., 2020). Indeed, low soil disturbance, continuous soil covering and high crop diversity define Conservation Agriculture (Kassam et al., 2009). Furthermore, the lack of tillage and the presence of residues improves soil structure and pore stability (Blanco-canqui and Lal, 2021) but at the same time there could be an increase in bulk density due to difficulties in mitigating soil compaction caused by machinery passes on the cultivated surfaces (Botta et al., 2010). This challenging condition increased the need for a dedicated design of planters and row-drillers. Moreover, both the drillers and planters interact with soil through the openers, the components that insert the seeds in the soil (Aikins et al., 2020). The main task of the openers is to: create a favourable environment for seed germination and crop emergence, limit compaction of seeding slot, manage the residues avoiding contact among seeds and residues (known as “hairpinning”) (Ahmad et al., 2017), control the seeding depth, proper seeds deposition and follow the field contours (Baker and Saxton, 2007). The openers can be analysed under several aspects, some of which are linked to shape and manufacturing (Dang et al., 2020), while others take into consideration seeding slot shape to study the effect of the openers on the soil (Chaudhuri, 2001). Several researchers evaluated seeding performance up to the first crop stage (Vamerali et al., 2006). However, few followed the entire crop development (Swanepoel et al., 2019). The aim of this study is to assess and quantify any effects on crop emergence, development and yield caused by different openers design at field level.

Materials and Methods

The test was conducted in 2021 (April - October) on a private farm in North-East Italy (45.359730N 12.035806E, 9 m a.s.l.). The 0.4 hectars field was tilled with a low disturbance subsoiler (He-Va, Denmark) and sown with a cover crop mix (50% *Trifolium incarnatum and 50% Phacelia tanaceti-folia)* in October 2020 with a Carrier Drill (Vaderstad, Sweden). No fertilisation was applied during the cover crop cycle. The cover crop mix was chemically terminated with 1100 g ha^{-1} glyphosate one week before planting. According to the FAO classification, the soil was a *Calcaric Cambisol*. According to the USDA, soil texture was classified as loam and characterized by 29.7% sand, 46.7% silt and 23.5% clay. Soil organic matter content was 2.93%, and pH was 7.7. The Local Agency provided climatic data for the Environmental Protection of Veneto (ARPAV, Padova, Italy). Considering the ARPAV dataset (1994 – 2019) referred to the area under study, annual average rainfall was 841.9 mm, 44% of which fell between June and October. The annual average temperature was 13.6 °C, with maximum and minimum peaks in July (23.8 °C) and January (3.3 °C), respectively. Maize (*Zea mais L.*) Hybrid seeds *Pioneer P0423* (Corteva agriscience) were sown on April 24th, setting the planter population density at 8.3 plants m^{-2}or at 22.64 kg ha^{-1}. During the growing season, the crop was managed as follows: one herbicide application was carried out on May 27th (Dicamba 450ml ha^{-1}; Nicosulfuron 120 ml ha^{-1}) with a boom sprayer (Hardi, Denmark), 367 kg ha^{-1} of granular urea (Yara Vera Eura 46) was provided with two spreading operations by broadcast distribution with oscillating arm spreader (Rondini, Italy), no water was applied during the whole crop cycle.

Five different openers (Figure 1) with which three different planters were equipped were compared: Double disc opener (DD), Punch planter opener (PP), horizontal slot placement with winged opener (HW), vertical slot placement with winged opener (VW), and shank opener (SO).
The planters followed a special design traffic pattern to obtain a constant distance between maize rows, set at 0.75 m, due to the different rows and working widths, as shown in figure 2.
The traffic pattern was repeated randomly in the field. The sampling areas were chosen randomly on homogeneous soil, avoiding headlands.
The comparison between planters performance for a no-tillage system took advantage of an innovative rolling Punch Planter manufactured by Kalos Srl (Udine, Italy) a Double Disc manufactured by Maquinaria Agricola Solà (*Prosem K mod.Variant* , Barcelona, Spain) and a shank opener prototype manufactured by AZ Farming d.o.o. (Ljubljana, Slovenija). All planters were tractor-mounted. DD and PP planters were also described in a previous experiment (Benetti et al., 2022). The basic information on the planters used in the experiment are reported in table 1.
The DD planter selected for the comparison was designed for no-till precision seeding and characterized by a vacuum seed meter and six planting units spaced 0.45 m apart. In this study, each of the six planting units was equipped with a tangential waved disc coulter, a row cleaner, a double-disc opener with two-gauge wheels, and rubber closing wheels set with metal teeth. During the test, the row cleaner was set in order to have a shallow activity on residues, thus decreasing soil disturbance. Only the two external rows were used during the test to match the selected row spacing. Other rows were lifted and blocked during the work to decrease soil disturbance.
The Punch Planter is a mounted implement designed for maize precision planting on plastic mulch in a no-till farming system. This planter is characterized by a modular assembly with paired planting units with a specular building, connected to the main frame by a jointed parallelogram suspension system. The mainframe has two paired wheels to follow the soil contours. A tangential waved disc was placed in front of every planting unit behind the mainframe wheels. Each planting unit has 12 punch openers, linked by a bearing on two wheels with an offset centre to maintain the openers horizontal during rolling. A side-mounted wheel was used for depth control and to chain-drive the metering unit. The special shaped openers have an openable metal plate on the bottom to allow the seed to be inserted and pushed into the soil in order to improve the seed-to-soil contact. Closing wheels

were not used. Finger meters (Precision Planting LLC, Tremont, IL-USA) were adopted for seed selection. Each opener is recharged in the upper part of every rolling cycle. Two special metal and rubber lips avoid seeds being lost from the top of the opener during the drop. During the test PP was set to plant one seed per hole.

The shank prototype had 5 rows units spaced 0.75 m. The row units were connected to the main frame by a jointed parallelogram suspension system. Row units had a radial waved disc coulter and a shank opener aligned rear to the disc. Both disc and shank were spring mounted on a row unit frame. A rubber closing wheel was installed on each row unit behind the shank with the purpose of closing the seeding slot and maintaining the seeding depth. The shanks were set with different configurations: 2 rows with horizontal slot on winged opener as described for machines that use the same opener (Vamerali et al., 2006), 2 rows with vertical slot with winged opener, 1 row with vertical slot without winged opener (shank). One seed tank with volumetric seed meter was installed on the main frame and provided seed metering to the five row units. Seeds were pneumatically transported from seed meter to the opener. An electric motor drove the seed meter thanks to a digital control unit. All the planting unit parts, such as closing wheels and coulters, affected soil measurements.

The performances of the different planting openers under study were evaluated taking into account the following effects of openers on seeding and effects of openers on crop development.

Effects of openers on seeding

Before planting, two undisturbed cores (8 cm diameter x 5 cm depth) for each soil treatment were collected using a hand auger (Ejikelkamp, Giesbeek, The Netherlands). Volumetric water content and bulk density were determined after oven-drying to constant weight. Mulch biomass samples were collected before planting for each treatment. A square-shaped iron frame, with a defined area of 0.16 m^2, was launched randomly on the field test area. The biomass samples were collected manually and then oven-dried at 105 °C until constant weight.

Soil penetration resistance was measured the day after planting using a surface pocket penetrometer (Clockhouse Engineering Ltd., Hertfordshire, United Kingdom) equipped with a flat-tipped measuring pin (6.4 mm diameter). Two measurements were made for each seed detected over a 15 m row plot: one on the vertical axis and another perpendicular to the side of the seeding slot, with regard to seed position.

Sowing depth was manually assessed the day after planting over a 15 m row with 3 plots 5 m longer, with a stick meter, using the levelling straight bar as referring to the field surface. Finally, data collected were used to calculate the ratio between standard deviation and targeted depth (Coefficient of Variation) in order to calculate sowing depth uniformity. Targeted depth was 5 cm. Statistical analysis was also conducted for this data.

Seed spacing was measured the day after sowing over a 15 m row plot. The data obtained were classified as regular (1), multiple (2) and missed (3) if they were ± 50%,< 50%, and > 50% of the theoretical seed space according to International Standard ISO 7256 (ISO/TC 23, 1984), data collected were expressed as:

$$Regular\text{ seeds rate placement } (A) = (n1/N') \cdot 100 \quad (1)$$

$$\text{Double seeds placement } (D) = (n2/N') \cdot 100 \quad (2)$$

$$Missing\text{ seeds placement } (M) = (n0/N') \cdot 100 \quad (3)$$

Where:

n_1 is the number of seeds correctly sown,

n_2 is the number of multiples,

n_0 is the number of misses,

and N’ is the number of intervals between seeds.

Effect of openers on crop development

Emerging seedlings were counted at 4, 6, 9, 10, 13, 16, 21 and 26 days after planting (DAP) on 2 rows of 6 metres for each opener on 4 random sampling points with a total sampling distance of 48 m. Mean Emergence Time (MET)(4), Emergency Rate Index (ERI)(5) were evaluated as follows (Kachman and Smith, 1995).

$$MET = \frac{Z1T1 + Z2T2 + \ldots + ZnTn}{Z1 + Z2 + \ldots + Zn} = [day] \quad (4)$$

$$ERI = \frac{S_{te}}{MET} = [\text{seedlings day} - 1\text{m} - 1] \quad (5)$$

Where:

MET is the Mean Emergence Time in days,

Z represents the number of seedlings since the time of the previous count,

T is the number of days after sowing,

ERI is the Emergency Rate Index, expressed in seedlings $day^{-1}m^{-1}$.

S_{te} is the number of seedlings per meter,

m is the number of seeds sown per meter

After preliminary statistical analysis, two sampling points were not considered in the comparison due to the low population caused by a *Gryllotalpa Gryllotalpa L.* attack.

Opener effects on roots were evaluated comparing roots dry mass sampled at BBCH 75 with a root sampler (Ejkelkamp, Geesbek, The Netherlands) up to 40 cm depth split into 0-20 cm and 20-40 cm samples. Samples were washed and cleaned of dirt with a 500 micron sieve and then weighed after oven-drying at 105 °C until constant weight. Yield and total biomass production were evaluated by collecting a 1 square metre sample and oven-dried at 105 °C until constant weight. Plant population at harvest time was obtained with the previous samples. The data obtained from the grain and biomass production were used to calculate the Harvest Index.

Statistical analysis was used to highlight significant differences in the dataset. Data were treated with an analysis of variance (ANOVA) model considering the main effects of the 5 tested factors and the experimental blocks. The chosen significant threshold was $p<0.05$. The Tukey HSD was used as post hoc test. Coefficients of variation of seeding depth were used to describe depth variability according to a previous study (Vamerali et al., 2006). Standard error was used to describe variability in the other data. The statistical analysis was performed with R software.

Results

The mean soil bulk density during planting was 1.06 g cm-^{3}, (SD = 0.016). The soil volumetric water content was 25.7% (SD = 0,527). The mean cover-crop canopy dry biomass was 3.63 Mg ha^{-1} (SD = 0.373) with a water content of 86.74% (SD = 0.186).

Effects of openers on seeding

The seed spacing results are reported in Figure 3.

The seed spacing showed no difference between DD and PP openers on regular spacing with 90% of Feed Index. However, DD resulted in higher multiple deposition compared to PP opener, which reported zero multiple depositions. The missing of multiple seeds in the discrete holes of PP was counterbalanced by the higher Missing Index (10%) compared to DD opener. The SO, HW and VW openers showed lower values on regular seed spacing with a Feed Index of 30% on average. Multiple depositions in SO, HW and VW were higher than those of PP and DD planters. The Missing Index reached 51% in SO opener and 48% and 49% in HW and on VW openers respectively. The statistical analysis showed significant differences between the single seed metering system used on DD and PP and the volumetric system used on SO, HW, VW openers.

The seeding depth and vertical penetration resistance are shown in the following table 2:

The SO opener placed the seeds statistically deeper compared to the other openers. No statistical differences were found in seeding depth between DD, PP, HW and VW. DD opener showed the lower variability in seeding depth. VW opener instead resulted in the higher coefficient of variation (CV). Penetration resistance on vertical axis of seed position gained the lower value in VW and especially in SO-openers. HW, DD and PP openers, on the contrary, were characterized by higher values. Furthermore, higher variability on vertical penetration resistance was found in winged openers. In DD the penetration resistance orthogonally to the seeding slot side (Slot Side Penetration Resistance, SSPR) was also evaluated, resulting in a mean of 194 kPa and standard error of 6.1. The SSPR on the other openers was not measurable due to the different slot shapes and missing of a defined slot.

Effect of openers on crop development

The crop response evaluation was determined analyzing firstly maize emergence results (table 3). MET index showed no statistical differences between the openers. However, PP highlighted the lower standard error on MET index. ERI index was statistically higher in DD compared to SO, VW and HW openers. PP was characterized by a ERI index not different from those of all the other openers. The root dry weight was displayed on table 4 and showed no difference between openers up to 20 cm of depth. Instead, the PP achieved a statistically higher dry weight compared to DD from 20 to 40 cm of depth. No difference was found between VW, HW and SO openers in root weight in the deeper layer. Grain yield are analyzed in table 5.

The statistical analysis showed that there were no significant differences in maize grain yield dry matter between the compared openers, as reported in table 5. However, in absolute value, maize yield obtained using the shank opener was decidedly lower than those obtained using the other compared openers (35% on average). No differences were found in the grain moisture content, whereas the dry grain production for each plant showed significant differences. VW was found to have a higher grain production per plant than SO opener, while there were no significant differences between HW, PP and DD. Moreover, PP achieved the lower variability in grain production per plant. The statistical analysis showed differences in plant population at harvest between the different openers, but without statistical significance (p value 0.076). The VW opener did not reach the population of 8.3 plants m^{-2} planned before planting. Furthermore, the winged openers VW and HW recorded a high variability in the final plant population. The HI showed significantly higher values on DD and PP with respect to that of SO opener, while VW and HW openers values are not different from those of DD, PP and SO.

Discussion

Effects of openers on seeding

The results obtained performing seeding slot analysis showed the effects of openers on seeding. However, the DD and PP spacing performance cannot be compared without taking into account the complete planter performance, as the metering unit and design were different and affected the seed spacing (Celik et al., 2007). The PP design caused a very low possibility of delivering two seeds per punch, and after per hole, as reported in figure 3. This happened because PP needs the perfect matching between metering unit and rolling punch openers during seed delivery, otherwise, the mismatching between the metering unit and rolling punch planter causes the seeds to fall out of the punch openers

(Benetti et al., 2022) and a missing seeds delivery with an increase of missing rates. Instead, the VW, HW and SO seeds spacing can be compared because the openers were the only different parts used on the planter. The high missing index was not different in the three shank-type openers and was counterbalanced by the high multiple index. The higher multiple index on HW was probably determined by the increased curve in the seeds transport tube, which caused seeds to bounce, resulting in a slowed and delayed seed placement on the slot (Kocher et al., 2011; Panning et al., 2000).

The opener design affected seeding depth, as displayed in table 2. In this scenario, the SO opener showed a statistically higher seeding depth, probably due to the unsuitable shape for the type of soil on which the experimental tests were conducted. However, the winged opener maintains a less constant depth probably due to the extra drag of the wing increasing the force that was acting on openers (Vamerali et al., 2006). Furthermore, the wing could improve the opener floating ability, achieving the set seeding depth, but with higher variability due to bouncing. This behaviour is confirmed by the higher standard error of penetration resistance (table 2) measured on winged openers VW and HW.

Effects of openers on crop development

The favourable conditions during planting could explain the higher, but not different from the other openers, MET of SO despite the statistically different seeding depth. Moreover, the softness of soil during planting enhanced the emergence performance of DD opener, thanks to the consolidating action on soil achieved by the double disc, similarly to tillage conditions (Baker and Saxton, 2007). This consolidating action caused an increasing in penetration resistance on DD opener, especially on SSPR, with values higher than 190 kPa as observed in previous research (Malasli and Celik, 2019). The higher penetration resistance affected the root system development (Nunes et al., 2021) on DD opener, as reported by the statistically lower root dry mass measured in the deeper layer (table 4). PP also displayed a high vertical penetration resistance, due to the punch consolidating action, but 16% lower compared to DD planter. However, the compaction caused by PP opener did not affect root growth, which instead resulted in the significantly higher root dry mass between openers. This finding can be explained by two factors: firstly, the opener design could mitigate the compacting action during the punch insertion in the soil. Secondly, the discontinuous soil disturbance caused by the rolling punch planter limits the compacted area in the seed deposition zone, instead of a continual smearing and compacting action caused by DD opener (Iqbal et al., 1998; Trentin et al., 2018). The SO opener action was characterized by high soil disturbance and resulted in lower penetration resistance and higher, but not statistically different, root biomass. VW opener also affected emergence; indeed, the effects were reported in the lower maize population compared to the other openers and to similarly designed VW and SO. Moreover, the low population achieved by VW was displayed in statistically higher grain and biomass production per plant due to the relative increase of resources available for those plants (Ross et al., 2020). This higher plant yield was counterbalanced by the low population, resulting in a not statistically different grain yield compared to the other openers, with higher population and lower in-plant production. The VW treatment underlined the negative effect of a winged opener in planting on a vertical slot, probably due to the high soil disturbance that decreased the soil moisture available for seedlings (Aikins et al., 2020; Choudhary et al., 1985; Hasimu and Chen, 2014). Furthermore, the difficulty of properly closing the seeding slot and giving the necessary seed to soil contact in the VW opener configuration used in the test was considered. Despite the lack of statistically significant differences on grain yield, the absolute value difference obtained from SO was 35% lower on average, compared to the other openers. The absence of significant differences in grain yield and canopy biomass could be partially explained by the maize hybrid capacity to adapt to the environment reaching similar yield results in all the treatments (Ross et al., 2020). Moreover, the variability found in yield and biomass data did not allow the accuracy needed to find any statistically significant effect of the compared openers at field level, although it is possible to state that the yield performance of SO opener was lower with respect to those of the other openers used. Thus, the more variable spacing and depth measured on the winged opener explain the high variability in plant biomass and grain production values. On the other hand, the lower depth and spacing variability of the DD and PP could explain the low variability in the final harvest index and grain yield (Knappenberger and Köller, 2012; Liu et al., 2021; Tokatlidis and Koutroubas, 2004).

Conclusions

The effects of five different openers on seeding and crop development were analysed. Although the analysis of seeding slot highlighted differences in openers seeding performance and crop growth. High absolute differences on yield mean were found, but they resulted not statistically different due probably to opener induced crop variability. Indeed, the opener effects on crop development could have been mitigated by the favourable environmental and soil conditions, such as water and nutrients availability. Moreover, the maize adaptability and plasticity could have partially mitigate the different openers effects. The optimal soil and environmental conditions during the experiment may have limited the impact of opener-induced stresses on seedling and plant development. However, the high variability of results found on winged and shank openers suggest the need to improve opener stability during the work. Obviously, further research activities are required in order to enhance the knowledge of opener effect on crop development under a wider scenario, considering other crops, soil conditions and monitoring other plants physiological and morphological parameters.

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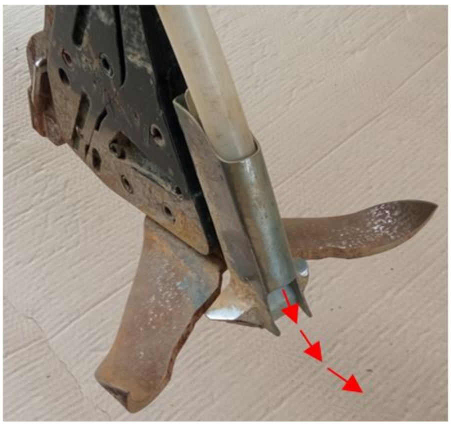
[DD]

[PP]

[HW]

[SO]



[VW]

Figure 1. The five different openers with which three different planters were equipped: Double disc opener (DD), Punch planter opener (PP), horizontal slot placement with winged opener (HW), vertical slot placement with winged opener (VW), and shank opener (SO). Red arrows highlight the seeds exit point in the openers.

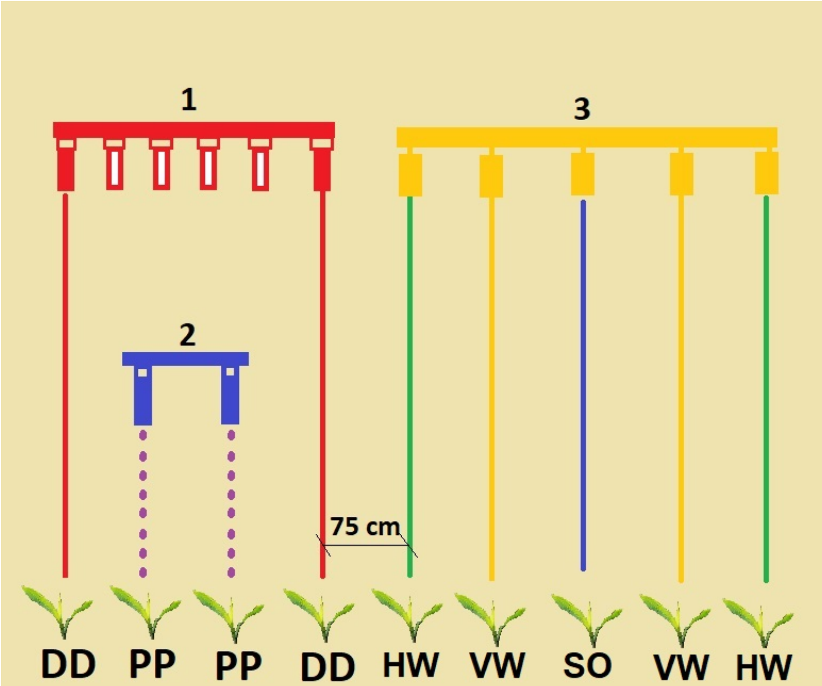


Figure 2. The planters traffic pattern used in the experiment. The three planters used were: 1) Six rows double disc (DD) opener no-tillage planter, only the external two rows were used in the test to match the row spacing; 2) Two rows rolling punch planter (PP); 3) Five rows no-tillage planter with three different openers: shank opener (SO), horizontal slot on winged opener (HW), vertical slot on winged opener (VW).

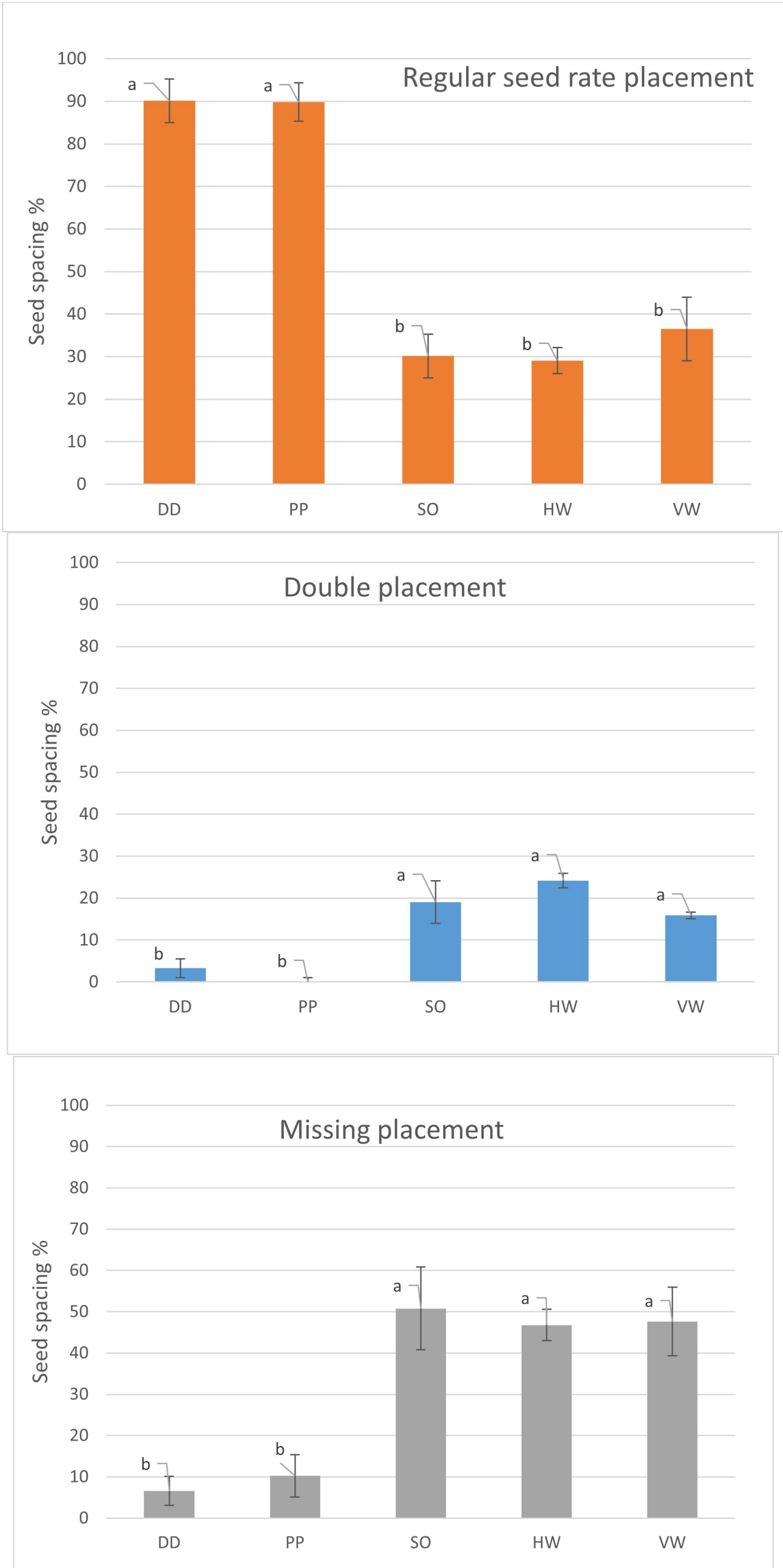


Figure 3. The seed spacing measured on seeding slot analysis. Regular seeds rate placement (A), Multiple seeds placement (D) and Missing seeds placement (M) were used to evaluate the five different openers: double disc (DD), punch planter (PP), shank opener (SO), horizontal slot on

winged opener (HW), vertical slot on winged opener (VW). Standard errors were used on error bar. The different letters highlight statistically significant differences.

Table 1. Basic information on the planters used on the experiment are reported in the table to evaluate five different openers: double disc (DD), punch planter (PP), shank opener (SO), horizontal slot on winged opener (HW), vertical slot on winged opener (VW).

Basic information on planters used on this experiment			
Brand	Solà	Kalos	
Model	Prosem K	Prototype	Prototype
Row number	6	2	5
Row distance (m)	0.45	0.75	0.75
Opener type	DD	PP	SO, HW, VW
Metering unit type	Pneumatic monograin	Mechanical finger type monograin	Volumetric metering unit
Linkage to tractor	Mounted	Mounted	Mounted
Disc coulter in front of opener	yes	yes	yes

Table 2. Seeding depth and penetration resistance measured on seeding slot analysis are reported in the table to evaluate the five different openers: double disc (DD), punch planter (PP), shank opener (SO), horizontal slot on winged opener (HW), vertical slot on winged opener (VW).

	Depth (cm)			**Penetration resistance (kPa)**		
	Mean		Coefficient of Variation	Mean		Standard Error
DD	4.83	b	0.11	143.59	b	4.39
PP	4.81	b	0.18	166.73	a	5.02
HW	4.47	b	0.36	134.44	b	8.72
VW	4.56	b	0.43	99.08	c	8.68
SO	6.50	a	0.23	51.27	d	4.24

Treatments with the same letter are not statistically different. Groups according to probability of means differences and alpha level (0.05).

Table 3. Seedling emergence was evaluated with medium emergence time (MET) and emergence rate index (ERI). The indexes are reported in the table to evaluate five different openers: double disc (DD), punch planter (PP), shank opener (SO), horizontal slot on winged opener (HW), vertical slot on winged opener (VW).

	MET			**ERI**		
	Mean	Standard Error		Mean	Standard Error	
DD	9.12	0.76	a	0.54	0.03	a
PP	9.10	0.36	a	0.49	0.05	ab
HW	10.07	0.64	a	0.41	0.03	b
VW	8.63	0.98	a	0.35	0.06	b
SO	10.81	0.51	a	0.40	0.02	b

Treatments with the same letter are not significantly different. Groups according to probability of means differences and alpha level (0.05).

Table 4. Root dry weight at 20 cm and 40 cm depth. The data are reported in the table to evaluate five different openers: double disc (DD), punch planter (PP), shank opener (SO), horizontal slot on winged opener (HW), vertical slot on winged opener (VW).

	Depth 20 cm			Depth 40 cm		
	Mean	Standard error		Mean	Standard error	
	g	g		g	g	
DD	2.88	0.16	a	0.58	0.04	b
PP	2.73	0.25	a	0.87	0.09	a
VW	2.55	0.18	a	0.69	0.06	ab
HW	2.70	0.21	a	0.69	0.09	ab
SO	3.27	0.23	a	0.61	0.05	ab

Treatments with the same letter are not significantly different. Groups according to probability of means differences and alpha level (0.05).

Table 5. Dry grain yield and plant population at harvest are reported. The five openers considered were: double disc (DD), punch planter (PP), shank opener (SO), horizontal slot on winged opener (HW), vertical slot on winged opener (VW).

	Dry grain yield (Mg ha^{-1})			Dry grain Yield for plant (g)			Plant population (plant m^{-2})			Harvest Index (%)		
	Mean		standard error	Mean		standard error	Mean		standard error	Mean		standard error
DD	6.66	a	1.08	78.35	ab	5.94	8.50	a	0.83	36.41	a	2.36
PP	6.82	a	0.91	81.89	ab	5.66	8.33	a	0.81	37.52	a	2.35
HW	6.90	a	1.07	78.15	ab	6.99	8.83	a	1.47	30.02	ab	2.30
VW	6.35	a	1.66	88.65	a	9.84	7.16	a	1.83	32.60	ab	2.67
SO	4.95	a	0.70	64.63	b	6.23	7.66	a	1.50	26.59	b	2.32

Treatments with the same letter are not significantly different. Groups according to probability of means differences and alpha level (0.05).