Effects of different soil management practices on soil mechanic resistance and seed depth placement in a maize crop in Alentejo, Portugal Mediterranean region

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Abstract

In Alentejo region, Portugal, maize crop field studies were conducted to compare the effect of different tillage systems and no tillage in seed depth placement. Seed depth placement was measured by maize mesocotyl length after crop emergence under conventional tillage (CT), minimum tillage (MT) and no-tillage conditions (NT). In no-tillage condition two work speeds, 4km^{-1} and 6 km^{-1}, were tested. Mean, standard deviation, coefficient of variation and correlation between seed depth placement and soil resistance values were measured. Results showed that independently of the soil practice, there was a negative correlation between seed depth placement and soil mechanic resistance being the higher correlation (r = - 0.77) in NT condition operating at 4 kmh^{-1}. Considering the lowest coefficient of variation of seed depth placement of 10.1%, best seeder performance was achieved in NT condition increasing work speed from 4 to 6 kmh^{-1}. A double-factor ANOVA showed that the effect of soil mechanic resistance and work speed in NT caused significant differences in depth seed placement.

Keywords: maize, no-till, precision farming, seeding

1. Introduction

In Portugal maize crop, silage and grain is nowadays the main irrigated field crop in an area of 138000 ha in 2011(www.anpromis.pt) with a total yield in 2010 of 635000 t of grain. Considering soil erosion and land degradation as well as the highest power requirements by tillage systems the application of energy-saving methods can make effective contributions to economy and environment. Although, many farmers traditionally seed maize crops under conventional tillage systems, no tillage and minimum tillage , year after year, are becoming cultural practices in use in Alentejo for maize crops. Besides, direct drilling option also represents cost and time saving (Carvalho, 1994) because under irrigation two crops per year become possible in Mediterranean regions . Official numbers showed that In Portugal in 2009, cereal crops area under direct drilling represents 47000 ha (INE, 2011). Although, seeders implements should be adapted to different soil physic conditions so that seed crop can be sown with correct seed deposition, without affecting seeders performance. Considering soil penetration resistance as the capacity of the soil in its confined state to resist penetration by a rigid object (Soil Survey Staff ,1993), it might be expected to be highly correlated with root growth (Carvalho *et al.,* 2006) and soil compaction (Freddi *et al*., 2009) and also with regard to soil density. A proper seeder, working at 5 kmh^{-1} should guarantee a regular vertical and horizontal distribution for homogeneous crop emergence with corresponding effect in regular mesocotyil length (Laborde, 2011). The performance of no-tillage seeders depends on several factors related to field conditions, including type and amount of residues at soil surface and opener design. Common types of furrow openers used for conventional tillage are hoe, shovel, shoe, runner, single disc, double disc, chisel and inverted T furrow openers (Chaudhuri, 2001). According to the type of residues, shoe, single and double disc are common furrow openers in no-tillage seeders used in Portugal (Carvalho, 2001). Its importance is to cut a furrow and allow seeds or seedlings to be deposited before being partially covered with soil. Thus, to maximize potential maize yield, seed placement close to optimum sowing depth must be maintained. Although, adequate moisture can usually be found with increasing depth hazards of soil mechanical impedance increase with sowing depth (Ozmerzi, 2002) affecting seeders distribution. In a preliminary trial Conceição *et al* (2011) evaluating the need for an active depth-control system for direct seeding by means of a GPS equipment, a linear variable differential transducer and a load cell assembled in a no till seeding line, demonstrated a moderate correlation (r= 0.4), between the force exerted on seeders line and corresponding seed depth as clssified in three intervals (0-10mm, 10-20mm, 20-30mm), while generating spatial variability maps for both parameters. In the same trial Garrido *et al* (2011) also demonstrated a negative relationship between soil penetration resistance and the load cell values recorded at the seed line. Seeders distribution can be evaluated in the longitudinal and vertical planes. Vertical plane is specified by seeding depth (Karayel *et al.*, 2008). Conventional criteria for examining vertical seed distribution of furrow openers has been through the use of mean, standard deviation or coefficient of variation of sowing depth. If, in one hand seeding depth uniformity is a goal for all crop establishment , in the other hand, seeders furrow openers depth control is never constant depending on soil conditions. Seed depth uniformity affects crop emergence. Liu *et al.* (2004) showed a higher correlation between crop productivity and emergence uniformity than regarding longitudinal plants distribution. Neto *et al.* (2007) evaluating seed depth placement by measuring maize mesocotyl length under no tillage conditions in 38 farms concluded that 20% of coefficient of variation suggests the need for improving seeders depth control mechanisms. Thus, the objective of this study was to evaluate seed depth uniformity derived from casual relationships between soil mechanic resistance and vertical distribution under three different soil practices and create spatial variability maps.

2. Materials and methods

This study took place in private farms, Pigeiro, Comenda and Lages in north Alentejo, with predominance of fluvisoil and luvisoil (FAO classification) areas between April and May 2011 in three different field crop conditions: conventional tillage (CT), minimum tillage (MT) and no tillage (NT) at Alentejo region, Portugal, geographic coordinates 38º36'29'' N, 7º23'17,01'' W; 38º53'37,35'' N, 7º02'41'' W; 38º38'51,25'' N 7º46'55'',55 W; respectively. None as a Mediterranean climate, Alentejo is characterized by mild and rainy winters and hot and dry summers. Some climatic factors for the region during trial period were monthly average temperatures and rainfall of 18.4ºC and 73.5mm in April and 21ºC and 88,3mm in May. Soil analyses indicates clay loam textures for CT and MT areas, while clay was found under NT. In CT seedbed preparation before sowing consisted of a chisel ploughing to an approximate depth of 30 cm, by means of two disc harrowing and a *rototiller* passage. For MT seedbed preparation before sowing, two disc harrowing passages was used. At seeding date soil moisture

percentage at 60ºC was 14.8%, 11% and 12,5% to CT, MT and NT condition, respectively. Maize seed of 320g 1000^{-1} FAO 500 was used in all three treatments.
A Rau maxem, a Semeato SPE and a Semeato SSE seeders (figure 1) with similar technical specifications comprising four-row seeder 0.75m width row, double disc furrow openers and a depth control wheel per row were used. Seeding rate was 85000 seeds per hectare to 3 cm planting depth. Seeders were operated at 4 km h^{-1} in CT and MT. In NT condition, two working speed, 4 and 6km h^{-1} were used

Fig. 1. Seeding and seeders in conventional, minimum and no tillage condition at Pigeiro, Comenda and Lages farm, north Alentejo, Portugal.

As soil condition is affected by the different tillage methods, a Dickey John soil penetrometer was used together with a global positioning system (GPS), Magellan Mobile Mapper CX; soil penetration resistance was measured three times for the upper 5 cm depth using: a 3/4" tip in CT and MT, while a 1/2" tip was used for NT, also data were geographically referenced during seeding operation while seeds depth placement was measured after plants emergence. Seed depth placement was evaluated by measuring maize mesocotyl length after completely extracting four plants from the soil in each reference point. Parameters were described using mean, standard deviation, coefficient of variation and correlation values. Soil mechanical resistance and seed depth placement maps were created with a ArcView 9.0 software, using IDW interpolation method. To determine the influence of soil mechanic resistance and tillage system ,collected data were subjected to a analyses of variance (ANOVA) and Tukey's multiple range test, in order to find which means are significantly different one another . Statistical analyzes were performed using Statistica 6.0 software (StatSoft®).

3. Results and discussion

Relationships between soil mechanic resistance and seed depth placement are given in figure 2. As referred by Garrido *et al* (2011), independently of the tillage system trend lines shows that there was always a negative correlation between the studied parameters. As represented in spatial variability maps, figure 3, lowest values of seed depth placement are related to higher soil mechanic resistance areas, in some way agreeing with Ozmerzi (2002) who reports that the deepest seed distribution may be affected by soil impedance.

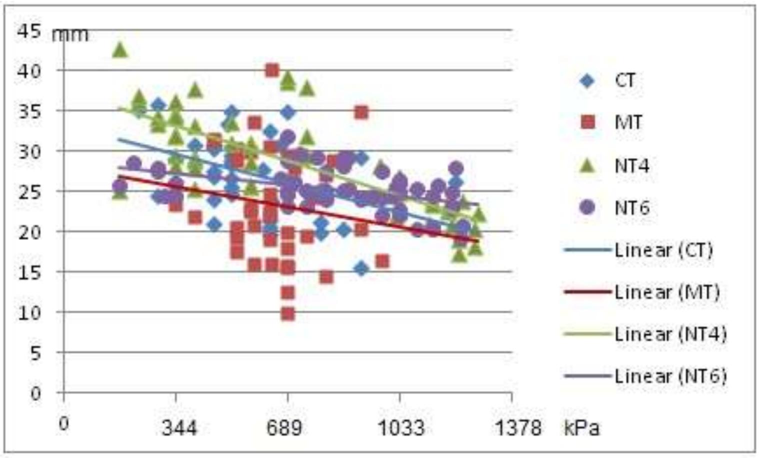

Fig. 2. Seed depth (mm) and soil resistance (kPa) relationship for different tillage systems and trend lines.

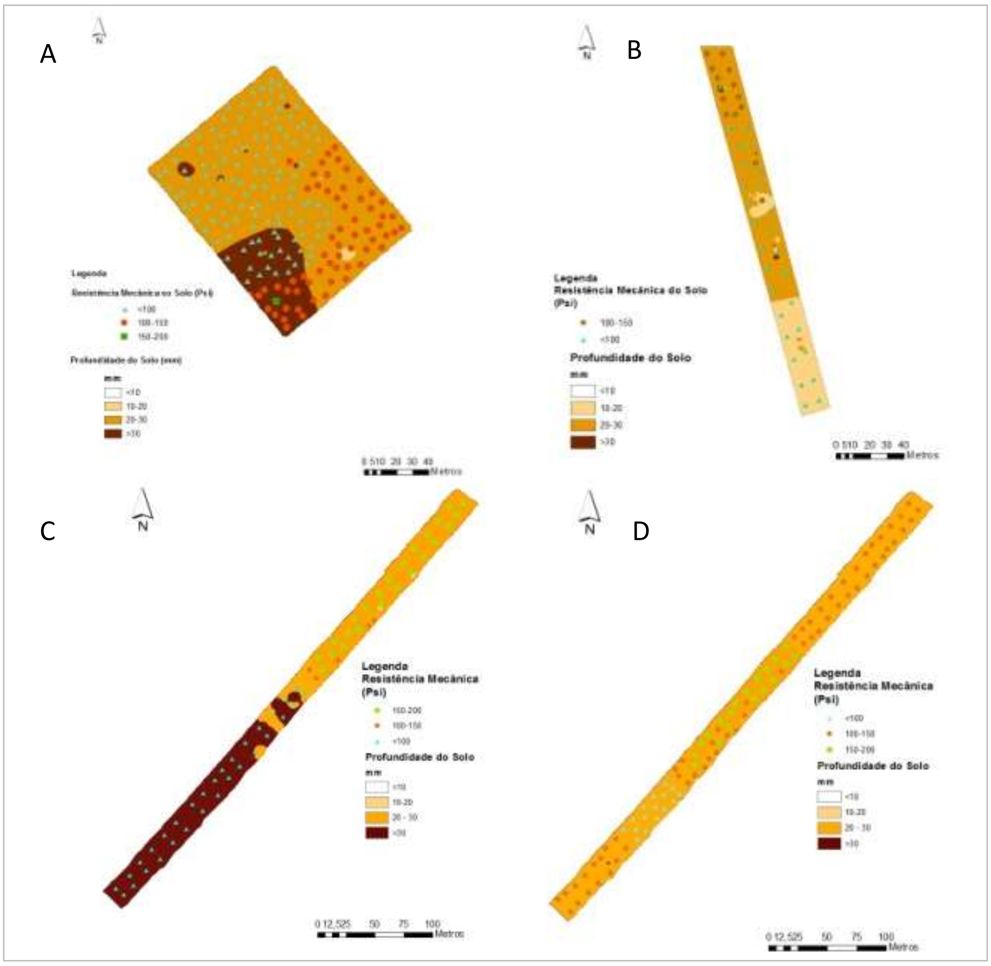

Fig. 3. Spatial variability maps for seed depth and soil resistance under different tillage systems, CT(A), MT (B), NT at 4km h^{-1} (C) and NT at 6km h^{-1}(D).

Comparing classes above 1033 kPa and 689 to 1033 kPa to values under 689 kPa, soil mechanic resistance determined significant differences to seed depth placement (table1). Although, all treatments presented acceptable means considering maize crop agronomic recommendations, vertical distribution measured by seed depth placement was significantly affected by tillage system affecting sowing uniformity, specially comparing CT and MT with regard to NT at 4 km h^{-1} (table 2). Higher influence of soil mechanic resistance to seed depth was demonstrated in NT at 4 km h^{-1} given by the highest correlation value of r = - 0.77. Best sowing uniformity was found for NT by increasing speed from 4 to 6 km h^{-1}. In MT, the highest coefficient of variation of 28,8% suggests similar results to those of Neto *et al* (2007), where a poor regulation performed by the operator or even inappropriate use of a no till seeder under minimum tillage condition is found, unfortunately a choice often made by no tillage seeders owners in this region.

Table 1
Influence of soil mechanic resistance to seed depth placement

Soil resistance (kPa)	> 1033 n = 37	689 - 1033 n = 69	< 689 n = 88	Signf
Seed depth (mm)	22.95 ± 2.54[a]	25.19 ± 5.6[a]	28.35 ± 5.39[b]	***

Note: Note:*** p <0.001
means within a group followed by same letter are not significantly different by Tukey's multiple range test

Table 2
Influence of tillage system to seed depth placement

Tillage system	Ct n = 42	MT n = 40	NT 4 n = 56	NT 6 N = 56	Signf
Depth (mm)	27.01 ± 4.74[ab]	23.43 ± 6.75[a]	28.49 ± 6.07[c]	25.27 ± 2.56[ab]	***

Note:*** p <0.001
means within a group followed by same letter are not significantly different by Tukey's multiple range test.

4. Conclusions

Based on this study, the following remarks are outlined:

- independently of the soil practice there was a negative correlation between seed depth placement and soil mechanic resistance being the higher correlation (r = - 0.77), and so the highest influence of soil resistance in seed depth was achieved for No Tillage condition operating at 4 kmh^{-1};
- The effect of soil mechanic resistance and work speed in NT caused significant differences in depth seed placement;
- Best sowing uniformity was in NT conditions working at 6 kmh^{-1} with the lowest coefficient of variation of 10.1%;
- On the contrary, the highest values of coefficient of variation of 28.8% in MT conditions suggests the inappropriate use of direct seeders under these tillage condition;
- These results on different soil management practices agree with preliminary trials, in the sense that a development of an seeder active depth-control system for seeders can be suggested as to improve sowing depth uniformity.

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