# Evaluating the need for an active depth-control system for direct seeding in Portugal

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## Abstract

The research evaluated the need for an active depth-control system for direct seeding in Portugal. Through the use of an LVDT (*linear variable differential transformer)* there were observed wide variations on the seed deposition depth (from 17.1 mm to 29.5 mm) during seeding tasks, being recorded by a load cell the force exerted by the seeding arm in order to penetrate the ground. The GPS installed on the tractor showed a variation in the seeding speed from 1 to 5 km/h; thus, a uniform seed deposition was hard to achieve. Problems encountered during the operation of the photocell hindered the obtaining of reliable data, with an achieved seeding dose much lower (2 .7 ± 1.9 seeds/m) than the pre-adjusted dose (5 seed/m). The seeding test confirmed that increasing the pressure of the seeding arm resulted in closer depth to the set-point. Nevertheless, due to soil strength variability (1001 ± 253 kPa by penetrometer resistance) and ground stubble, a high percentage of seeds were deposited on the surface (above 30%, according to chassis seeder displacement measured by the LVDT). In order to improve work quality, the development of an active control system for the seeder under certain soil conditions (heavy field texture with 5.21% of humidity) attains great importance in Alentejo (main grain growing Portuguese region).

**Keywords:** seeder, working depth, precision seeding, no-till.

## Introduction

Direct seeding, by maintaining vegetative covering, may reduce erosion by wind and water and have a subsequent impact on soil fertility as well as saving costs and time in mechanization. This is a feasible option for most direct seeding crops in Portugal. Several tests (Carvalho & Basch, 1994) that took place in the Alentejo region, which is the main Portuguese region of grain growing since the 1980's, proved that in the case of cereals there are not any grain yield reductions with direct seeding. In 2009 from a total area of 300000 ha of cereals nearly 60000 ha were grown under direct seeding technology which will lead to an increase of 0.03% per year of organic matter in the soil and retention of 3 tons/year $CO_2$ in the soil (Portuguese National Institute of Statistics, 2009).
The current Portuguese agriculture policy, supported by PRODER (Rural Development Program) encourages farmers to adopt this technology by a payment of 15 to 115 €/ha for autumn and spring grain cereals respectively, depending on the seeding area.
In direct seeding systems, variability of the ground resistance and the remains of previous crops amplify the difficulties in seed placement and emergence, with

sometimes dramatic consequences in superficial productivity (Valero *et al.*, 2010). Even under laboratory conditions, furrow opener depth is never constant, and the nature and behavior of different types of furrow openers is likely to produce depth fluctuations resulting in variations in emergence, plant growth, and yield. (Karayel & Özmerzi, 2008). Consequences of the lack of seeding depth control were illustrated by Sunderman (1964) for nine wheat varieties. He showed that mean emergence dropped from 74% to 23% as depth changed from 7.6 to 12.7 cm.

During the operation of direct seeding, seed deposition depth and its uniformity becomes one of the strongest points in terms of work quality. According to Bragachini & Peiretti (2007), maize seed must be placed at the appropriate depth to generate uniform plants that do not compete with each other, avoiding the growth of weaker and dominant plants that, in the case of maize, can affect yield by up to 10%.

The application of PA (Precision Agriculture) on direct seeding can significantly improve the energy efficiency and the results of emergence, compared with its application to conventional seeding. The key advantages in using passive and/or active depth-control systems that allow adjustment of the normal force of the grate or discs against the ground during seeding are minimizing drawbar pull (energy consumption) and increasing operation speed (work capacity, ha/h). Active control systems improve seed depth uniformity by adapting to the soil profile and resolving differences in vegetal remains throughout the field.

The first sensors proposed for instantaneous work depth determination during seeding were ultrasonic. Nowadays the possibilities include a variety of sensors such as load cells mounted in the spring of the depth control and LVDTs (*linear variable differential transformer)* or transducers to establish the angular or vertical displacement of the seeding arm. Most of these sensors can be found in commercial control systems.

Regarding the state of the art on precision seeding, Marlowe *et al*. (2009) performed a study focused on increasing crop emergence in non-tillage systems in order to promote the technique to farmers of Hokkaido (Japan). Several modifications were proposed to a conventional planter machine for non-tillage applications; also tests were carried out on intermixed plots of conventional tillage, replicated residue-free non-tillage, and actual non-tillage treatments for sugar beet and soybean cultivation. Seedling emergence population was monitored for both controlled and uncontrolled seeder rows. Crop yields between tillage treatments were measured and analyzed statistically. The results showed that the proposed active control was very effective as much in conventional seeding as in direct seeding although the improvement was double for direct seeding when compared to the conventional. The use of a seeder machine equipped with these systems implies both fuel saving and better emergence.

In Table 1, some of the sensors used for the study of the working depth and parameters to be measured by different researchers are summarized

Table 1. Sensors and parameters measured by different researchers in order to study the working depth.

| Sensors used | Parameters evaluated | Authors and year |
| --- | --- | --- |
| A load cell and a circular potentiometer | Controlling tillage depth “on-the-go”. | Goruco et al. (2001) |
| Ultrasonic and linear displacement sensors. | Regulate seeding depth | Marlow et al. (2009) |
| Ultrasonic | Minimize the difference of the manure injection depth | Saeys et al. (2007) |
| Load cells and sets of strain gauges | Measure the load applied to the implement during tillage. | Adamchuck et al. (2004) |

Another study was carried out by Canakci *et al*. (2009), in which direct seeding in maize, cotton and soybean were compared for different conditions of soil moisture content (3.5% against 18.7%) and ground stubble (1,320 kg/ha against 2,230 kg/ha), using, in both cases, double disc openers. This study mentioned the comparative advantage due to the feasibility of carrying out direct seeding under dry soil conditions although it is recognized that critical situations that limit the emergence could take place. Some of the most important results indicated that, under conditions of higher soil moisture-content, the seeds took more time to germinate because of the increase in seeding depth when compared to dry soil conditions. On the other hand, the amount of crop residue did not have a significant effect on emergence.
International standards for seeding equipment testing (ISO 7256-1:1984) established procedures for seed depth characterization on standard soil sand bed with well defined characteristics (composition and moisture content). These conditions are not achievable at any field test. Additionally, this standard did not state an optimal seeding depth profile as this is relevant at an agronomical level. Forage corn yields were significantly diminished when plant density was reduced (Campo, 1998). Thus, seeds located out of the optimal depth interval (2-4 cm) resulted in plant density and yield reduction, which suggests the need of an active depth control system.
Due to the great importance that direct seeding has within the Portuguese panorama (erosion problems, ground fertility, cost…), as well as the interest for improving technique performance by means of precision agriculture practices (homogenous depth-seeding); this work aims to evaluate the need for active control systems on seed placement.

## Materials and methods

The equipment to be installed on the seeder should allow us to know the values of seeding depth that the seeder arm was working at, as well as to record its work conditions (pressure on soil). Therefore, important parameters were established as measured during the test: the vertical seeding arm variation, and the force that is exerted on the ground to open the seedbed.
The mechanical seeder used for field work was a “SSE 5/6” (Semeato, Brazil) with 4 seeding arms. The sensors placed on one of the seeder arm are shown in Figure 1 and listed below:

- A load cell (K-2529 GMBH, Lorenz Messtechnik, Germany) located in the seeding arm spring, recording the force exerted by the spring on the seeding arm as it penetrated the ground.
- A LVDT (SX20MECR050, Sensorex, USA) located in the suspension wheel frame of the seeder machine to measure the distance between this axis and the extreme of the seeding arm.
- A Photocell (EX-32-B-PN, Sunx, USA) installed within the seeding tube to quantify the seed flow.
- Two GPS antennas (17x HVS, Garmin, USA) and (Arvanav 2, Arvatec, Italy) installed on the cabin of the tractor and in the seeding arm respectively, in order to georeference the sensor data as well as to measure ground speed.


Figure 1. Location of the sensors installed on the seeder arm: Photocell (A), LVDT (B) and load cell (C).

A datalogger (DT80, Datataker, Australia) was used for reception and recording of the values registered by the sensors. Also a signal amplifier and an electric power supply were required, all being located in the front grill of the seeding machine.
The test field (38º53'47.52" N, 7º2'53.86" W) of area 4.16 ha was located in Elvas, Portuguese district of Portalegre, in the region of Alentejo. Prior to test, a georeferenced soil analysis was carried out (see Figure 2).
A calibration and adjustment of the seeder machine took place prior to the experiment, with the following values: work speed 3 km/h; seeding rate 6.67 seeds/$m^2$ (5 seeds/m)[1]; seeding depth limiter disc was set to 3 cm; fertilizer depth limiter disc was set to 5 cm; working width 4 x 0.75m= 3 m.
Also prior to seeding, a mowing and removal of weeds was required due to their height (around 1 m). The field test took place between the $15^{th}$ and $17^{th}$ of June 2010.
While the seeder machine worked with all the measuring equipment, an operator made manual verification of seeds while also georeferencing this value. Table 2 summarizes the experimental set up and the seeder adjustment during the field test.

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[1] seed/m, stands for number of grains per meter in a seeding line.

Table 2. Experimental summary set up and seeder adjustment during field test.

| | |
|---|---|
| **Field co-ordinates** | 38º53'47,52" N  7º2'53.86" W |
| **Field area** | 4.16 ha |
| **Seeder model** | SEMEATO SSE 5/6 |
| **Seeding depth limiter disc** | 3 cm |
| **Seeding dose** | 6.67 seeds/m$^2$ or 5 seed/m |
| **Work speed** | 3 km/h |
| **Number of modalities (tested spring tensions)** | 7 (increasing spring stress offset under manual adjustment) |
| **Seeding date** | 15$^{th}$ and 17$^{th}$ of June 2010 |
| **Density and germination study date** | 19$^{th}$ and 20$^{th}$ of July 2010 |
| **Post-processing software** | Matlab 7.0 |

Figure 2 summarizes the types of data acquired during testing: one set by manual techniques and the other automatically. It is important to highlight that both types of data were georeferenced by means of GPS.

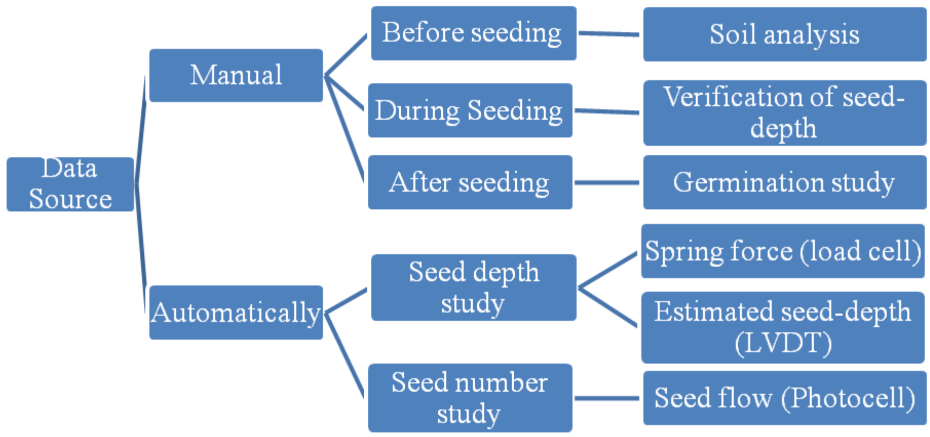


Figure 2. Diagram of the two acquisition data sources used for the field test.

## Results and discussion

The soil analysis on which the tests were carried out showed a moisture of 5.21%, by drying at 60 º C to constant weight. Also determined a bulk density of the particles of 1.53 g / cm ³ (dry weight at 105 ° C, divided by the mass of water that would occupy the volume of the ring) and a heavy texture area with an electrical conductivity of 0.07mS/cm. Figure 3 shows the mean values obtained by the operator during the soil analysis using a manual field penetrometer (Soil Compaction Tester, Dickey-john, USA), 3 replicates per location at 10 cm, in a total of 8 spread locations over the field, as well as values recorded by the load cell during the seeding tasks. For the realization of such zoning a grouping criterion, by Kriging interpolation, within three classes according to the penetration force (<920 kPa, 920-1100 kPa and >1100 kPa) was used.
Figure 3 shows that on the first day of planting (from the middle gap of load cell missing points to the right), the soil strength was low. On the second day of planting (from the gap to the left), it was higher. This is consistent with the mean daily values for the load cell (741.70N for the first day, and 1044.86N for the second), weighted with the number of data points gathered each day.

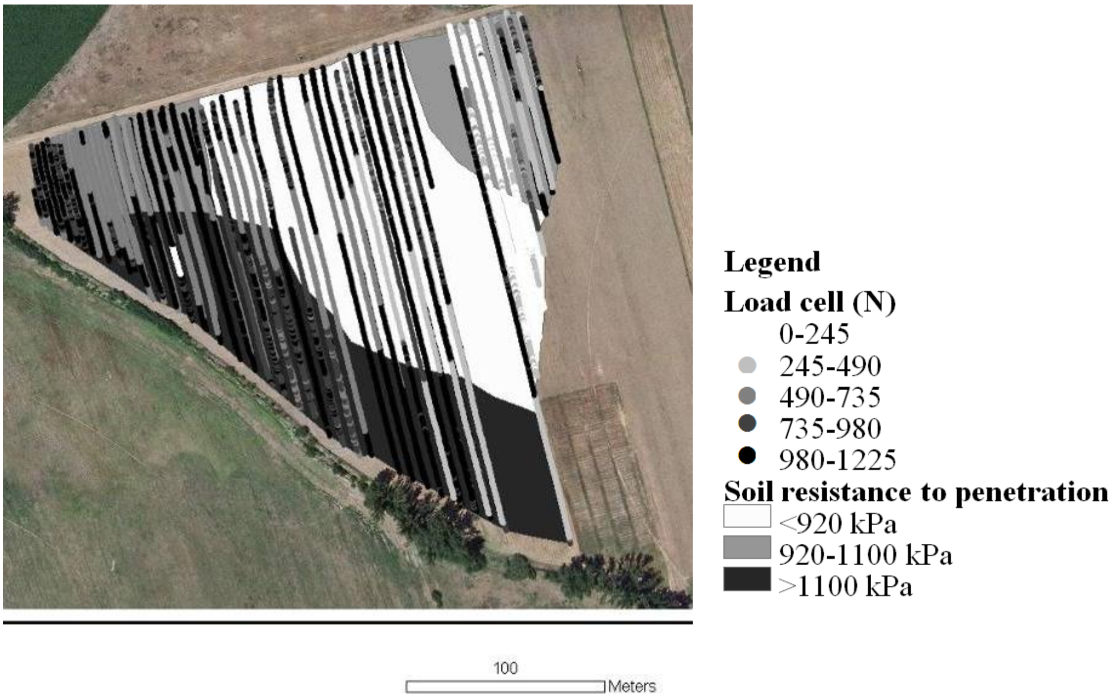

Figure 3. Georeferenced representation of the different zones depends on penetrometer force. The values recorded by the load cell are also displayed.

Table 3 shows the average data values, standard deviations and percentage of seeds deposited on the soil surface (depth<6mm), as inferred by the LVDT, by subtracting the maximum range of the sensor (50mm) and the recorded value. This number was subtracted, for calibration, by the minimum value obtained by the sensor (offset) in order to obtain the estimated depth, and load cell for each test conditions of the experiment (modalities 0 to 6). Each modality refers to increasing spring stiffness offset under manual adjustment. As the seeding work was being performed, an evaluation of its quality was carried out (subjective number of seeds on surface) and new adjustments (modality) were established. This resulted in a different number of data for each one of the modalities. The table shows the high percentage of seeds deposited at depths lower than 6mm, about 43% in the case of modality 6. It was hoped that increasing the force exerted on the seeding arm would reduce this percentage. However, results indicated that it was not evident due to the fact that the test plot did not have comparable soil conditions, having greater stone content and soil dryness for the modalities 4, 5a, 5b and 6 than for the previous ones, also corresponding to the second day of seeding. Estimated depths, according to increasing pressure of the seeding arm spring did get closer to the ideal depth (30mm), with a lower standard deviation; that is, a more homogeneous work by the seeding machine was achieved by this process.
Figure 4 shows that work speed was more stable and lower for the first day (modalities 1-3a) than for the second seeding day (modalities 3b-6). The seeding tasks for the second day were set to a high work speed at the beginning (for modality 3b approx. 4-5 km/h) but were reduced to values around 2-3 km/h for the last seeding modalities, being able to observe, in this way, the influence of driver change during the test. Under this aspect, it was observed the absence of relationship between the seeding depth reached and the working speed of the seeder. Figure 4 also shows (crosses), the location of georeferenced seeding depth by the operator during seeding tasks evenly over the field,

using a calibrated ruler and a GPS, with the surface as reference level. Average manual verification of seeds by the operator and estimated seed depth by the LVDT did not match, with a correlation (r = -0.612). This may be due to the scarce number of points collected manually for actual seed depth, but also to the fact that the penetration of the seeding arm in the soil (estimated by the displacement of the LVDT) does not always imply a certain depth in seed deposition.

Table 3. Representation of the number of data, average, standard deviation values and percentage of seeds deposited on surface, obtained from the load cell and LVDT for each modality during the test. The Standard error associated with the % of seed on the soil surface followed a binomial distribution.

| | | Number of data | % seed on surface (less than 6 mm) | Estimated depth | | Load cell | |
|---|---|---|---|---|---|---|---|
| | | | | Average (mm) | Standard deviation | Average (N) | Standard deviation |
| 1st day | Modality 0 | 785 | 23.7 ± 1.5 | 17.1 | 5.4 | 439.04 | 136.22 |
| | Modality 1 | 1,727 | 23.9 ± 1.0 | 20.3 | 5.5 | 216.58 | 123.48 |
| | Modality 3a* | 4,139 | 31.4 ± 0.7 | 23.1 | 4.4 | 1018.22 | 174.44 |
| 2nd day | Modality 3b* | 508 | 13.4 ± 1.5 | 23.1 | 3.6 | 949.62 | 153.86 |
| | Modality 5a* | 1,484 | 36.1 ± 1.2 | 24.8 | 3.6 | 1132.88 | 72.96 |
| | Modality 5b* | 5,086 | 33.1 ± 0.7 | 29.5 | 4.5 | 1022.14 | 143.08 |
| | Modality 6 | 2,024 | 43.0 ± 1.1 | 23.5 | 3.8 | 1061.34 | 186.2 |
| | **TOTAL** | **16,185** | **33.9** | **24.6** | **4.3** | **902.58** | **147.98** |

* Modality 3a and 3b corresponds to the same modality but on different days, while 5a and 5b corresponds to a different LVDT adjustment. Each modality refers to increasing spring stress offset under manual adjustment.


| Manual data seed depth | | |
|---|---|---|
| **Modality** | **% on Surface** | **N$^{er}$ of data** |
| **3b** | 14 ± 13 | 7 |
| **5a** | 25 ± 13 | 12 |
| **5b** | 32 ± 7 | 50 |
| **6** | 32 ± 9 | 28 |

Figure 4. Georeferenced representation of the work speeds (km/h) of the seeder as well as the location of the seeding depth samples obtained by the operator.

Figure 5 shows the estimated depths measured by the LVDT during the seeding for each of the modalities mentioned above. Note the high number of seeds that were deposited at an estimated depth less than 6 mm (considered as surface deposition). This fact confirms the importance of developing an active system that reduces seed deposition on the surface. With regard to the high number of surface seeds (even with a higher spring arm pressure), it is important to mention that soil moisture and stoniness conditions for each of the two areas used on the second day had very different characteristics, with a higher content of stones. This increased the difficulty of burying the seeds, reducing seed germination calculated one month after field test.
Figure 6, shows the relationship between the LVDT and load cell. The estimated depth was closer to the set-point with increased pressure offset on the seeding arm. For the first modalities the ranges of work in relation to the estimated depth were much greater than for the modalities in which increased pressure was used in the seeding arm spring. The higher the spring stress offset, the lower the variation in seeding depth.


| Germination study | | |
|---|---|---|
| **Modality** | **Average ($pl/m^2$)** | **Standard deviation** |
| **1** | 2.33 | 2.98 |
| **3** | 4.58 | 4.29 |
| **5a** | 6.27 | 3.05 |
| **5b** | 3.15 | 3.37 |
| **6** | 3.48 | 4.19 |

Figure 5. Georeferenced representation of the estimated depth (mm) measured by the LVDT and the germination values obtained one month after the test. In modality 3a there were missing data.

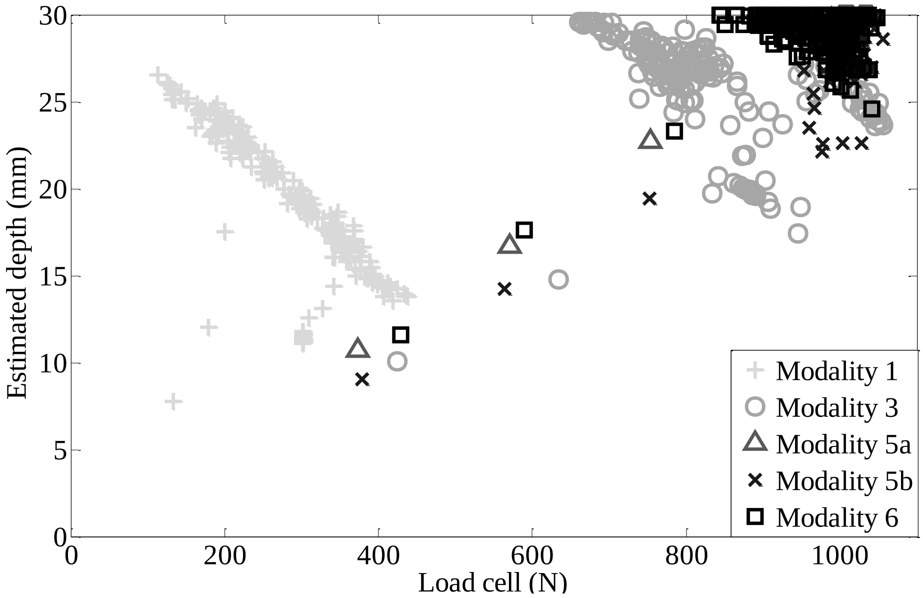

Figure 6. Comparison of estimated depth measured by the LVDT (mm) and spring force by the load cell (N) for the different modalities where the seed depth was deeper than 6mm.

With regard to the photocell used to count seeds, it was concluded that mounting restrictions led to large under-estimation of values. Only the first moments of work (a small part of the modality 1) were reliable for seed counting showing values of 2.7 ± 1.9 seeds/m, which is higher than the actual number of plants assessed after emergence at 1.3 ± 0.4 pl/m.

## Conclusions

Precision direct seeding is a recent term where the modality of direct seeding with the technologies and foundations of the precision agriculture are combined, not being the parcel considered like a set, but differentiating the local needs.

The test carried out in this research work, with a soil conditions and specific seeder equipment, shows a high number of seeds that were deposited on the surface (from 13 to 43% depending in seeder adjustment). For this reason, the need for the development of a depth-control active system can thus readily be suggested. Active systems could rely on the contribution of the load cell as well as on LVDT data.

For the Portuguese region of Alentejo (place where the test were carried out), the development of an actuator that positions the seeds always at the same depth, could also entail a power saving during the seeding tasks, due to the large soil variations. A better quality of the work would be added to this advantage, thus preventing the formation of dominant and dominated plants that generate a yield reduction of the crop.

Further studies in Portuguese region, will also include fuel consumption as an important fact for PA.

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