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Use of electronic sensors to identify seed sowing depth variation

***Abstract**. Uniformity of seed sowing is very important for modern industrial production technologies, which is reinforced by the need for high automation and robotization of this process. The work in progress concerns the possibility of using sensors to control the sowing depth in real time. The sowing depth control function implemented in this way allows the seeder to automatically respond to changes in the conditions of the soil layer in which the seeds are placed. In domestic conditions, Kogut [1] developed a method for evaluating the working depth of row seeding coulters using Correvit-H400/250 sensor for measuring the distance between the soil surface in the coulter working line and the reference surface and using Correvit-L3 type sensor for recording the seeding machine working speed and the distance travelled during the determination of the tested parameters. In this paper, using optical and ultrasound sensors, the depth of seed placement in soil was estimated, taking into account the working speed of the seeder and the soil compactness conditions. Moreover, maps of spatial variation of the measured parameter were created within the experimental field, the area of which was 38 ha. The best adjustment of sowing parameters was found in the range of driving speed from 4 km/h to 6 km/h. The applied non-contact method of sowing depth measurement gave a higher accuracy of indications in comparison with contact sensors.*

***Streszczenie.** Głębokość siewu nasion jest dla współczesnych technologii produkcji bardzo ważna, co potęguje fakt wysokiej automatyzacji i robotyzacji czynności technologicznych. Prowadzane prace dotyczą możliwości zastosowania sensorów umożliwiających sterowanie głębokością siewu w czasie rzeczywistym. Tak realizowana funkcja regulacji głębokości siewu pozwala na automatyczną reakcję siewnika na zmianę warunków warstwy gleby w której umieszczane są nasiona. W warunkach krajowych Kogut [1] opracował metodę oceny głębokości pracy redlic siewników rzędowych stosując czujnik CORREVIT-H400/250 do pomiaru odległości między powierzchnią gleby w linii pracy redlicy a powierzchnią odniesienia oraz stosując czujnik typu CORREVIT-L3 do rejestracji prędkości roboczej siewnika i drogi przebytej podczas wyznaczania badanych parametrów. W artykule wykorzystując czujniki optyczne oraz czujniki ultradźwiękowe oceniono głębokość umieszczenia nasion w glebie dla dwóch rodzajów siewu tj. taśmowego i rzędowego uwzględniając prędkość roboczą oraz warunki zwięzłościowe podłoża. Ponadto stworzono mapy przestrzennego zróżnicowania mierzonego parametru w obrębie poligonu doświadczalnego, którego powierzchnia wynosiła 38 ha. (**Wykorzystanie czujników elektronicznych do identyfikacji zróżnicowania głębokości siewu nasion**).*

Keywords: optical sensors, precision agriculture, mechanical engineering
Słowa kluczowe: czujniki optyczne, rolnictwo precyzyjne, inżynieria mechaniczna

Introduction

The variation of physical and chemical properties of soil, on the surface of an agricultural field, is one of the reasons for the introduction of precision farming technologies [2,3]. Precision refers to each technological operation and it is particularly important in the case of sowing seeds. The requirements for uniformity and depth of seeding in the furrow result from agrotechnical recommendations and for fine seeds the seeding depth ranges from 0.01m to 0.02m, for medium seeds from 0.03m to 0.04m and for coarse seeds from 0.08m to 0.1m. This entire spectrum of depths forces producers to use very precise adjustment of coulter working depth, while maintaining the regime of seed distribution in the coulter and the required seeding capacity. Systems allowing real-time control of sowing parameters with an appropriate system of archiving spatial data on the implemented process become a necessity. Kogut [1] used optogeometric sensors to measure the depth of the drill and the working speed of the aggregate.

Kiełbasa et al. [4,5] used H-CE and CORREVIT L-400 sensors in measuring the potato planting depth and working speed of the planter and tillage tools binding all signals into one measurement system. When choosing the optimum depth, the main factor is to achieve seed contact with the water-conducting soil layer [6,7,8]. Too high sowing depth leads to worse plant emergence, but with low sowing depth, in addition to the problem of water shortage, there is also the danger of germinating beet being damaged by fertilizers or herbicides. In recent years, KLEINE and ACCORD have introduced seed drills with electric drive, operated directly from the tractor cab. This drive system provides the possibility to change the sowing distance while driving. This system enables by means of an electromagnetic clutch, to disengage the drive at any point, which is used for setting up a driving track for an organized movement of machines in the field.

Proximity sensors can be measured either invasively (in situ or ex situ), when contact is made with the soil, or non-invasively, without contact. Depending on the source of energy, sensors can be active or passive, using energy from an artificial source or from natural surrounding light, can operate as stationary or mobile, and inference of the measured property can be direct or indirect. Proximity sensors work at a distance of no more than 2 m from the soil, and do not include remote sensing or laboratory methods, except for the need for laboratory measurements to calibrate the device (such as in vis-NIR measurements) [9].

Proximity sensing are mostly indirect, less accurate measurements, and are constantly being improved. They may require more investment, but the aforementioned advantages mean that such sensors will contribute to greater adoption of precision agriculture [10]. Adamchuk [11] reports that most sensors used for this purpose are: electrical and electromagnetic, measuring electrical resistance/conductivity, capacitance or inductance, which is influenced by the texture of the soil under test; optical and radiometric, using electromagnetic waves to detect the level of absorbed/reflected energy through soil particles; mechanical, measuring the force resulting from the work of a tool in the soil; electrochemical, in the form of ion-selective electrodes that show the voltage created by selected ions (H+ , K+, NO_3, Na+, etc.). These ions influence the electrical parameters of soil [12,13].

To assess the state of soil compaction, including the detection of plow sole or subsoil compaction, sensors are used to measure the shear resistance of a tillage element or the penetrometric resistance the soil puts up when trying to decompact it with a cone [14].

Materials and methods

The objective of this study was to identify variation in seeding depth of the KVERNELAND Accord Monopill S precision seeder (Figure 1) using optical and ultrasonic sensors (Figure 2).

The quality of seed deposition in the soil is determined by its vertical distribution, i.e. depth, and the uniformity or variability of its horizontal distribution in the seeded rows. Seeders were monitored at four operating speeds of 8, 10, 12, 14 km/h and three repetitions During the measurements We followed the ISO 7256/2 standard for evaluating seeders with continuous seeding.

Fig. 1. KVERNELAND Accord Monopill S precision seed drill

Sowing depth as defined by STN 46 5451 means the distance from the bottom edge of the seed to the soil surface above the seed after it is placed in the soil. Two measurement systems were used for the measurements, a contact (inductive) sensor and a non-contact (ultrasonic, optical) sensor in combination with an A/D converter with recording on an IM memory card. Seeding depth was measured by continuously measuring the distance between the seeding foot position and the soil surface. The results were confronted with ISO 7256/2. Figure 2 shows the location of the optical sensor for distance measurement.

Fi. 2. Location of the optical distance sensor

In contrast, Figure 3 shows the location of the force sensor.

The scope of the research included measurement of the above mentioned seeding depth at different working speeds of the seeder and different parameters of the soil on which the seeding was carried out as well as geometrical properties of the seeds that were sown. The spatial variation of the experimental factors was visualized by means of appropriate maps, which were made using the IDW method in the WGS 84 coordinate system with the number of sampling points being 33 (Figure 4). It should be noted that soil condition and seed shape parameters were monitored to exclude the influence of these factors on the experimental results. In the experiment, several variants of seeder speed, which made it possible to determine in the end the optimal working speed, the use of which minimizes the unevenness of seeding depth under the given conditions.

Fig. 3. Location of the force sensor

Fig. 4. Testing ground

The vertical distribution of the seeds is determined by their depth - the depth of sowing. Sowing depth is understood, according to EN 46 54 51, as the distance from the bottom edge of the seed to the soil surface above the seed after it has been placed in the soil. In the case of beet sowing, it is necessary to make the above definition more precise. Sowing depth (h) is determined not only by the depth of the seed in the soil (i.e., the distance between the bottom edge of the seed and the original soil surface), but also by the height of the soil packet above the seed.

Results

Figure 5 shows the spatial variation of the soil lateral resistance force placed on the measuring coulter of the seeder, working at the depth of seed sowing. The soil was found to vary with respect to its preparation for sowing. In extreme cases, a twofold difference in resistance values of the working coulter was recorded (red and yellow). Analyzing the spatial structure of variation in resistance of the sowing coulter, it should be noted that extreme values of forces were recorded incidentally, mainly in the extreme parts of the field. Mean values of resistance to work of the seeder coulter ranged from 86 N to 119 N were recorded on the prevailing area of the field.

Fig. 5. Spatial variation of the resistance force of the drill coulter at the depth of potential seed sowing

The coulter working resistance force was contrasted with the spatial distribution of soil compactness, which was measured at a depth of 0.05 m (Figure 6). The average value of soil compactness was 0.08 MPa and was located in the central part of the field. The higher and lower values of soil compactness were incidental and occupied a relatively small area of the field concentrated mainly at the field periphery. A high spatial convergence was found in the variability of both parameters of the soil layer in which the seeds were placed. This confirms the correctness of the developed system for measuring the resistance force of the sowing coulter.

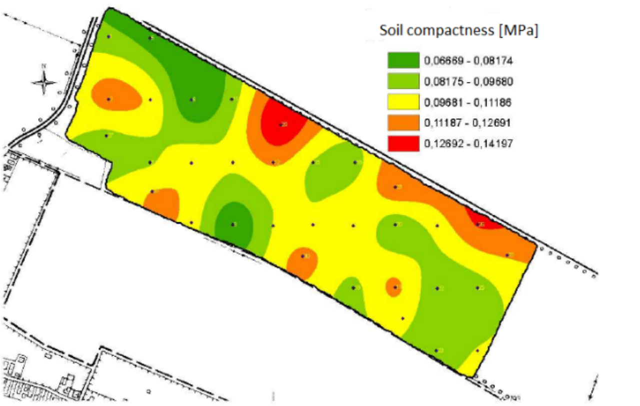

Fig. 6. Spatial variation of soil compactness at the depth of potential seed sowing

On the other hand, Figure 7 shows the soil compactness at a depth of 0.15m, where a gradual increase in areas of higher compactness was noted (red). A slightly different characteristic of the variation in compactness within the analyzed field was noted at a depth of 0.3m. The highest compactness was characterized by the southeastern part of the field (red) and the lowest by the central-eastern part of the testing ground.

The soil moisture in the area of potential seed sowing is very important from the point of view of homogeneity of seeding conditions. Figure 9 shows the spatial variation of soil moisture as an average value from 0.01 to 0.1 m depth. There was little variation in soil moisture except for a small area (yellow) located in the middle of the field where soil moisture was lowest at about 6%. Areas with significant soil moisture that exceeded 20% were identified, but were located mainly at the edge of the field. The average soil moisture value was 12% and was dominant within the analyzed field.

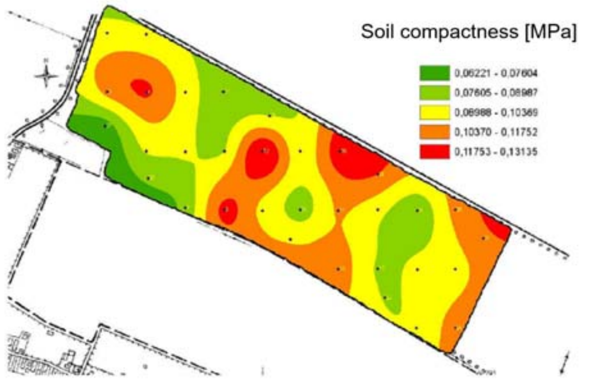

Fig. 7. Spatial variation of soil compactness at the depth 0,15 m

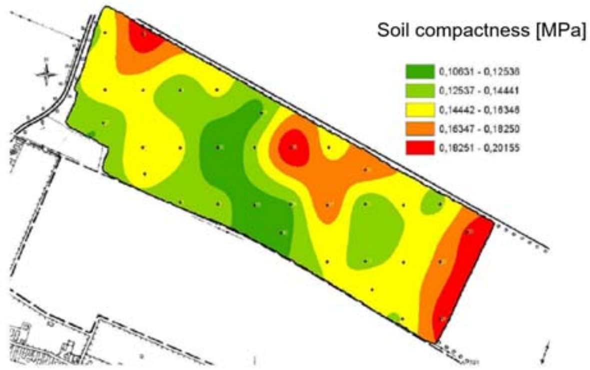

Fig. 8. Spatial variation of soil compactness at the depth 0,3 m

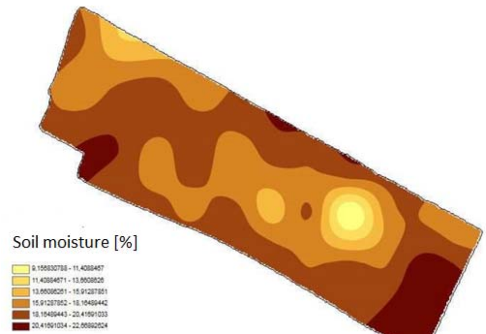

Fig. 9. Spatial variation of soil moisture on seed sowing depth

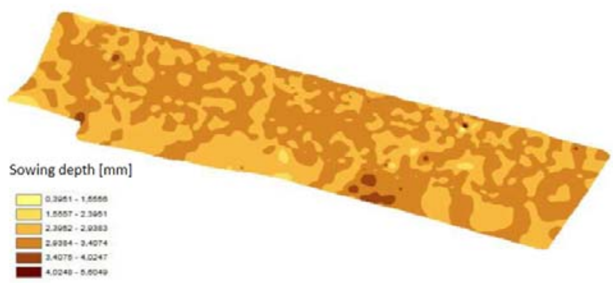

Fig. 10. Spatial variation of seed sowing depth

Analyzing the sowing depth using different operating speeds, it was found that the least variation in sowing depth values was recorded for operating speeds ranging from 4 km/h to 6 km/h. The use of an optical sensor enabled the seed sowing depth to be identified at a frequency that allowed the spatial distribution of the measured depth to be generated. Figure 10 shows the spatial variation of seed sowing depth within the experimental field at an operating speed of approximately 8 km/h.

The average seed sowing depth was found to range from 0.0025 m to 0.0035 m (dark yellow) and had little spatial variation within the experimental field. Small point-like areas were observed where the seeding depth was greater than 0.004 m. A few very small areas were also observed where there was a pronounced shallowing of seed sowing. It should be noted that there was no effect of variation in operating resistance strength and variation in topsoil moisture content on seed sowing depth because the areas where this variation was identified do not overlap.

Conclusion

The aggregate driving speed was also varied, while the lowest variability of sowing depth was recorded in the speed range from 4 km/h to 6 km/h. The use of higher driving speeds resulted in greater variability of the sowing depth and its shallowing. The non-contact method of sowing depth measurement used gives higher accuracy of readings compared to contact sensors irrespective of the sensor type i.e. laser or ultrasonic. Findura [15] also achieved some results in measuring seeding depth by focusing on accurate measurement of seeding depth in precision seeders, similar results were obtained by Boll [16] who monitored not only the effect of operating speed on seeding depth but also the sticking of seeding depth according to different soil compaction and type of seeding coulters. There was no significant relationship between soil resistance force and sowing depth.

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