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# INFLUENCE OF DESIGN OF THE DISK FURROW OPENER OF NO-TILL SOWING MACHINES ON THE SEEDBED QUALITY

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## ABSTRACT

**In the context of modern agriculture knowledge of soil properties becomes essential for the optimization of crop production. An increasing interest can be observed in last few years for conservative soil management practices such as no-tillage, that promise many long-term benefits for soil health. Aim of this research was to investigate the soil preparation mode for three models of disks (one flat and two corrugated) across different sowing speeds (3, 8 and 11 km/h) in order to identify ways to optimize no-tillage technology for crops with higher row spacing. Results have shown that soil cone index is a useful indicator for characterization of the general effect of sowing equipment on seedbed quality and consequently on root growth and plant development. More attention should be given in the future to possibilities to develop furrow openers and machines adapted to particular soil conditions as well as with real-time adjustment, in order to increase precision and feasibility of no-till sowing.**

**Keywords:** no-tillage, furrow opener, sowing, seedbed, soil physical properties.

## INTRODUCTION

In the perspective of a sustainable agriculture, soil is the most important resource and the knowledge of the soil properties are essential for profitability of the production (Furriel et al., 2015). Soil properties were demonstrated to be an important factor of influence on spatial variability of yield (Rodrigues et al., 2012). Mechanical action on soil along with chemical stress comprise the main threats to the sustainable provisioning of ecosystems services ensured by soil biotic community (van Capelle et al., 2012; Köhl et al., 2014).

Conventional tillage (CT) is the most widely used soil management regime and it is characterized by profound changes of the physical, chemical and biological conditions in the upper soil layer (up to 35 cm depth) (Köhl et al., 2014). In CT systems the soil ploughing and harrowing ensures weed suppression and levels soil surface enabling a precise seeding. However, CT causes degradation of soil structure, leading to erosion, subsoil compaction, soil surface seals and decrease of organic matter besides the adverse effects on soil biodiversity and sustainability of production (van Capelle et al., 2012). By contrast, in no-tillage (NT) system, the soil is not disturbed (Köhl et al., 2014). Instead, the top layer of the soil is touched only once and worked by seeding-machine furrow openers only to the extent required for the insertion of plant seeds (Sarauskis et al., 2013). Advantages of NT technologies are diverse. Soil under NT shows more micropores, higher water volumetric content, lower evaporation loss during vegetation period and higher levels of available P, Ca and K (Isro et al., 1994). In addition, NT reduces carbon emissions in agriculture due to reduced energy and machinery use and stimulates all biologically derived benefits for the crops, such as improved biologic N fixation, natural suppression of disease and pests, and increasing carbon sequestration (van Capelle et al., 2012). Also, NT soils characteristics tend to be highly stratified (Schlatter et al., 2020).

Some authors report that by applying conservative soil management, such as no-till,

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the yields can be reduced compared to conventional technologies (Hughes et al., 1992; López and Arrúe, 1997; Salem et al., 2015). But other authors, citing experimental data indicate that at high N rate maize grain yields were higher under NT than in CT management (Isro et al., 1994).

However, one issue that has to payed attention to is that under no-till the soil pH in the seed zone tends to decrease especially under N fertilization. Thus, soil pH correction might be required, otherwise after 2-3 years of no-till the exchangeable Al and Mn could reach high levels. Normally, the organic matter accumulation near the surface under NT should contribute to diminishing the adverse effects of soil acidification (Isro et al., 1994; Schlatter et al., 2020).

Out of the desire to save this hard-to-regenerate resource, minimum-tillage or no-tillage systems have begun to be used on larger scales (Sarauskis et al., 2013; Lamande et al., 2007; Fritton, 2008; Cavalieri et al., 2008).

The SCI (soil cone index) is an extremely important soil quality parameter with regard to the ability of roots to penetrate soils (Tracy et al., 2011). Root responses to soil cone index and drought stress can be an important basis for crop management (He et al., 2017).

In Romania a scale was proposed by Canarache (1990) for the classification of soil cone index (Table 1).

*Table 1*. Limits for soil cone index (Canarache, 1990)

| **Resistance class** | **Limits (MPa)** | **Root growth** |
|---|---|---|
| very low | ≤ 1.0 | unrestricted |
| low | 1.1. - 2.5 | |
| medium | 2.6. - 5.0 | limited |
| high | 5.1 - 10.0 | |
| very high | 10.1 - 15.0 | no root growth |
| extremely high | > 15.0 | |

Results obtained by Lin et al. (2016) suggest that maize roots are more vulnerable to soil cone index than to drought stress when soil has a high bulk density.

Aim of this research was to investigate influence of the design of the disk furrow openers on the soil cone index.

## MATERIAL AND METHODS

In experimental conditions were tested three disk furrow openers: flat disk A (smooth); corrugated disk B (14 rifles); corrugated disk C (26 rifles).

These tests were conducted at the Institut für Agrartechnik from University Hohenheim, Stuttgart, Germany.

The testing channel presented soil comprised by 72% sand, 16% clay, 12% silt. The channel had a length of 46 m, width of 5 m and depth of 1.2 m (Figure 1).

The tractor of the testing channel was equipped with hydrostatic transmission, both for propulsion system as well as for implements. This allows a precise setting and monitoring of the PTO rotational speed and torque.

For experiments the soil was prepared with the harrow (Figure 1), roller (Figure 2) and irrigation installation.

*Figure 1*. Preparing the soil from the channel

*Figure 2*. Roller levelling the soil

The rotative harrow was used for breaking and smoothing the soil, then soil was levelled with the roller and at the end it was watered with the irrigation system. After watering, the soil was covered with a rubber cover and left for 24 hours in order to obtain a uniform distribution of water in the soil.

The tested furrow openers were attached on a universal frame that would allow easy attachment to all machines tested. The frame was designed and build by the author in the workshop of the Hohenheim University.

Before testing the machines, the soil samples were tested by classic method through drying in the oven. Humidity was also determined by piezoelectric hygrometer. Soil cone index was determined with penetrometer with 11 needles (Figure 3). The data acquired was stored as text files and from each measurement were obtained between 5000 and 7000 data points. Soil cone index is considered the main indicator to evaluate the overall friability, since the classical method to determine the degree of soil crumbliness is not suitable in the case of no-till.

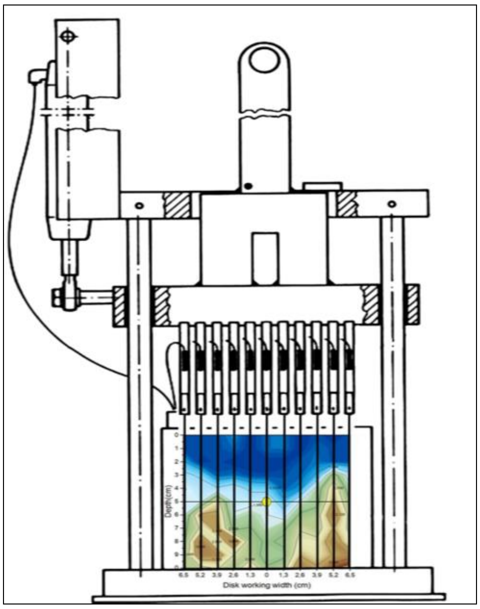

*Figure*. 3. Penetrometer

Through pushing the handle, all needles are inserted into the soil. The degree of resistance the needles meet determines ring sensors to deform proportional to the force exercised on them. On each sensor there is a tensiometer probe that converts the deformation into electric signal. This signal is transmitted to an informatic acquisition system that stores the information representing the path for each needle. Data acquisition was performed with LABTECH.

In the present study was used a prototype designed by author, for no-tillage technology, respectively adapted for direct seeding of maize.

The experimental prototype was equipped with three disk furrow openers:

a) flat disk (smooth) - disk A (Figure 4);
b) corrugated disk (14 waves) - disk B (Figure 5);
c) corrugated disk (26 waves) - disk C (Figure 6).

*Figure 4.* Flat disk - disk A

*Figure* 5. Corrugated disk - disk B

*Figure 6*. Corrugated disk - disk C

The testing was performed on three rows at speeds of 3, 8 and 11 km/h. For each variant were performed two measurements, noted “d” and “g”, regarding the soil cone index: first one after the disk furrow opener (d) and the second one after the sowing equipment, after passing of the press wheel (g), which was made from two discs placed in V-shape (Figure 7). The seed placement depth was considered to be 5 cm, the results being reported in particular at this depth.


*Figure 7*. Experimental prototype with rifle disk

## RESULTS AND DISCUSSION

Analysis of the isometric lines of soil cone index presented in figures 5 and 6, shows that by utilizing the flat disk at 3 km/h measurement-d (after furrow opener), at sowing depth there is registered a value of 0,54 MPa (Figure 8).

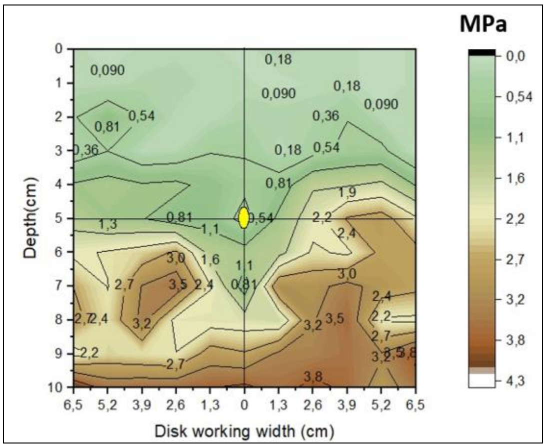


*Figure 8.* Soil cone index after disk model “A” at 3 km/h, measurement-d

The situation changes in the case of measurement-g (after the press wheel), when soil cone index decreases to around 0,1 MPa (Figure 9), fact that translated in a better loosening of the soil.

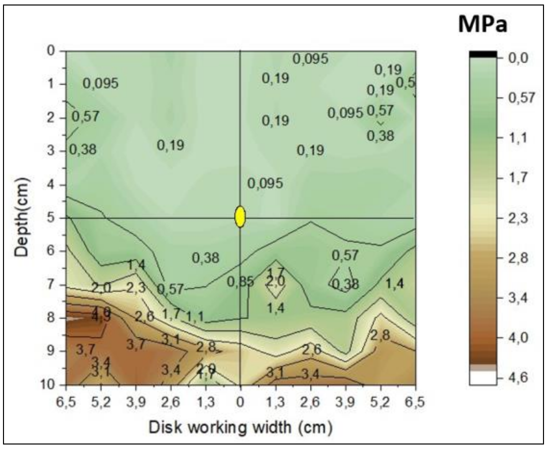


*Figure 9.* Soil cone index after disk model “A” at 3 km/h, measurement-g

From the data presented in figures 10 and 11, by analyzing isometric lines can be observed that at speed of 8 km/h increases the degree of soil movement after the furrow opener disk (Figure 10).

After the press wheel the values registered at 5 cm depth increase until about 0.71 MPa, ensuring the covering of the seed with fine soil particles. These results suggest that by utilizing this disk model for direct sowing at 8 km/h can be obtained good results, ensuring both soil loosening as well as an intimate contact between seed and soil particles, after the passage of the entire section and the press wheel (Figure 11).

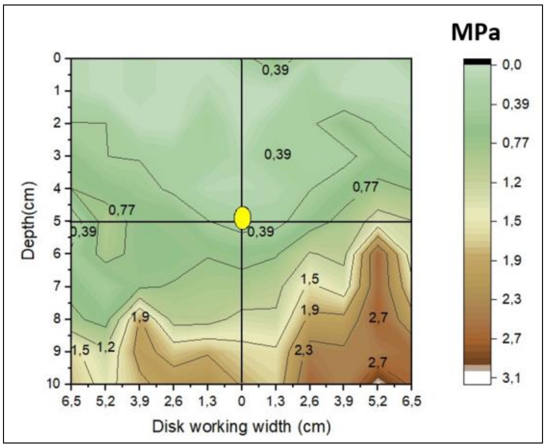


*Figure 10*. Soil cone index after disk model “A” at 8 km/h, measurement-d

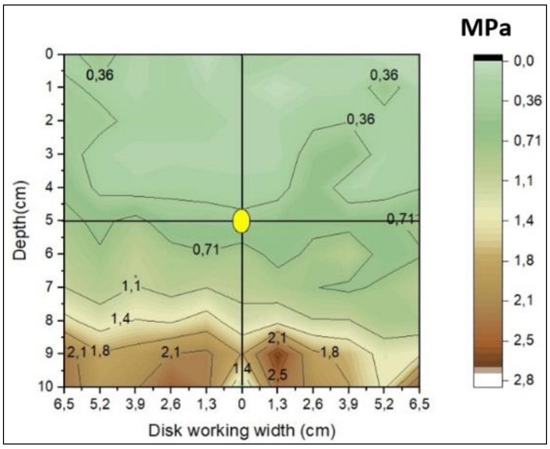


*Figure 11*. Soil cone index after disk model "A" at 8 km/h, measurement-g

In the case of utilizing the flat disk model at a speed of 11 km/h, from the analysis of isometric lines can be observed that also at this seed the soil loosening and soil cone index are within acceptable levels for direct sowing (Figure 12, Figure 13). At 10 cm depth can be observed that the soil loosening decreases. Soil cone index values of about 3 MPa are considered superior acceptable limits by López-Garrido et al. (2014) at which roots can develop unrestricted in no-till systems.

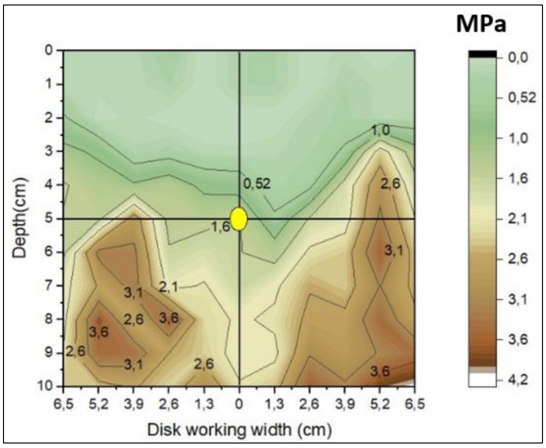


*Figure 12*. Soil cone index after disk model "A", at 11 km/h, measurement-d

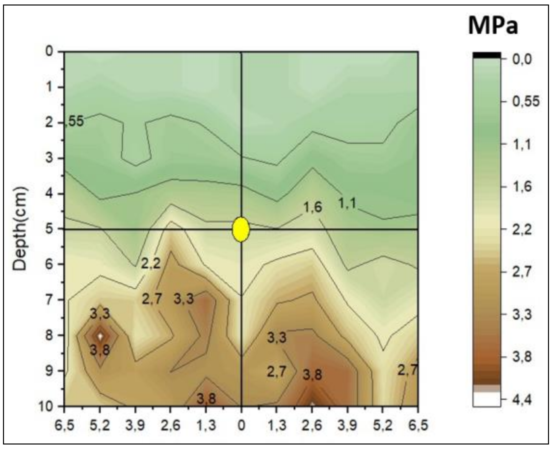


*Figure 13*. Soil cone index after disk model "A" at 11 km/h, measurement-g

In the case of the disk B (with 14 undulations) and a speed of 3 km/h, the results indicate a good soil movement level. The values registered at sowing depth (5 cm) after the opener disk were around 0,54 MPa (Figure 14), while after the press wheel was registered a slight increase in soil compaction, ideal for ensuring the intimate contact between seed and soil particles (Figure 15). Thus, this effect can be attributed to the pressing wheel.

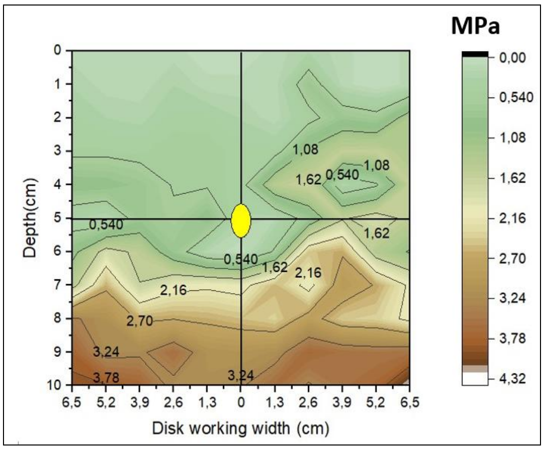


*Figure 14*. Soil cone index after disk model "B" at 3 km/h, measurement-d

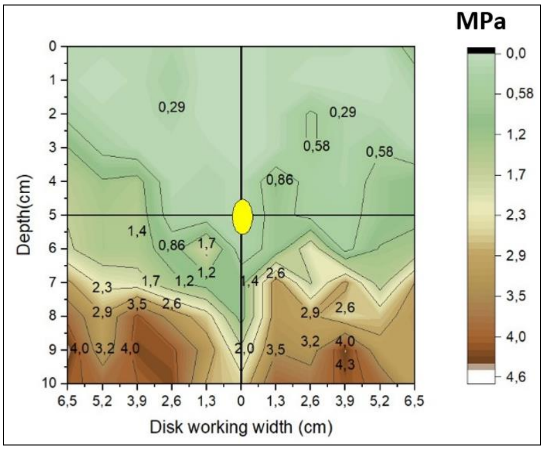


*Figure 15*. Soil cone index after disk model "B" at 3 km/h, measurement-g

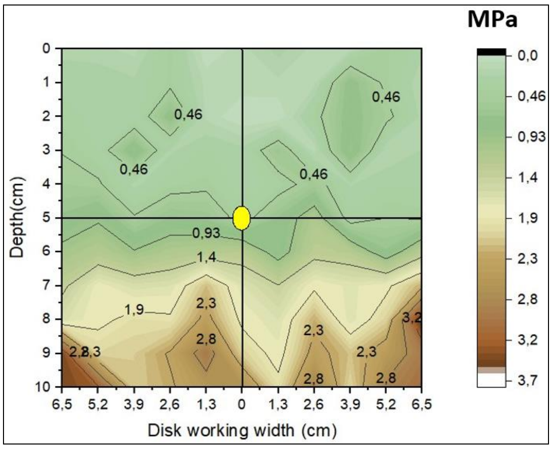


*Figure 17*. Soil cone index after disk model "B" at 8 km/h, measurement-g

By analyzing isometric lines obtained after the testing of the disk B at a speed of 8 km/h, was determined that soil cone index values at seed depth were below 1 MPa. Specifically, after the furrow disk opener the soil cone index was around 0,74 MPa (Figure 16) while after the compaction wheel at same depth the soil compaction increased slightly and reached values around 0,93 MPa (Figure 17).

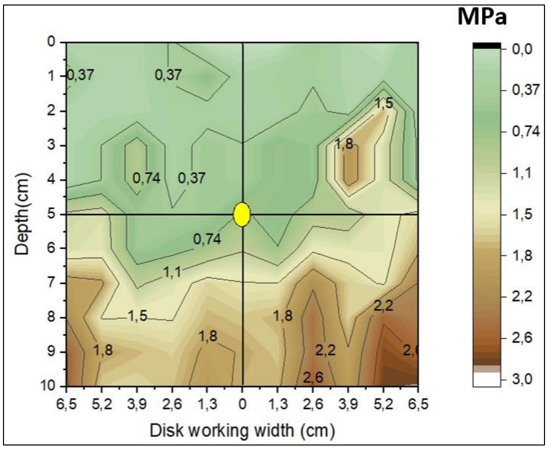


*Figure 16*. Soil cone index after disk model "B" at 8 km/h, measurement-d

It should be noticed that in this case the increased speed had an energic action at sowing depth resulting a better soil movement both on soil profile as well as horizontally.

By utilizing the disk model B at a speed of 11 km/h was observed a sufficiently well soil loosening at seed depth that guarantees a subsequent optimal plant development following direct sowing.

By analyzing isometric lines from figure 18, can be observed a lower degree of soil movement at higher speed compared to lower speeds, for the same disk model.

The measurement-g (Figure 19) in the case of the disk model B, indicated that soil movement is within the acceptable limits for the no-tillage system, fact that further demonstrates that even when highest sowing speeds are used the plants are expected to have an adequate root system development. Furthermore, horizontally the soil movement registered was also within adequate parameters.

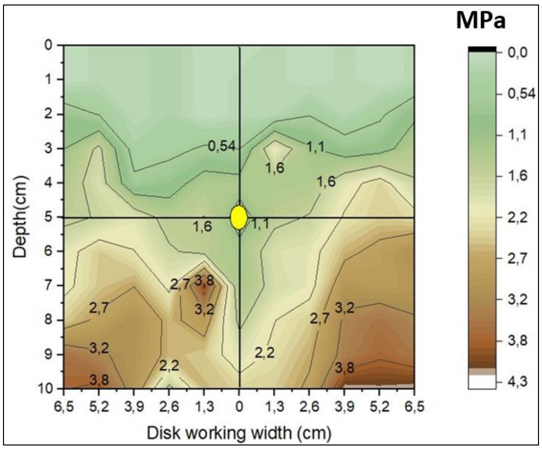


*Figure 18*. Soil cone index after disk model “B” at 11 km/h, measurement-d

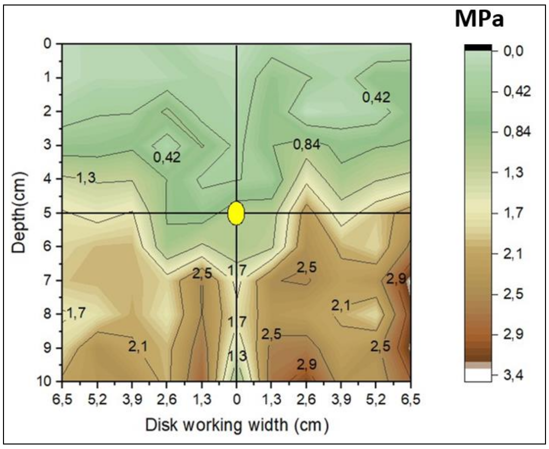


*Figure 19*. Soil cone index after disk model “B” at 11 km/h, measurement-g

From the results presented in figure 20, becomes evident that by using opener disk model C (with 26 waves) at 3 km/h can be achieved an adequate working width at which the level of soil movement horizontally at seeding depth ensured values that would not affect plant development, values registered were between 0,54-0,91 MPa. This soil loosening can be a possible combined effect of furrow opener and press wheel (Figure 21).

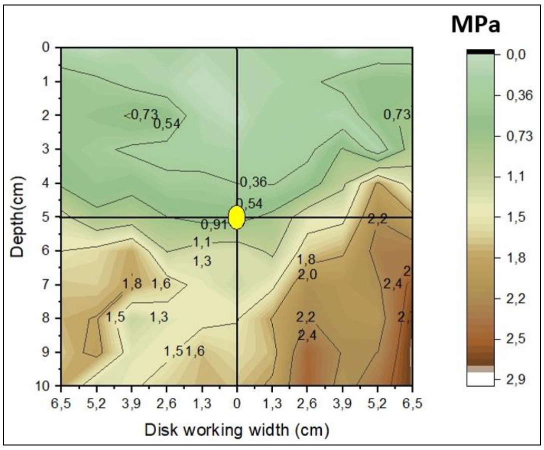


*Figure 20*. Soil cone index after disk model “C” at 3 km/h, measurement-d

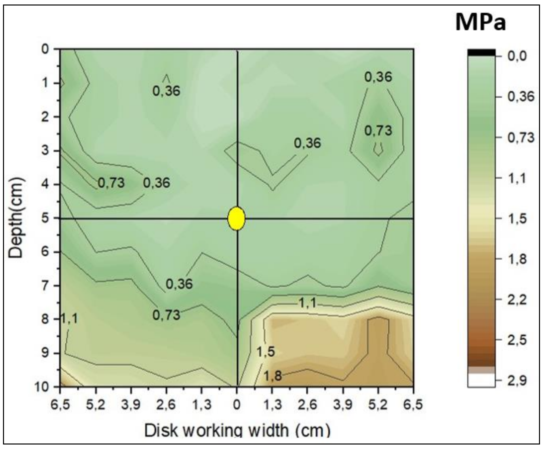


*Figure 21*. Soil cone index after disk model “C” at 3 km/h, measurement-g

Compared to the speed of 3 km/h, soil cone index after disk model C at 8 km/h caused a decreased mobilization of the soil. Thus, according to Figure 22, the isometric lines obtained indicate an increased resistance to soil penetration measured after the opener disk, with values between 1,4-1,9 MPa.

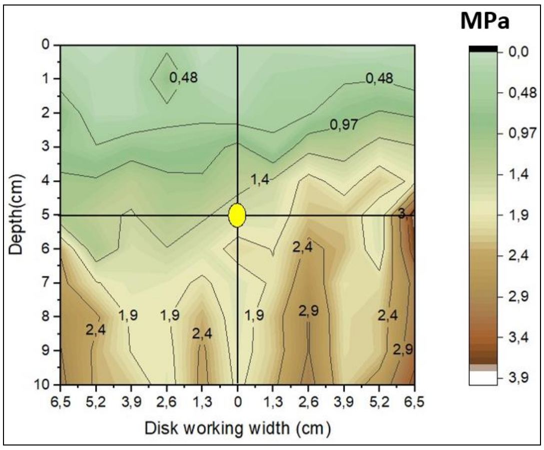


*Figure 22.* Soil cone index after disk model "C" at 8 km/h, measurement-d

If one analyses isometric lines obtained through graphical representation of the data for measurement-g, can be observed that degree of soil mobilization increased (Figure 23). This fact can be attributed firstly to the fact that higher speed exercised a more energic action on the soil, and secondly this can be attributed to some extent also to the combined effect of the furrow opener and pressing wheel.

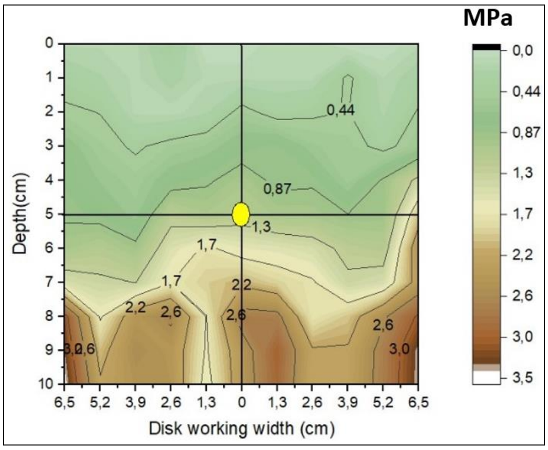


*Figure 23.* Soil cone index after disk model "C" at 8 km/h, measurement-g

By analyzing the isometric lines presented in graph from figure 24, can be observed that at speed of 11 km/h, soil mobilization was qualitatively adequate for no-tillage system. If one compared the results obtained for the same disk type at 3 and respectively at 8 km/h can be observed that degree of soil mobilization increased both on depth as well as horizontally. This effect can be attributed to the disk geometry that ensured a more efficient loosening of the soil even at higher speed.

The results of measurement-g presented in graph from figure 25 indicates to an increased resistance to soil penetration compared to measurement-d, with values around 1 MPa.

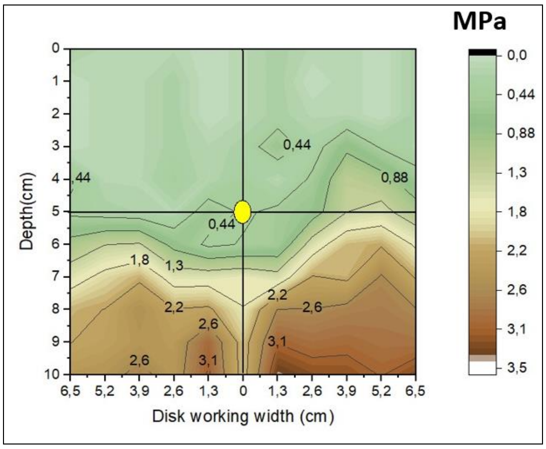


*Figure 24.* Soil cone index after disk model "C" at 11 km/h, measurement-d

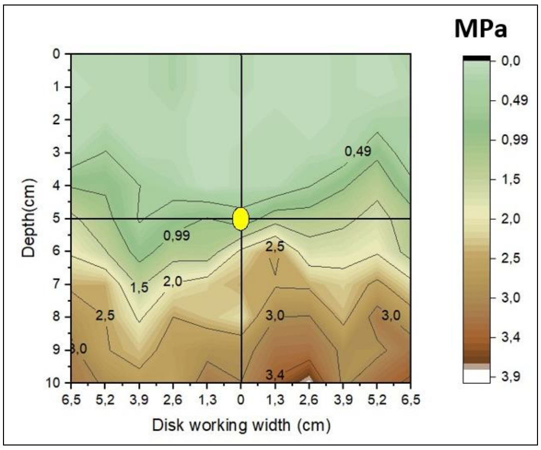


*Figure 25.* Soil cone index after disk model "C" at 11 km/h, measurement-g

Direct sowing is a technology that can contribute substantially to the reduction of energy consumption as well as crop production costs, ensuring a sustainable development of agriculture.

The study on the possibility to extend the direct sowing technology for maize crop has as main argument the fact that maize is one of the most important field crops in Romania and direct seeding is feasible for this crop.

Research has shown that 65% of spatial distribution pattern for maize yield was explained by spatial distribution of soil properties under no-tillage management (Rodrigues et al., 2012). This indicates that soil parameters such as soil cone index are important extrinsic factors conditioning crop productivity. This relationship between soil cone index and yield can be further illustrated by results of Busscher et al. (2000), who reported that wheat yields increased 1.5 to 1.7 Mg $ha^{-1}$ and soybean yields increased 1.1 to 1.8 Mg $ha^{-1}$ for every megapascal decrease in mean profile cone index.

Usefulness of soil cone index as an indicator stays in the fact that by combining extensive SCI values with measurements for other soil properties could be obtained a complex spectra on the influence of field management practices on soil functions, having many practical applications (Kuhwald et al., 2016; Alesso et al., 2019).

Based on an equation model was predicted by Vazquez et al. (1991) that variation of soil cone index is explained mainly by soil bulk density (24%) and depth (30%). Also, there is a multicollinearity relationship between soil cone index values measured at different soil depths (Stelluti et al., 1998).

Literature reports that in general, a penetrometer value around 3 MPa can be regarded as the upper limit for unrestricted root growth, while optimum is below 1.5 MPa. The consequence of a poor root growth due to higher soil cone index is reduced crop production caused by decreased water and nutrient absorption (López-Garrido et al., 2014).

It is generally accepted that critical soil cone index limit for conventional tillage is 2 MPa. But research has shown that regardless of the cropping systems, the critical SCI limit should be considered 3 MPa for minimum tillage with chiselling and 3.5 MPa for no-tillage (de Moraes et al., 2014).

Soil management was shown to influence chiselling (Katsvairo et al., 2002; Lampurlanés and Cantero-Martínez, 2003; Tormena et al., 2017). For example, at topsoil level, moldboard plow ensured lower penetration resistance (0.97 MPa) compared to ridge tillage (1.39 MPa) (Katsvairo et al., 2002).

Early experiments demonstrated that limiting chiselling for *Avena sativa* root growth was higher in the no-tilled A-horizon (4.6-5.1 MPa) compared to tilled Ap-horizon (3.6 MPa) (Ehlers et al., 1983).

Assessment of the compaction level evaluated at the end of an eight-year *Avena sativa* - *Glycine max* double-cropping, identified that most significant long-term effect of no-tillage on soil cone index occurred at the depth 15 cm, compared to conventional tillage (Vazquez et al., 1991).

## CONCLUSIONS

The results obtained in this study highlight the possibility to optimize no-till technology for soil preparation.

Disk geometry designed by the author: the one with 14 and respectively with 26 waves, ensured a mobilization of the soil optimal for no-tillage system, even at higher speeds of 8 respectively 11 km/h. The soil cone index displayed adequate parameters at the sowing depth as well as horizontally.

Results obtained following the testing of the three disks models demonstrated these can be successfully used for direct sowing. It is essential to keep in mind that trials were performed in experimental conditions and it is important to extent the research in the future in order to take into account more characteristics, such as: soil type, climatic and agro-technique conditions. There is possibility to optimize the exploitation system by adjusting the disk type or the speed. This aspect is essential considering the meteorological conditions from last few years that are in continuous changing, thus the possibility to use a higher speed brings advantages for farmers.

Following the analysis of the obtained results, the recommendation emerges, the direct sowing system becomes more efficient in the conditions in which the machines are equipped with adapted furrow opening disks. The adaptation consists in the correct choice of the disk diameter, the angle of the cutting edge, the type and amplitude of the waves, the number of undulations, all these parameters correlated with the pedoclimatic and agronomic conditions.

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