THE EFFECT OF MOVEMENT OF TRACTORS AND MOBILE SYSTEMS ON SOIL COMPACTION AND THE YIELD OF VARIOUS MAIZE HYBRIDS IN THE CONDITIONS OF SOUTHERN SERBIA

Saša BARAĆ [1], Milan BIBERDŽIĆ [1], Dragan PETROVIĆ[2], Jelena STOJILJKOVIĆ[3], Aleksandar ĐIKIĆ[1], Rade RADOJEVIĆ[2], Aleksandar VUKOVIĆ[1]

[1]University of Priština - K. Mitrovica, Faculty of Agriculture,Kopaonička bb,38219 Lešak, Serbia
[2]University of Belgrade, Faculty of Agriculture, Nemanjina 6, 11080, Belgrade-Zemun, Serbia
[3]The agricultural expertise service, Jug Bogdanova 8a, 16000 Leskovac, Serbia
*Corresponding author: sasa.barac@sbb.rs

Abstract

Movement of tractors and mobile systems during the plant production can be divided into the movement of the interior of the plot and the movement on the headlands. Both movements result in soil compaction of various intensity, whereby the compaction is more expressed on the headlands, unlike the interior of the plot due to lower speeds in turning. The consequences of compaction create unfavorable conditions for growth and development of cultivated crops, permanent soil damage, reduction of yields and increase production costs. The paper shows the results of measuring the impact of tractors and mobile systems movement on soil compaction changes and the yield of various maize hybrids. The tests were carried out in the conditions of the Jablanica County, and the soil compaction was measured by the Eijkelkamp 6.0 penetrologer in accordance with EN 5140, while the soil moisture was measured by the Theta probe. Cone resistance was measured at the inner part and the edges of the plot at the beginning of the vegetation (emergence phase) and at the end of the vegetation (harvesting phase). The aim was to determine the effects of changes in soil compaction, on the growth, development and yield of various maize hybrids. The obtained results showed that the soil compaction in the emergence phase of maize on the headlands was on average higher by more than 92% in relation to the interior of the plot. In the harvesting phase on the headlands, more intensive soil compaction values were measured in relation to the plot’s interior, and the soil compaction increased more than 57%. Due to the more intensive soil compaction on the headlands, the yields of maize on average were reduced more than 60%, compared to the plots interior.

Keywords: *Soil compaction, tractor, maize, yield.*

Introduction

Soil compaction is one of the main forms of degradation and it is present in total degradation with 11%, while in Europe it is the cause of degradation of 33 million hectares of agricultural land (Akker and Cararache, 2001; Lynden, 2000). The threat of soil compaction is greater today than in the past because of the dramatic increase in the size of farm equipment (Sjoerd, 2004). On the headlands compared to inner parts of plots, at all the plants because of slower speeds of machinery and longer exposing to the normal charges, soil compaction is more intensive. On a headland were measured high values of soil compaction, 4.35, or 4.50MPa (Savin *et al.*, 2004; Nikolić *et al.*, 2007).The increase of soil compaction is especially expressed at a depth of up to 50 cm, with more difficult water and nutrients absorption, an increased risk of erosion and increased energy consumption for soil cultivation (Yavuzcan *et al.,* 2005; Šeremešić *et al.,* 2005; Gajić, 2006; Manuwa *et al.,* 2011; Jerzy and Leszek, 2012). The negative consequences of soil compaction are multiple and significantly affect the reduced yield (Ishaq *et al.,* 2001; Friton, 2001; Nikolić *et al.,* 2002 Savin *et al.,* 2003; Hamza and Anderson, 2005; Ramazan *et al.,* 2012). By applying lighter mechanization, soil compacting can be significantly reduced with reduced energy consumption (Mouazen and Palmqvist, 2009). The soil compaction changes with the depth of measurement, and the cone resistance when measuring soil compaction at a depth of 20-30 cm was 2 MPa (Yavuzcan *et al.,* 2002). In the emergence stage of maize, the soil compaction on the headlands was higher for 102.87% in relation to the interior, and in the harvesting phase for 59.37% (3.30 MPa - 35 cm depth). In the inner part of the plot the yield of maize grains was higher for 42.81 % in relation to the headlands (Jarak *et al.,* 2005).

Material and Methods

During 2017, in the vicinity of Leskovac (43°04'18.7" N 21°46'52.9" E and 43°01'08.0" N 21°56'11.0" E) the influence of the movement of tractors and mobile systems on changes in the soil compaction and the yield of different maize hybrids on two soil types were carried out. In production of maize, the usual production technology was applied, and all the tools were aggregated to the tractor of power 36.9 kW. The tests were carried out on Vertisol and Aluvium soil, and maize hybrids were represented NS 4051, AGR DIAN, ZP 666, AS 534 and Bećar. The soil compaction was measured in the inner part of the plot and on the headlands, in the maize sprouting phase and in the collection phase. In order to make a consideration of the right headlands, the parcels were selected along the path, so that the turning of the tractor and mobile systems was done only on a plot where the proper headland were formed Width of each experimental plots was 20 m, and length of 100 m. A penetrologer was used to measure soil compaction - Eijkelkamp hardware version 6.0, software version 6.03. Soil compaction was measured at the depth of 0-35 cm, by pressing the cone of the surface 1 cm^2 with the tip of the cone 60^0, in accordance with the standard NEN 5140, the penetration rate of 2 cm sec^{-1}, with no deviation greater than 0.5 cm s^{-1}. The used embossing cone was of standard size, and the standard is defined according to ASAE standard (ASAE S313.1). During the measurement, the penetrologer inclination did not exceed 3.5^0 in relation to the vertical (the position was monitored by the penetrologer libel), while the penetration rate was followed by a speed indicator in a display that was close to the median position (position between "S" and "L"). The soil moisture at the moment of compression measurement was determined by the Theta probe and expressed in % vol. On the soil type Vertisol, in the emergence phase of maize, soil moisture in the interior of the plot was on average 27%, and on the slopes 23%, and in the harvesting phase 19% and 17%. On the soil type Aluvium, in the emergence phase, the soil moisture was 26% in the interior of the plot and 23% on the slope, while in the harvesting phase it was 24% in the interior and 20% on the slopes. The cone resistance was measured in 5 repetitions with a distance of 2 m between the measuring points, with the centre point located in the middle of the headland.

Results and Discussion

On Figure 1 and 2 the soil compaction values are shown during the production of different maize hybrids during the emergence phase, during the harvesting phase of maize in the interior of the plot and on the headlands. Based on the results in Figure 1, it is noticed that the soil compaction in the interior of the plot during the maize sprouting phase was significantly lower in relation to the headland, and with the increase in the depth of measurement, the compaction increased. Soil moisture during the measurements in the inner part of the plot amounted to an average of 27%, and on the headlands of 23%. The lowest soil compaction of Vertisol type was measured at the stage of maize sprouting in the interior of the plot at 0-5 cm and it was on average 0.19 MPa, while on the headland at the same depth the compression was 0.37 MPa, which is the increase of soil compaction from 94.74 %. The highest compression in this phase of measurement was measured on the headland at a depth of 35 cm and amounted to 4.46 MPa, while the inner part of the plot composed at the same depth 2.32

MPa, which is a difference of 92.24%. Similar differences in the soil compaction were observed in other measurement depths in the maize emergence phase (Figure 1). In the phase of harvesting the maize with the depth of measurement, soil compaction increases, where the soil is significantly more compact on the headlands than in the inner part of the plot.

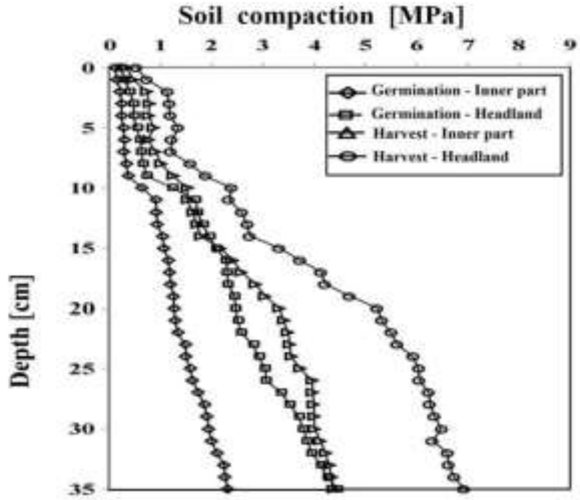

Figure 1. Vertisol's compaction in the inner part of plots and on the edges in the stage of sprouting and harvesting of maize [MPa]

At a depth of 0-5 cm in the interior of the plot, the average soil compaction of 0.65 MPa was measured, while at the same depth on the headland the compression was 1.01 MPa, an increase of 55.38%. On the headlands, the highest values of soil compaction were measured at a depth of 35 cm, and 6.54 MPa, while in the inner part of the plot the compaction was 3.98 MPa, which is a difference of 64.32%.The soil moisture in the maize harvesting phase was 19% in the inner part of the plot, and 17% on the headlands.

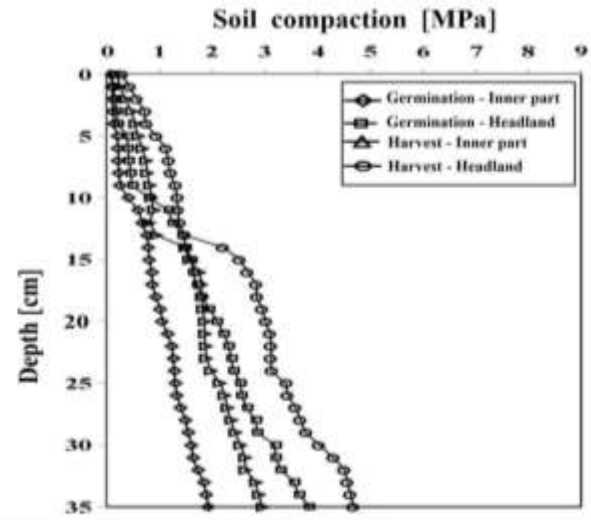

Figure 2. Soil compaction of Alluvium soils in the inner part of the plot and on the headlands in the stage of sprouting and harvesting maize [MPa]

The results of the measurements shown in Figure 2 show that the lowest soil compaction in the Aluvium in maize sprouting phase was in the inner part of the plot at a depth of 0-5 cm, on average 0.11 MPa, while on the headlands at the same depth the soil compaction amounted to 0.20 MPa. The highest values of soil compaction were measured at a depth of 35 cm 3.84 MPa, while in the inner part of the plot at the same depth the compaction amounted to 1.93 MPa, which makes a difference of 98.96%. Similar differences in the soil compaction were also observed in other depths of measurements in the maize sprouting phase (Figure 2). The average soil moisture in the maize sprouting phase was 26% in the interior of the plot and 23% on headland. At the stage of harvesting the maize, the lowest compaction was measured in the interior of the plot at a depth of 0-5 cm, on average 0.38 MPa, while on the same depth, on the headland, the compaction amounted to an average of 0.55 MPa (Figure 2). On this type of soil, during the maize harvesting phase, the highest soil compaction values were measured at a depth of 35 cm, so the increase in soil compaction on the headlands related to the inner part was 58.82%. Similar differences are observed in other measurement depths. The soil moisture at the stage of harvesting the maize was 24% in the inland plot and 20% on the headland.

Extremely high values of compaction of soil type Vertisol, in the harvesting period, can be explained as a result of unfavourable climatic condition during the measuring, as well as the result of soil properties of this soil type.

The results of our research agree with the findings of other authors (Savin *et al*., 2004; Yavuzcan *et al.,* 2005; Šeremešić *et al.,* 2005; Gajić, 2006; Nikolić *et al.,* 2007; Jerzy and Leszek, 2012; Ramazan *et al.,* 2012; Manuwa *et al.,* 2011).

Due to the intensive soil compaction, the yield on the headland decreased related to the inland of the plot, so that the maize yield on the Vertisol-type soil on the headlands was 3.12 t ha^{-1} to 3.43 t ha^{-1}. In the interior of the plot the yield of maize varied from 5.45 t ha^{-1} to 5.95 t ha^{-1} (hybrid AGR DIAN, or NS 4051). A similar influence of the compaction on the yield was recorded in other maize hybrids (Figure 3).

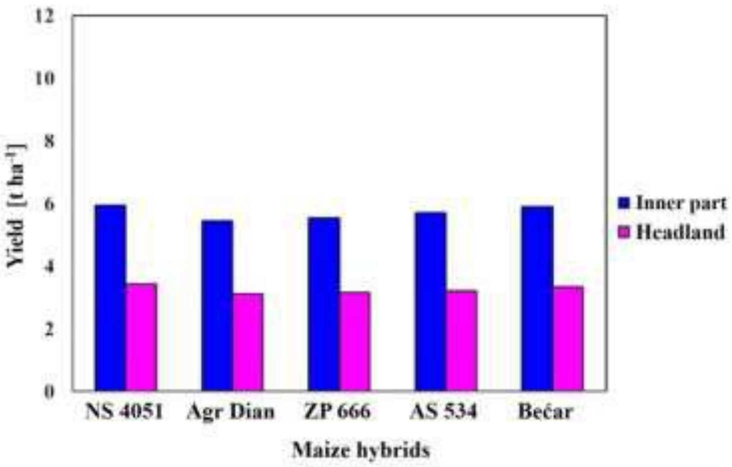

Figure 3. Average values of maize yields realized on Vertisol type

More intensive soil compaction on the headland compared to the inland of the plot showed a significant influence on Aluvium, so that the yields achieved were significantly lower and varied in the range of 5.24 t ha^{-1} to 6.70 t ha^{-1} (hybrid ZP 666). Inside the land plot yields were within the range of 9.18 to 11.90 t ha^{-1} (hybrids NS 4051, ZP 666) (Figure 4). In the case of other maize hybrids, a similar effect of changes in compression on the yields was recorded.

The obtained results show the negative impact of more intensive soil compaction on the headlands compared to the inland of the plot, so that the yields of maize in the examined

conditions on both types of soil on the headland in relation to the inland were lower by more than 60% on average.
Similar results in their research are also reported by other authors (Ishaq *et al.,* 2001; Friton, 2001; Nikolić *et al.,* 2002; Savin *et al.,* 2003; Hamza and Anderson, 2005; Jarak *et al.,* 2005; Ramazan *et al.,* 2012).

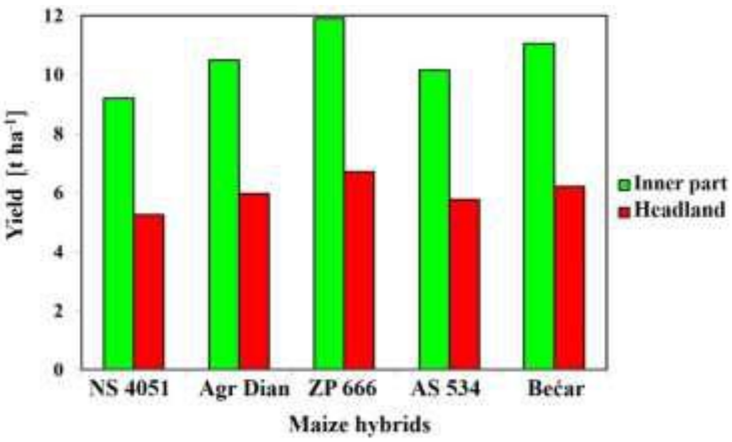

Figure 4. Average values of maize yields realized on Alluvium type

Conclusions

On the basis of the obtained results, it can be concluded that in the inland of the plot, the soil compaction is lower in relation to the headland in both crops, with the lowest values being measured in the phase of emergence on both types of soil. Soil compaction increased in the depth of measurement during all stages of measurement. The lowest compaction in the maize-sprouting phase was measured on the Aluvium at a depth of 0-5 cm and an average of 0.11 MPa, and the highest on Vertisol at a depth of 35 cm on average 4.46 MPa. Soil compaction on the headlands was, on average, higher by over 92% compared to the interior of the plot on both types of soil individually at all depths of measurement. In the harvesting phase, the lowest compaction was measured at Aluvium at a depth of 0-5 cm, it was an average 0.38 MPa, and the highest on Vertisol at 35 cm 6.54 MPa. On the headlands of both soil types at all depths of measurements, compaction was more than 57% higher. The mutual differences in the compactness of both soil types between the plot's interior and the headlands in the maize harvesting phase are less expressed than in the emergence phase, with less generalized compaction values on Aluvium than on Vertisol. As a result of intensive compaction, yields on the headland were reduced related to the inner part of the plot, so the lowest yields were measured on the headlands (Vertisol) 3.12 t ha^{-1} (hybrid AGR DIAN). The highest maize yields were achieved in the interior of the plot (Aluvium) 11.90 t ha^{-1} (hybrid ZP 666). The average reduction in the yield of maize on the headland in relation to the interior of the plot for all the hybrids is over 60%

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