-Report -
Viridisfarm – 2024

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Professional research project

"Efficiency of Viridisfarm-AS d.o.o. products in the system of conservation soil treatment"

Report-2024

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Aide mémoire

This Report-2024 came out as a result of a professional research project conducted in 2024 on the basis of a SERVICE CONTRACT between Viridisfarm-AS d.o.o., Rudarska 8, Potpićan OIB: 02700141454 (Project Client), signed by dr. sc. Mirsad Sadiković and prof. dr. sc. Danijel Jug, full professor in permanent election, employed at the Faculty of Agrobiotechnical Sciences Osijek, OIB: 49264410840, Kralja Zvonimira 61, 31216 Antunovac (Project Executor), in Osijek on March 20, 2024.

General information on the study site and test field

Description of the study site

The field experiment was set up in the fall of 2023 at the test station in Križevci in western Croatia on the Glaysol soil type. The experiment is located in the subregion of Northwestern Pannonia and is one of the most productive regions of Croatia. The test field is set up on a slope of 1%, Long. 16.55835 E, lat. 46.02719 N and Alt. 141 m (*Annex: location of the test field*).

The average annual precipitation for this area is 877-1104 mm, and the average temperature is 9.3-9.9 °C. The coldest month is January with an average temperature of 0.1 °C to -1.4 °C, and the warmest July with a temperature between 18.9 °C and 19.7 °C. The temporal and spatial changes of the main climatic elements follow, in most cases, the following schemes; temperatures rise from west to east, and from northwest to northeast, and precipitation follows in reverse (source DHMZ).

The location of the research belongs to areas that are strongly influenced by climate and weather conditions in the Pannonian basin and the peri-Pannonian area. The subregion has a wide range of different landscapes and types of vegetation. Due to the heterogeneity of the parent material and the very different relief, the subregion abounds in very different soil types. The predominant soil types are Glejsols, widespread in numerous valleys formed by rivers and streams. The common characteristics of the soil of this subregion are intense water erosion, mostly due to limited soil permeability and intensive rainwater runoff. Climatic features also contribute to erosion.

The experiment was set up according to the design of a random schedule with four repetitions (*Appendix: Experimental Field Scheme*). The size of the basic test plots for each individual treatment of soil cultivation is 640 m2, liming 320 m^2 and 40 m2 for each individual treatment with Viridisfarm foliar preparation. Apart from the treatment of soil tillage, liming and application of foliar preparation, all other technological interventions (which are not directly involved as experimental factors), e.g. cultivar, sowing, pest control, machinery and equipment were used uniformly in all treatments.

Growing season (2023/2024)

Material and methods

Tillage Treatments

Three (3) different tillage systems were applied as the main factor as follows:

- ST – Conventional / Standard tillage with ploughing to a depth of 30 cm,
- CTD – Conservation deep tillage – loosening to a depth of 25 cm,
- CTS – Conservation shallow treatment – shallow loosening to a depth of 10 cm.

Treatment of calcification

Two (2) liming treatments as a second factor, as follows:

- N-treatment without liming
- Y-treatment with the application of liming

Fertilization treatment

Two (2) tremans of fertilization as the third factor, as follows:

- FR-fertilization according to the recommendation (N:P:K-0:20:30 750 kg/ha, UREA 98 kg/ha, KAN 444 kg/ha)
- FD-fertilization as recommended reduced by 50% (N:P:K-0:20:30 375 kg/ha, UREA 49 kg/ha, KAN 222 kg/ha)

Foliar preparations (tested products)

Three (3) different treatments with Viridisfarm foliar preparations, as follows:

- I – Control = no foliar preparation,
- II – VibroCalcit (2 kg/ha, 05% concentration),
- III – VibroPhosphate (2 kg/ha, 05% concentration),
- IV – VibroSorb (2 kg/ha, 05% concentration),

Soil properties in the experimental field

According to the proposal of the Croatian soil classification, the soil at the experimental field in Križevci is classified as *hydromorphic soils*, the class *of hypogle soils*. The soil type is *hypoglea*, the subtype *is non-carbonate*, the variety *is mineral*, the form: *medium-deep glacial, unsalted and non-alkalized*.

According to WRB (2015), the soil at the site belongs to the Gleysols reference group.

The structure of the profile is Pa – Gso – Gso/Gr (Figure 1)

In the genesis of hypogleia, relief is the most significant factor. These are the soils of lowland areas formed along watercourses, in the lowest zones of river terraces. With such relief forms, the presence of groundwater within 1 m of the soil surface is typical. During the year, depending on the amount of precipitation, the depth of groundwater oscillates, which results in the creation of three zones along the entire depth in which oxidation and reduction processes alternate.

In the lower zone, the glial horizon is completely saturated with water, reduction processes (Gr) dominate, the intensity of which increases with depth due to anaerobic conditions. By reduction, compounds of divalent iron and manganese are formed, so that the soil takes on different shades of gray-blue and greenish.

In the middle zone (Gso), due to groundwater fluctuations, reduction and oxidation processes alternate. Secondary oxidation processes are intense, which is evident in a large amount of insoluble oxidized iron and manganese compounds in the form of dark granular concretions and yellowish, reddish and brown mazotins and spots.

In the upper zone, a horizon of various shades of gray to black with a thickness of up to 50 cm is formed. Due to the greater amount of organic residues originating from hydrophilic vegetation, aquatic or swampy humus is formed. However, with the lowering of groundwater levels, the processes of wetland (hydrogenation) weaken, and the consequence is the development of typical terrestrial humus horizons.

Figure 1. Profile of hypogleia at the experimental field in Križevci

Chemical properties of hypogleia

Table 1 shows the chemical properties of hypogleum at the experimental field in Križevci. The pH values increase with depth, so with a pH-KCl of 5.22 in the anthropogenic hydromorphic horizon (Pa) to 5.68 in the glial (Gso/Gr) horizon, the reaction is strongly to moderately acidic along the entire depth of the profile. Active acidity in the pH-H$_{2O}$ range of 6.65 to 7.50 indicates a neutral to weakly neutral reaction. Given that the hydrolytic acidity is 2.47 cmol$^{(+)\ kg-1}$ (Table 1), calcification is not a mandatory measure. However, the anthropogenic hydromorphic horizon is poorly supplied with humus (1.64%) and of light texture (powdery) with a low clay content (9.61%). Therefore, the introduction of liming material will help neutralize the acid reaction and improve the stability of the structure, that is, the resistance of the aggregate to changes.

Table 1. Chemical properties of hypogleum in Križevci

Depth	**Horizon**	**Soil reaction**		**mg 100 $^{g-1}$ soil**		**OT**	**CaCO3**	**Hk**
cm		**pH-KCl**	**pH-H2O**	**AL-P2O5**	**AL-K2O**			
0 - 36	So	5,22	6,65	15,37	7,45	1,64	-	2,47
36 - 97	GMOs	5,73	7,44	2,59	5,21	0,52	1,27	-
97 - 175	Gso/Gr	5,68	7,50	3,15	4,84	0,41	1,69	-

Interpreter of abbreviations: OT = soil organic matter, %; CaCO3 = carbonate content, % vol.; Hk = hydrolytic acidity, cmol$^{(+)\ kg-1}$

The AL-method determined the content of phosphorus and potassium available to plants (Table 1). The level of phosphorus supply is good (15.37 mg AL-P2O5 100g-1 soil), and very low for plants accessible with potassium (7.45 mg AL-K2O 100g-1 soil) in the Pa horizon. With depth, their concentration decreases significantly.

Carbonates are not present in the Pa horizon, while in the glial horizons (Gso and Gso/Gr) a low carbonate content (1.27 – 1.69 % $CaCO_3$) causes a neutral to slightly alkaline reaction (Table 1).

Table 2. Composition of the adsorption complex of the hypogleum in Križevci

Depth	**Horizon**	**KIK**	**Cation content of the soil adsorption complex, %**						**BS**	**Bse**
cm			**Ca2+**	**Mg2+**	**K+**	**Na+**	**H+**	**Al3+**		
0 - 36	So	11,46	61,24	14,93	1,00	0,76	21,56	0,51	77,93	99,35
36 - 97	GMOs	9,76	72,31	25,10	0,93	1,16	-	0,49	99,51	99,51
97 - 175	Gso/Gr	10,10	70,68	26,40	0,92	1,53	-	0,48	99,52	99,52

Interpreter of abbreviations: KIK = cation exchange capacity, cmol$^{(+)\ kg-1}$; BS = base saturation, %; BSe = effective saturation of bases, %

The cation exchange complex (KIK) is at the boundary between mean (9.76 cmol$^{(+)\ kg-1}$ in Gso to 11.46 cmol$^{(+)\ kg-1}$ in the Pa horizon (Table 2). The proportion of base cations Ca2+ and Mg2+ increases with depth. In the anthropogenic hydromorphic horizon, the highest content is calcium (61.24%), followed by hydrogen (21.56%), and magnesium content is 14.93%. The proportion of aluminium decreases with depth, from 0.51 % in Pa to 0.48 % in Gso/Gr. There are no hydrogen ions in the deeper horizons that are neutral to weakly alkaline reactions, so the composition of the adsorption complex is dominated by Ca^{2+} ions (72.31 – 70.68 %) and Mg2+ ions (25.10 – 26.40 %).

Base saturation is, as expected, the lowest in the anthropogenic hydromorphic horizon (BS = 77.93%). In the deeper horizons, BS values are > 99%. Effective base saturation (BSe) ranges from 99.35 to 99.52%, which is visible in Table 2.

Physical properties of hypoglia

Mechanical analysis (Table 3) of samples taken from genetic horizons shows that the profile is of light texture along the entire depth. The lowest clay content is in the anthropogenic hydromorphic horizon (9.61%), and the texture is powdery. In the glial horizons (Table 3), the texture is powdery loam with a clay content of 14.08 – 14.90 %. The stability index of microaggregates in Pa and Gso horizons is 80.25 – 78.26, which indicates stable microaggregates. In the transitional Gso/Gr horizon, stability is lower (Table 3).

Table 3. Soil texture and stability of microaggregates in the hypogle profile

Depth	Horizon	Percentage of soil particles			Textural class	Stability of micro aggregates	
cm		Sand	Powder	Clay		Ff	rating
0 - 36	So	7,44	82,95	9,61	Pr	80,85	Stable
36 - 97	GMOs	5,52	80,41	14,08	At	78,26	Stable
97 - 175	Gso/Gr	6,15	78,96	14,90	At	69,86	It's quite stable

Interpreter abbreviation: Pr = powder; PrI = powdery loam; Ss = microaggregate stability index, %

The values of the volume density of the soil indicate moderate compaction in the anthropogenic hydromorphic (ρ_b = 1.42 g $^{cm-3}$) and glial horizons of secondary oxidation (ρ_b = 1.60 g $^{cm-3}$). The data presented in Table 4 indicate an increase in compaction in the Gso horizon, which may be related to an increased clay fraction content. The density values of the solid phase depend on the ratio of mineral and organic matter in the soil. By decreasing organic matter, ρ_{it} becomes higher, which can also be observed in the hypogleal profile (Table 4).

Table 4. Physical properties of hypoglia

Horizon	θv	FC	ρ_b	ρ_{with}	PD	ε	AC	εair
So	38,79	42,44	1,42	2,69	1,51	47,21	4,77	8,42
GMOs	35,06	37,69	1,60	2,73	1,73	41,39	3,70	6,33

Interpreter of abbreviations: θ_v = volumetric water content, %vol.; FC = water retention capacity, % vol.; ρ_b = volume density of soil, g $^{cm-3}$; ρ_s = solid-phase density, g $^{cm-3}$; PD = packaging density, g $^{cm-3}$; ε = total porosity, % vol.; AC = air capacity, %vol.; εair = aeration porosity, %vol.

A more reliable estimate of soil compaction is made using the density of the package, as the calculation also takes into account the content of the clay fraction, which can significantly affect the increase in compaction. Hypogle is a medium compacted soil up to 97 cm deep because PD values range from 1.51 g $^{cm-3}$ in the Pa horizon to 1.73 g $^{cm-3}$ in the Gso horizon (Renger, 1970).

The total amount of pores (ε) decreases with depth. In the surface horizon, the hypopyleus is, according to Pernar et al. (2013) porous soil already 47.21% of the pores. The deeper horizon (Gso) is weakly porous with a reduced proportion of pores (41.39%). The air capacity of the soil (Table 4) ranges from low (4.77 %vol.) to low (3.77 %vol.). The porosity of aeration is low (< 10%) and decreases with depth as a result of the reduced amount of pores.

Technological-breeding parameters

According to the technological scheme of the previous crop rotation, the pre-crop was winter wheat (the harvest was done in the summer of 2023), after which soybeans were cultivated. The 2023/2024 growing season (the subject of this Report) began with agrotechnical interventions in the fall of 2023 (fertilization and tillage).

According to the experimental plan, basic fertilization (based on the fertilization recommendation) and tillage were carried out in the fall on November 14, 2023. Glyphosate treatment was carried out on 12 April 2024 due to intensive weed emergence. The closure of the winter furrow with a toothed harrow (in one pass) was carried out on April 25, 2024, but only on ST tillage. CTD and CTS treatments were without any preparation for tillage—only mulching (mostly dry weed residues). Pre-sowing fertilization, performed with mineral fertilizer applicators superficially, was carried out on April 25, 2024. Pre-sowing preparation was completely absent on all variants because there was no need for it. Basic and supplementary tillage is carried out as follows:

- ST – Conventional / Standard tillage – ploughing up to 30 cm deep, closing the winter furrow with a toothed harrow (1 pass), pre-sowing soil preparation was not performed,
- CTD - Conservation deep tillage – loosening up to 25 cm deep + disc + hollow roller (1 pass), without closing the winter furrow and pre-sowing preparation,
- CTS - Conservation shallow tillage – shallow loosening up to 10 cm deep + hollow roller (1 pass), without closing the winter furrow and pre-sowing preparation.

The corn hybrid RWA "Gloriett" (FAO 380) was sown with a Vaderstad Tempo 6 seeder, to a depth of 4-5 cm, a row spacing of 70 cm and to a planned set of 75000 plants per hectare. The sowing date was May 2, 2024. In the vegetation year 2024, effective weed control was carried out in addition to the usual chemical treatment. The application of the herbicide was applied the day after sowing (June 5, 2024), with a combination of herbicides: Adengo - 2.5 l ha-1 + ELUMIS PEAK 4.5 L + 60g - 1.5 l / ha. The insecticide Force 1.5G 20 kg/ha was also applied (due to the potential risk of wireworm (Elateridae)). There was no need for another insecticide or fungicide treatment.

The maize harvest was done manually on October 10, 2024 and by a combine harvester (to harvest the remaining crop from the surface) after sampling all the plant material. The harvester had an integrated chopper system for better cutting and a better and more even distribution of harvest residues over the surface.

The application of Viridisfarm foliar preparations (tested products) VibroCalcit, VibroPhosphate and VibroSorb was carried out in two terms with a manual automatic sprayer. The first date was May 20, 2024, and the second on June 5, 2024. A third treatment was planned, but due to the phenotype of plants, it was not possible to perform foliar treatment in a quality way.

Agrometeorological conditions

Entire experimental season (vegetation period), starting from autumn 2023 to harvest period 2024) It was very varied with great variations in precipitation and temperature. Corn was sown in relatively optimal soil conditions (optimal moisture and temperature), but the day after sowing, more than 10 mm of rain fell. After a long period of mild weather in early spring, there was an extremely wet period with very low temperatures (there were several days with temperatures around 0 °C). Almost throughout the spring period, the temperature was very low (well below the multi-year average), and the amount of precipitation was very high (significantly higher than the multi-year average). Overall, spring was colder and rainier than average, with a few heavy rainfall episodes. The second part of June and the whole of July, August and September were very dry and hot and in some places with little rain (significantly below the multi-year average). Crops at that time suffered from a lack of accessible water (from rain or from deeper layers of soil). This very warm and dry period lasted until the end of the maize growing season (harvest period). In general, the entire growing season has been very variable, from very humid and cold to very dry and hot days, but also weeks.

(Graphs 1–18 show atmospheric average weather conditions and some related meteorological soil conditions at the experimental site in 2023/2024.

All raw data on average weather conditions and some related meteorological conditions of the soil are recorded in excel files and can be obtained on request.

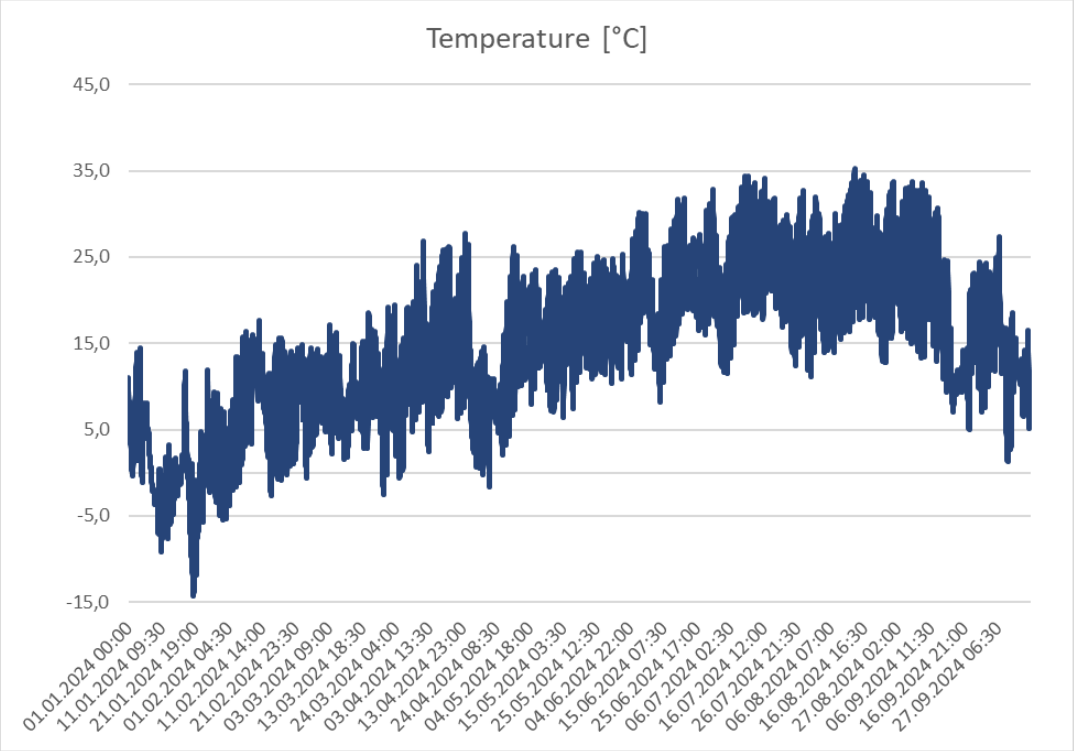


Chart. 1. Air temperature (°C)

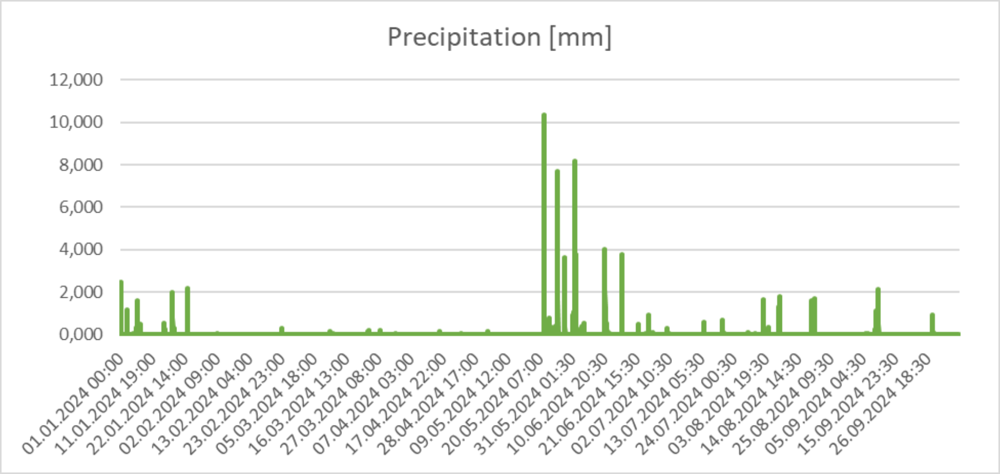


Chart. 2. Precipitation (mm)

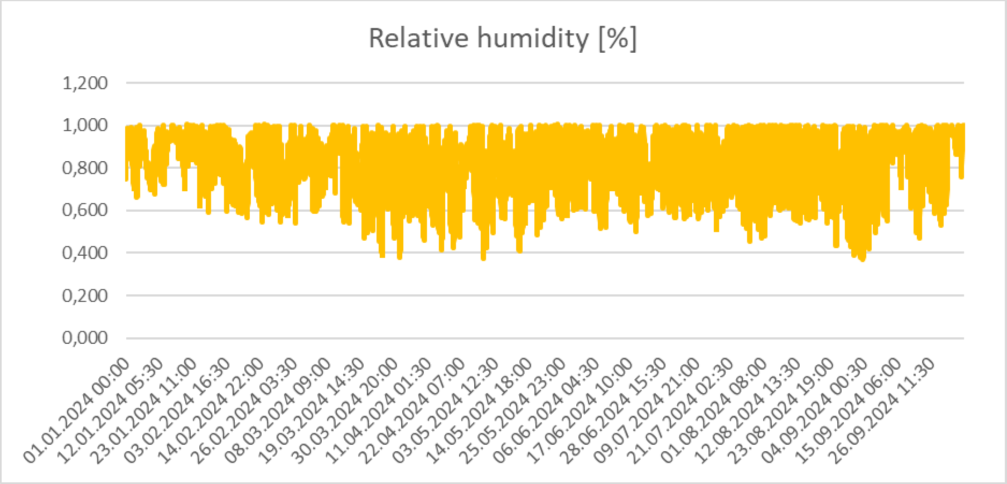


Chart. 3. Relative humidity (%)

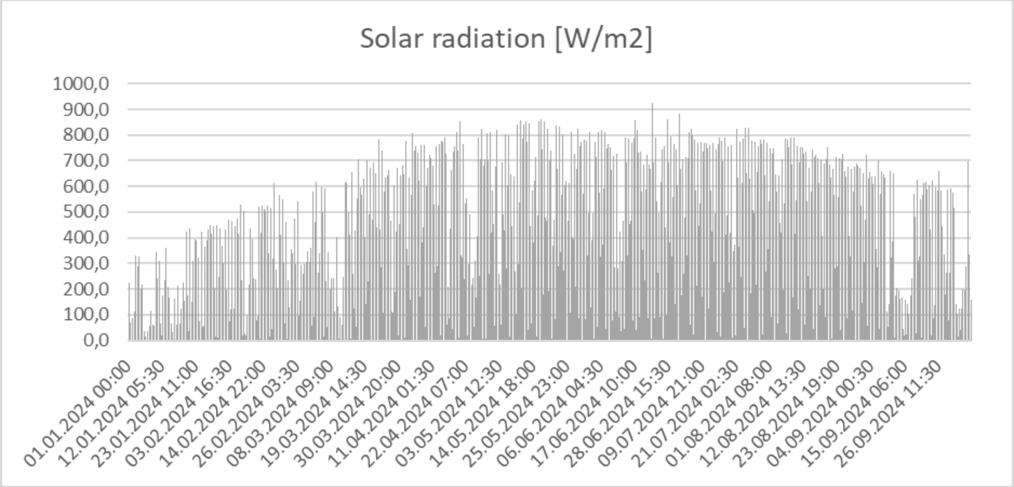


Chart. 4. Solar radiation (W $^{m-2}$)

Measuring devices installed on ST tillage treatment

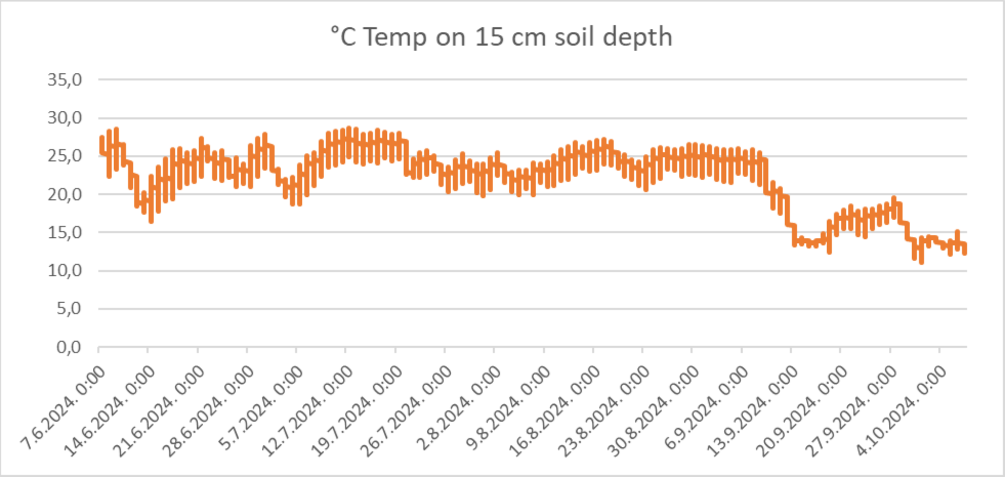


Chart. 5. Soil temperature (°C) at 15 cm depth

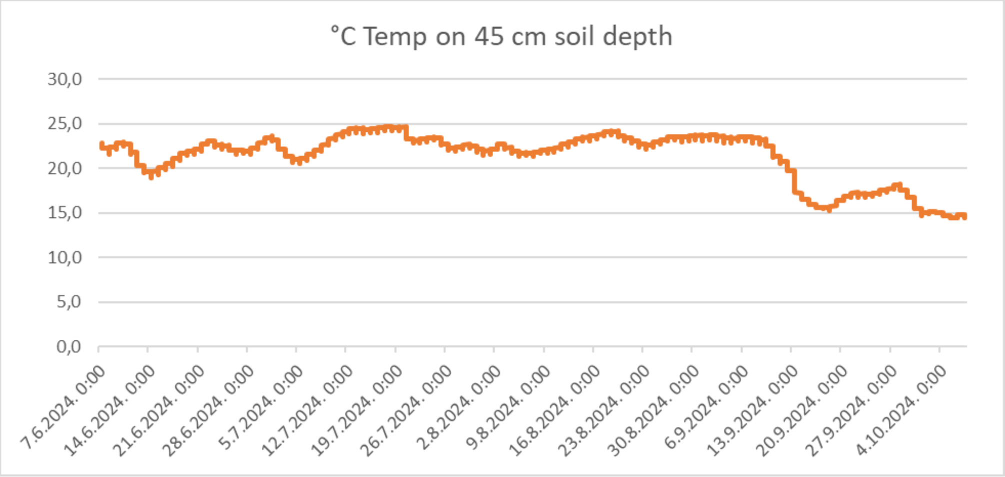


Chart. 6. Soil temperature (°C) at a depth of 45 cm

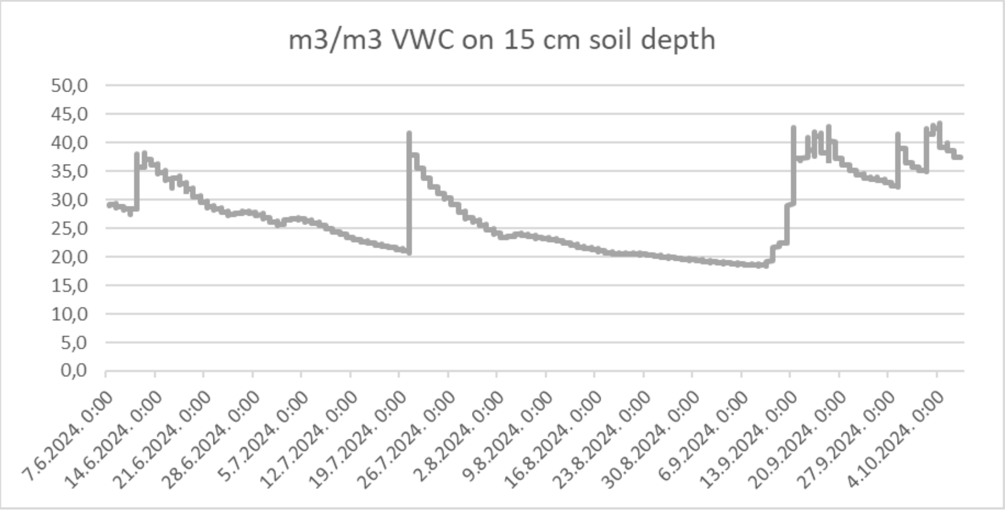


Chart. 7. VWC m^3/m3 at 15 cm ground depth

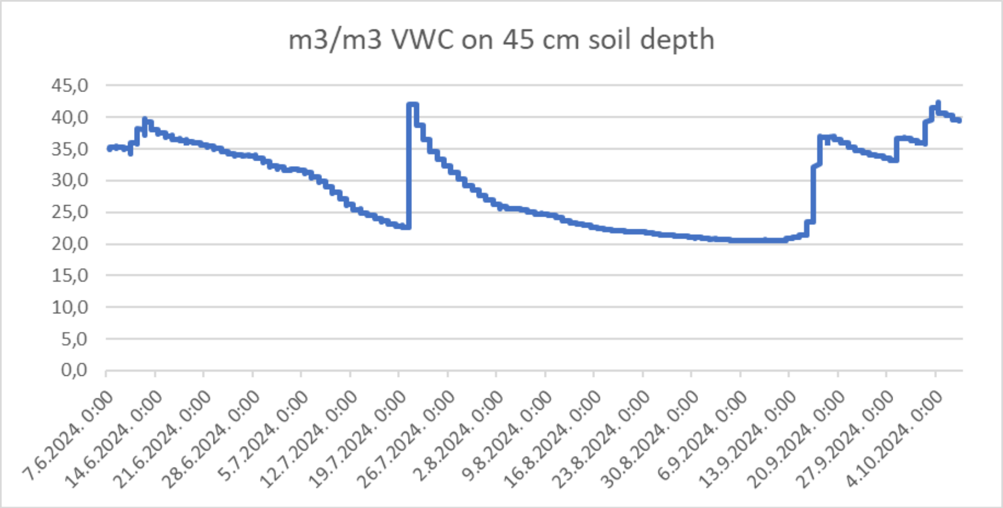


Chart. 8. VWC m^3/m3 at 45 cm ground depth

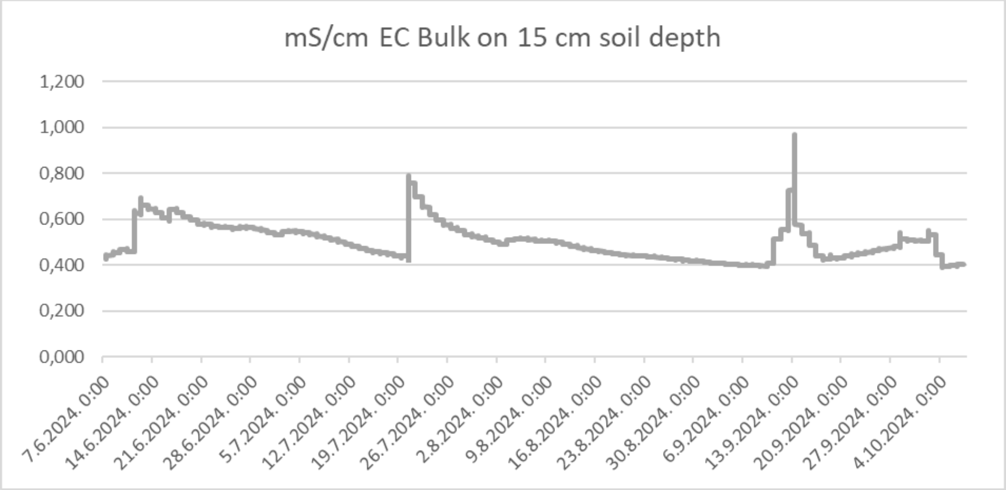


Chart. 9. Electroconductivity at 15 cm depth of ground

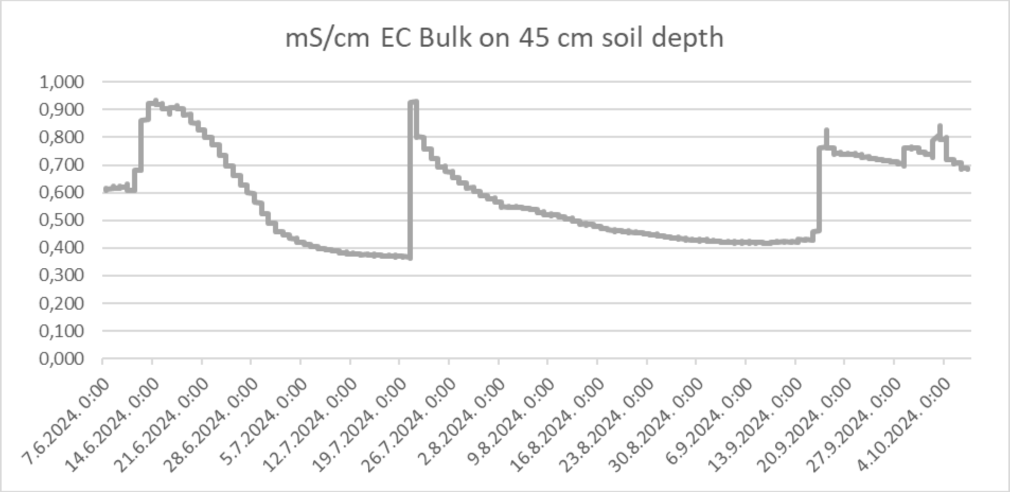


Chart. 10. Electroconductivity at 45 cm depth of ground

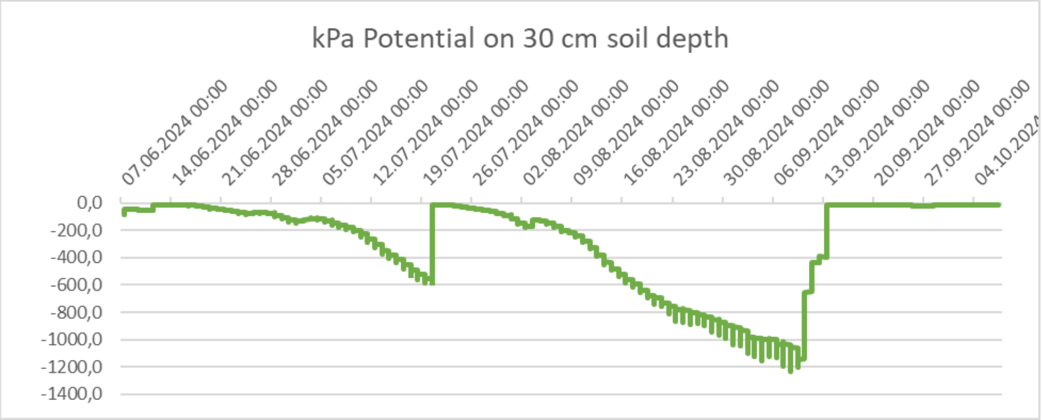


Chart. 11. Soil moisture potential (kPa) at 30 cm soil depth

Measuring devices installed on CTS tillage treatment

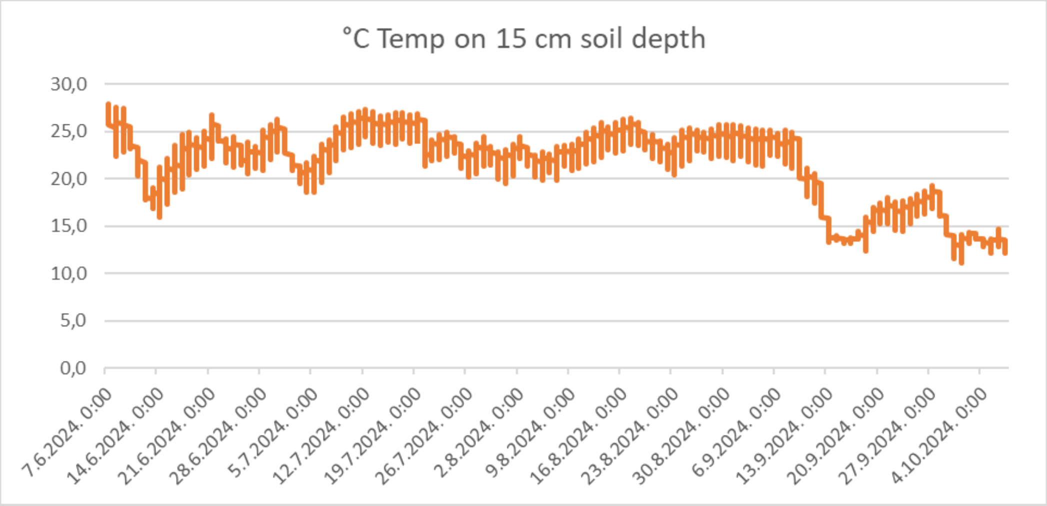


Chart. 12. Soil temperature (°C) at 15 cm soil depth

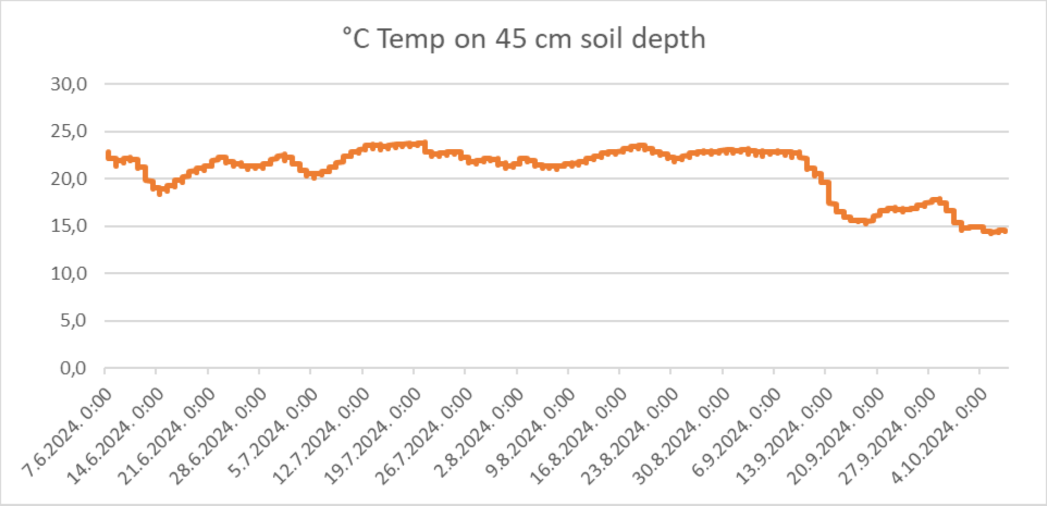


Chart. 13. Soil temperature (°C) at 45 cm soil depth

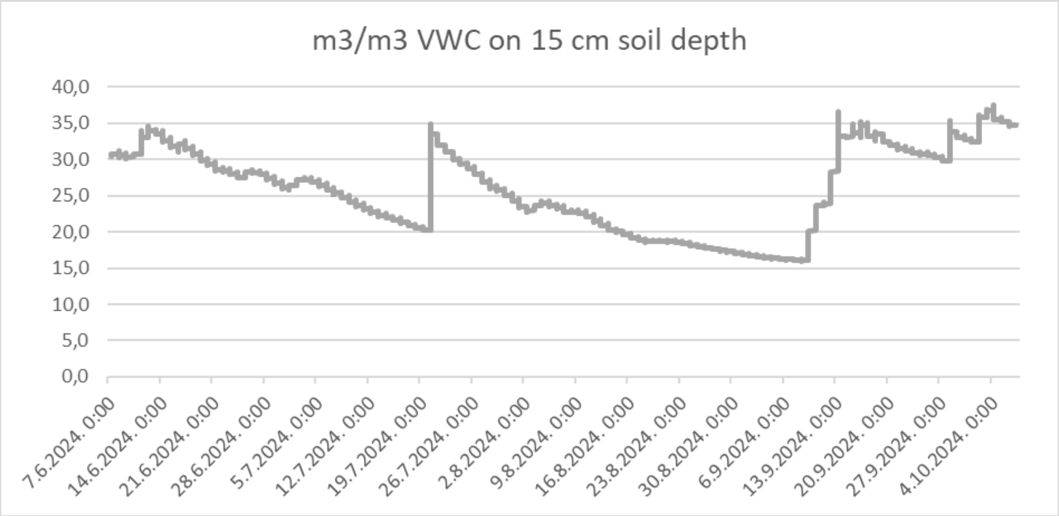


Chart. 14. VWC m^3/m3 at 15 cm ground depth

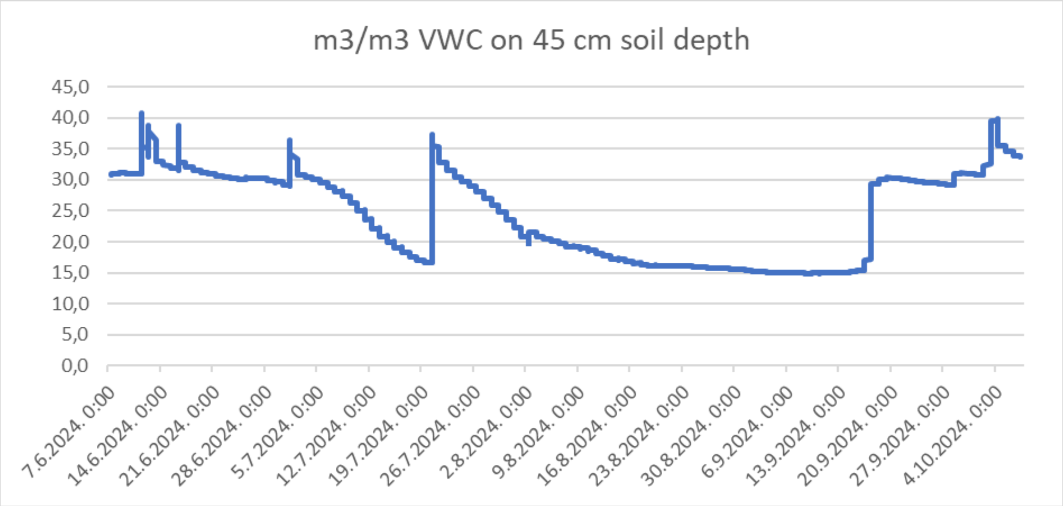


Chart. 15. VWC m^3/m3 at 45 cm ground depth

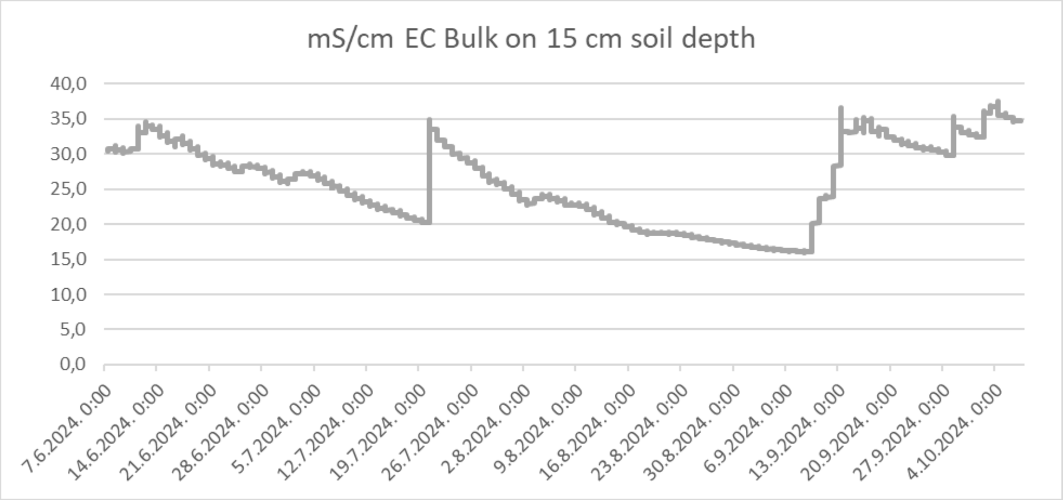


Chart. 16. Electroconductivity at 15 cm depth of ground

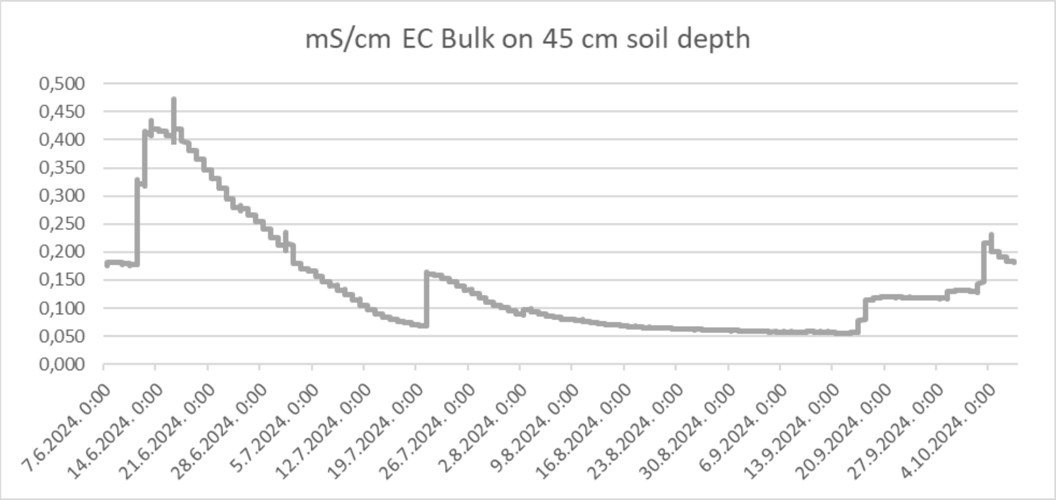


Chart. 17. Electroconductivity at 45 cm depth of ground

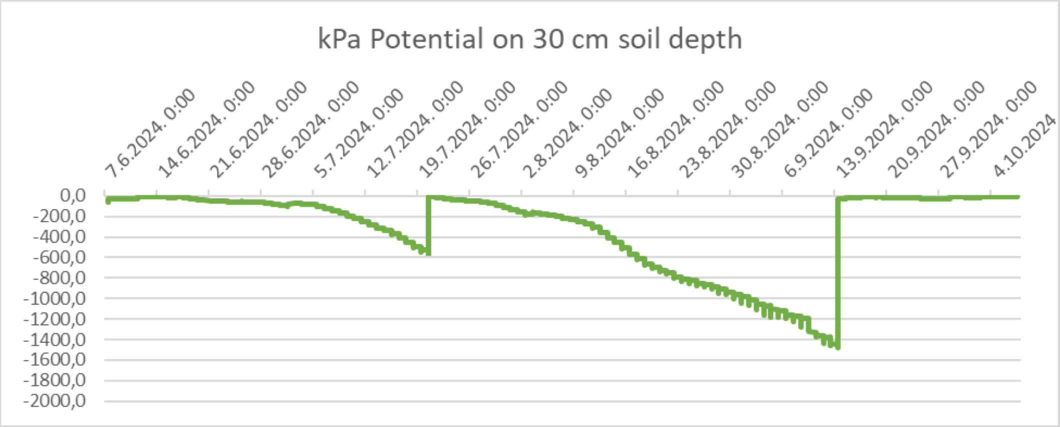


Chart. 18. Soil moisture potential (kPa) at 30 cm soil depth

Soil penetration resistance and soil moisture measurement

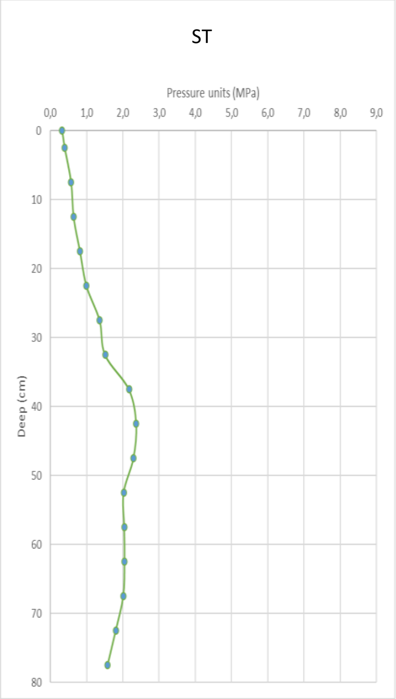
Measuring soil resistance is one of the most important and effective indicators of soil degradation by compaction. It is an indispensable method for assessing the impact of different tillage treatments on soil compaction, and directly or indirectly indicates a number of other physical conditions of the soil as well as a number of plant-breeding parameters.

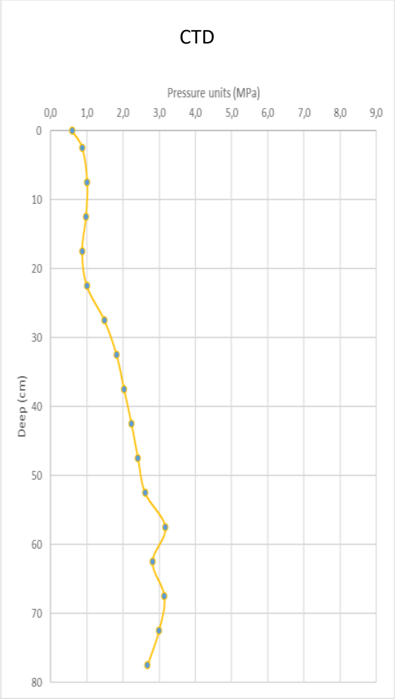
Measurements of soil resistance were carried out on all three treatment systems with an electronic penetrometer "Eijkelkamp Penetrologger SN". A cone tip with a base area of 1 cm^2 and an angle of 60° was used, and it was measured up to 80 cm deep (maximum length of the conical bar). The penetrologist automatically records readings every 1 cm deep, with an average speed of 1 cm/s. After the experiment was set up, and before the first measurement of ground resistance, a GPS location network was created to more precisely determine the location of all subsequent measurements. Each point on the grid was 2 m in diameter. The number of measurements per each parcel of basic treatment was 8 (×3 repetitions = 24 measurements per treatment), a total of 72 measurements were made for all treatment treatments in one sampling date and one location.

Measurements of soil resistance were performed a total of three times during the vegetation period (for a better representation of the state of soil compaction), and graphical representations are visible in Graphs 19-27.

All raw *data* on the conducted soil measurements are recorded in excel files and can be obtained on request.

The following Graphs (Graphs 19-27) show the average soil resistances measured in June, July and September 2024, on three different tillage treatments.





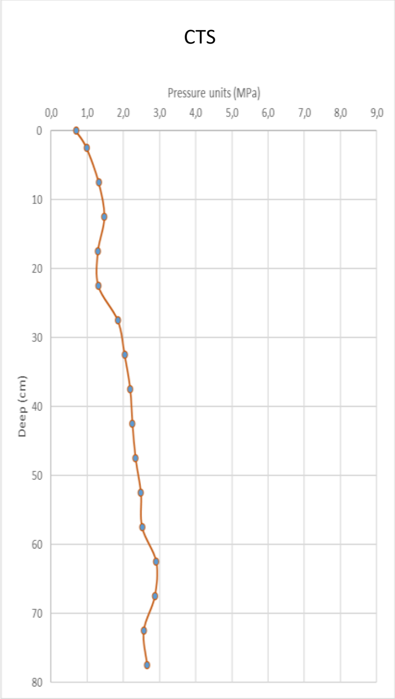


Chart. 19-21. Average values of soil resistance, measured in June (1st measurement)

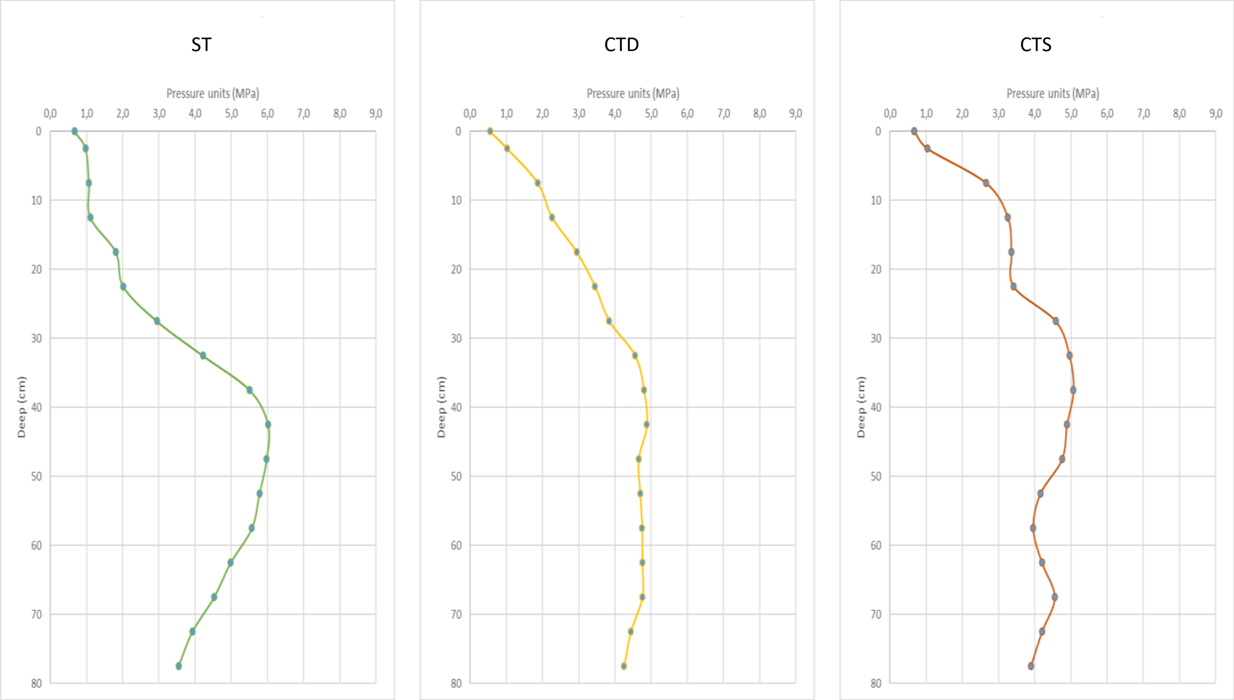


Chart. 22-24. Average values of soil resistance, measured in July (. measurement)

Measuring soil resistance gives the best results (or the most valuable results) when measurements are taken in spring and/or autumn. For the first measurement term in spring, about a month after sowing corn was chosen. During this period, the soil is usually consolidated and the soil moisture is optimal for measurement. For the second and third measurements, the dates chosen depend on the dates of phenological development and harvest.

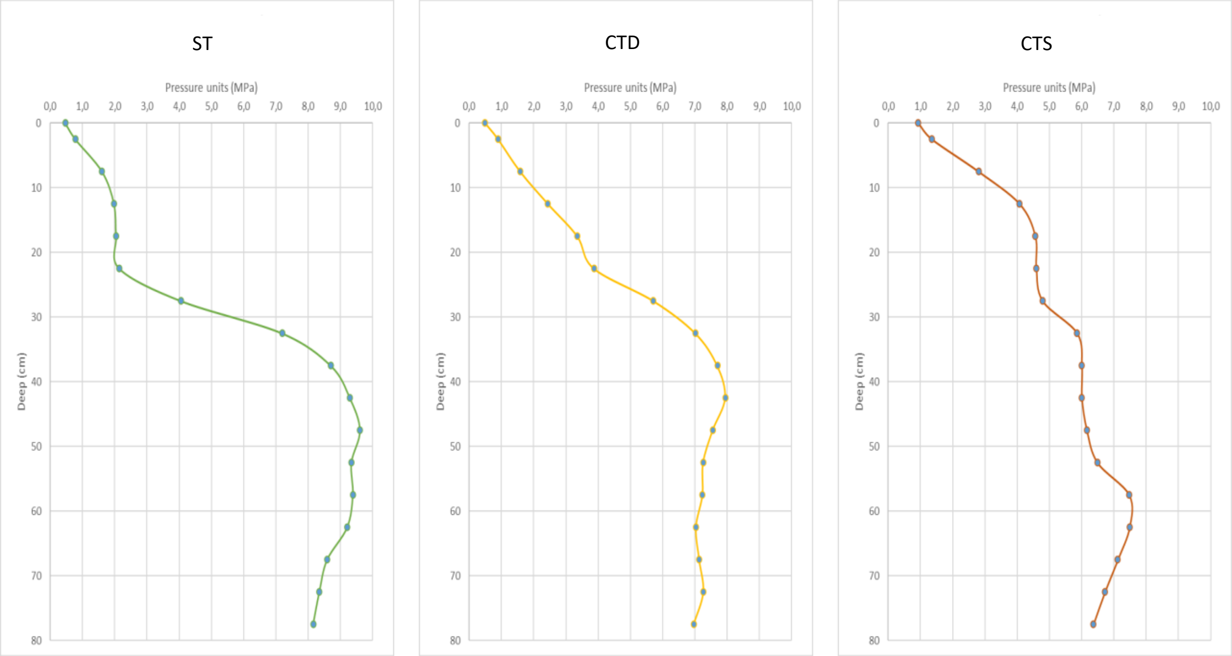


Chart. 25-27. Average values of soil resistance, measured in September (3rd measurement)

Measuring soil resistance helps to identify compacted areas at different depths, which is mainly the result of the application of inappropriate tillage techniques. Compacted soil layers interfere with root growth and reduce yields.

Comparing the values of each tillage treatment separately, but in terms of measurement dates/months, it is quite clearly visible that the soil resistance values increased over time. It is very important to conclude that the highest resistance values were measured on ST treatment. In general, this growing season was very unfavorable for growing crops, especially summer crops.

Since soil resistance is highly dependent on soil moisture, the water content in the soil was determined simultaneously with the resistance measurement (Table 5).

Samples for soil moisture analysis were determined gravimetrically. Samples were taken in metal rings (metal cylinders with a volume of 100 cm3) from different soil layers (0-20, 20-40, 40-60 and 60-80 cm deep), by drying and calculating the % of soil moisture. In measuring soil moisture, we decided to use the gravimetric method instead of the TDR soil probe. The main reason is the higher precision of the gravimetric method, although the TDR method is faster.

The highest soil resistances were measured at a depth of 40-45 cm and did not change significantly up to 80 cm. It is assumed that stronger soil compaction at a depth below 40 cm is the result of the formation of a more compact soil layer due to the periodic alternation of wet and dry periods, which is expected on this type of soil. These results follow expectations of periodic alternation of dry and too wet hydrological conditions, especially if one takes into account that higher compaction values, and thus resistance to penetration, can be expected on wetter soils.

Table 5. Average soil moisture content (% vol.)

Soil depth (cm)	1. Measurement			2. Measurement			3. Measurement		
	ST	CTD	CTS	ST	CTD	CTS	ST	CTD	CTS
0-20	39,6	36,6	39,7	24,5	28,2	27,3	27,2	16,4	19,7
20-40	40,3	37,4	42,6	13,8	20,1	18,7	25,4	14,3	19,0
40-60	39,9	40,9	37,0	16,2	15,7	19,4	21,0	16,4	18,8
60-80	42,1	40,0	38,7	16,6	16,2	15,6	21,4	17,9	18,1
average	*40,48*	*38,73*	*39,51*	*17,76*	*20,05*	*20,26*	*23,74*	*16,26*	*18,90*
Min	*39,63*	*36,65*	*36,99*	*13,80*	*15,70*	*15,63*	*20,96*	*14,32*	*18,13*
Max	*42,12*	*40,91*	*42,63*	*24,47*	*28,18*	*27,32*	*27,18*	*17,94*	*19,65*
Me	*40,09*	*38,68*	*39,20*	*16,38*	*18,16*	*19,04*	*23,40*	*16,40*	*18,92*
SD	*0,97*	*1,77*	*2,06*	*4,02*	*5,00*	*4,32*	*2,63*	*1,29*	*0,54*
CV	*2,41*	*4,57*	*5,20*	*22,61*	*24,95*	*21,30*	*11,08*	*7,91*	*2,86*

Crust and surface soil cover with plant residues

The appearance of surface crust on agricultural soils is a negative phenomenon that reduces the infiltration and storage of water in the soil, and increases its loss. The crust on the soil surface also reduces the exchange of gases in the soil with the atmosphere, causing the development of anaerobic conditions in the soil and several other negative effects that directly and indirectly affect the condition of the soil and the development of crops. The formation of a surface crust of soil is most pronounced on soils with a fine structure, on soils with poor structure and poor aggregate stability, or on soils with a higher clay content.

The surface crust is best assessed after wet periods followed by a drying period, and before the next crop cultivation. The crust measurement was performed on the same date as the 2nd measurement of soil resistance, i.e. July 3, 2024. (Table 6).

Table 6. Average size of the polygon of the crust, Križevci, 2024

Processing Treatment	**Foliar preparation**	**Polygon**			
		Length (cm)	**Width (cm)**	**Thickness (cm)**	**VS**
ST	Control	12,0	11,0	5,0	0
	VibroCalcit	13,2	12,2	5,8	0
	VibroPhosphate	13,0	10,5	3,7	0
	VibroSorb	13,0	8,5	3,5	0
CTD	Control	9,0	6,3	1,8	2
	VibroCalcit	8,5	7,3	1,5	2
	VibroPhosphate	8,0	5,8	2,2	2
	VibroSorb	7,2	5,5	1,8	2
CTS	Control	*	*	*	2
	VibroCalcit	*	*	*	2
	VibroPhosphate	*	*	*	2
	VibroSorb	*	*	*	2

*The polygons could not be defined, the average thickness is 1.5-2.0 cm, they are easy to shred, there is a large proportion of plant residues on the surface.

The appearance of the soil crust was determined by a modified method that included a visual and a metric component. The soil crust was estimated according to the values and criteria shown in Table 7.

Table 7. Estimation of crust intensity

VO-VS	**Visual Assessment - VS**	**Numerical value***
2	(Affordable)	< 2
1	(Central)	2 - 3
0	(Unfavorable)	> 3

*Thickness of the cover in cm

Covering the soil surface with plant residues (Table 8) after harvest and before sowing the next crop helps prevent crust formation by minimizing the dispersion of the soil surface by rain or irrigation. It also helps reduce crust formation by stopping large raindrops before they can hit and compact the soil surface. The vegetative cover and its root system return organic matter to the soil and promote soil life, including the abundance and activity of soil earthworms.

The physical action of the roots and fauna of the soil, and the "adhesives" they produce, promote the development of soil structure, soil aeration and drainage, and help break up the crust. As a result, the level of infiltration and the movement of water through the soil increase, reducing surface runoff, soil erosion, and the risk of flash flooding. The surface plant cover also reduces soil erosion by cushioning the impact of raindrops. Furthermore, plant residues serve as a sponge, retaining rainwater long enough to infiltrate the soil. Moreover, the root system reduces soil erosion by stabilizing the soil surface and holding the soil in place during heavy rainfall. As a result, the quality of water in watercourses is improved with a lower proportion of sediments, nutrient content, etc. It is usually calculated that the application of conservation tillage can reduce soil erosion by more than 90% and water runoff by over 50%.

Table 8. Soil surface coverage (%) by plant residues, measured after sowing maize, Križevci, 2024.

Repetition	**Processing Treatment**		
	ST (%)	**CTD (%)**	**CTS (%)**
1	1	42	95
2	2	41	89
3	1	49	96
4	2	43	89
Average	***2***	***44***	***92***

Biometric analyses and measurements and elemental composition of plant matter

During the growing year (2024), the application of VIRIDIS FARM products was carried out, and during the growing season of maize, in certain phenological phases, sampling and measurement of maize plant material was performed, and the results were presented in tables and graphs.

Plant height

Plant height plays a crucial role in agricultural production, as it can significantly affect various aspects of growth, productivity, and crop management. The height of the plants affects the following parameters:

- Crop yield and productivity:
  - The height of plants is often related to their capacity for photosynthesis, as taller plants tend to have a larger leaf area, which allows plants to take advantage of the sun's energy. In certain crops, optimal height contributes to better development of grains or other parts of the plant that are used as agricultural yield.
- Competitive relations related to resources:
  - Tall plants can shade shorter plants, which can affect their growth and development. This factor is especially important in mixed crops (joint sowing). On the other hand, shorter plants may have advantages in limiting water loss due to less exposure to wind and solar radiation.
- Resistance to stress and adverse conditions:
  - The height of the plant can affect the tolerance to wind, rain or snow. For example, plants that are too tall are more susceptible to lodging (e.g. with cereals such as wheat and corn), which can reduce yield and make harvesting difficult. Low plants are often more resistant to strong winds, but they can have disease problems due to reduced aeration near the ground.
- Photoperiodism and lighting:
  - Optimal plant height can improve the flow of light between rows in the field, allowing all plants in the crop to grow more evenly.

Proper management of plant height through the selection of cultivars and agrotechnical measures is key to increasing the efficiency of agricultural production.

In the conducted study, the average height of maize on all treatments was 241.33 cm, with Sd = 16.439 and Cv = 6.81 %. The highest height was measured on the CTD-N-FR-VibroCalcit treatment (273 cm), and the lowest on the CTS-N-FD-Control (205 cm).

On ST tillage, the average height of maize was 249.50 cm with Sd=14.297 and Cv=5.73%. The highest maize was measured on the non-calcified treatment with VibroPhosphate (265 cm) at optimal fertilization, but the same value was achieved by the corn treated with VibroCalcite on the treatment without liming. Compared to the control, VibroCalcit, VibroPhosphate and VibroSorb had higher maize plants, and among the products listed, VibroSorb obtained the lowest results in maize plant height (Graph 28).

On CTD tillage, the average height of plants was 242.75 cm. The tallest plants (273.00 cm) were measured on a non-calcified treatment with optimal fertilization with the application of VibroCalit (Graph 29), and the smallest plants had maize on a liquified treatment with reduced fertilization on the control plot (210.00 cm).

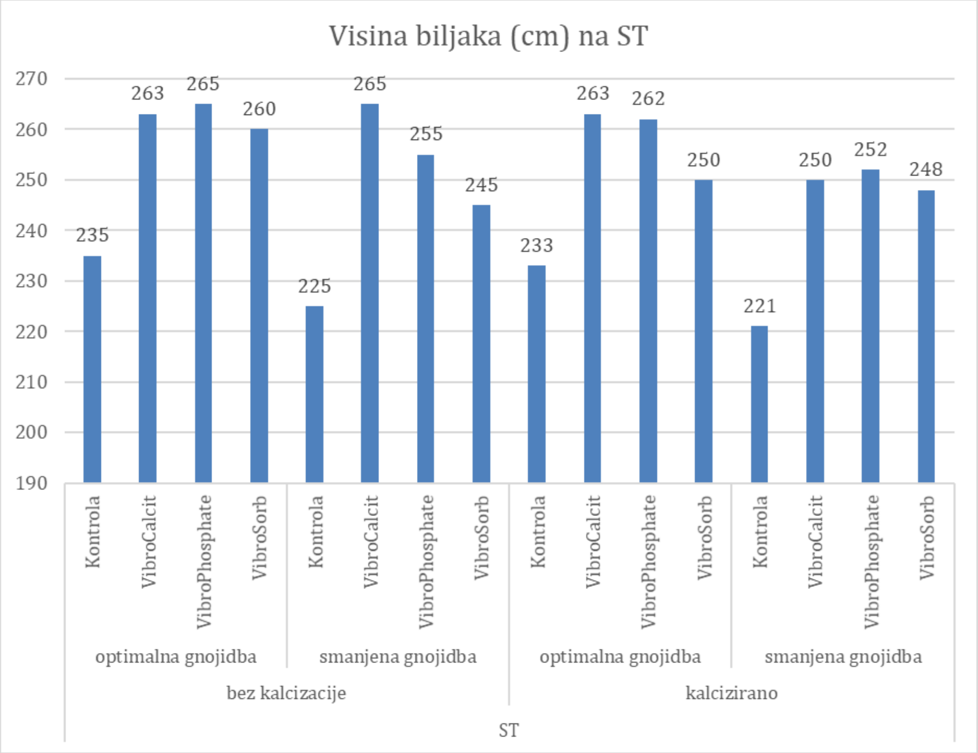


Figure 28. Height of maize plants in the R6 phenological phase (in harvest) on standard tillage.

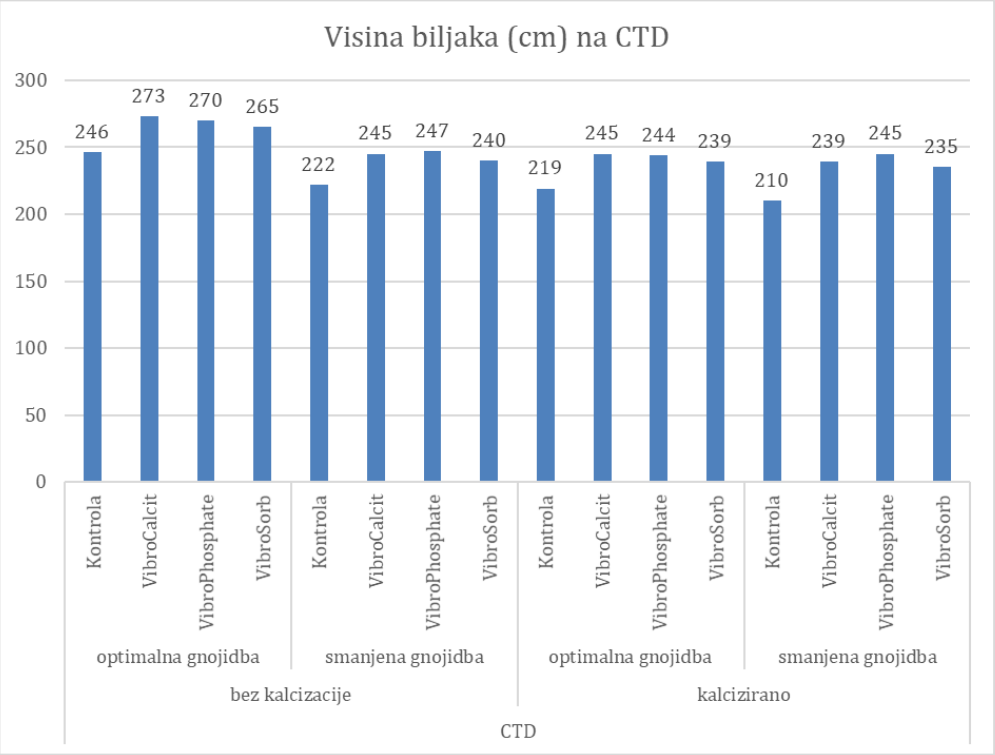


Figure 29. Height of maize plants in the R6 phenological phase (in harvest) on conservation deep tillage.

On CTS tillage, the average height of maize was 231.75 cm with Sd=13.429 and Cv=5.79%. The highest maize was measured on the liming treatment with VibroCalcite at optimal fertilization (249.00 cm), and the lowest at Control, without liming at optimal fertilization (205.00 cm). Compared to the control, VibroCalcit, VibroPhosphate and VibroSorb had higher maize plants, and among the products listed, VibroSorb and VibriCalcit had very similar results in maize plant height (Graph 30).

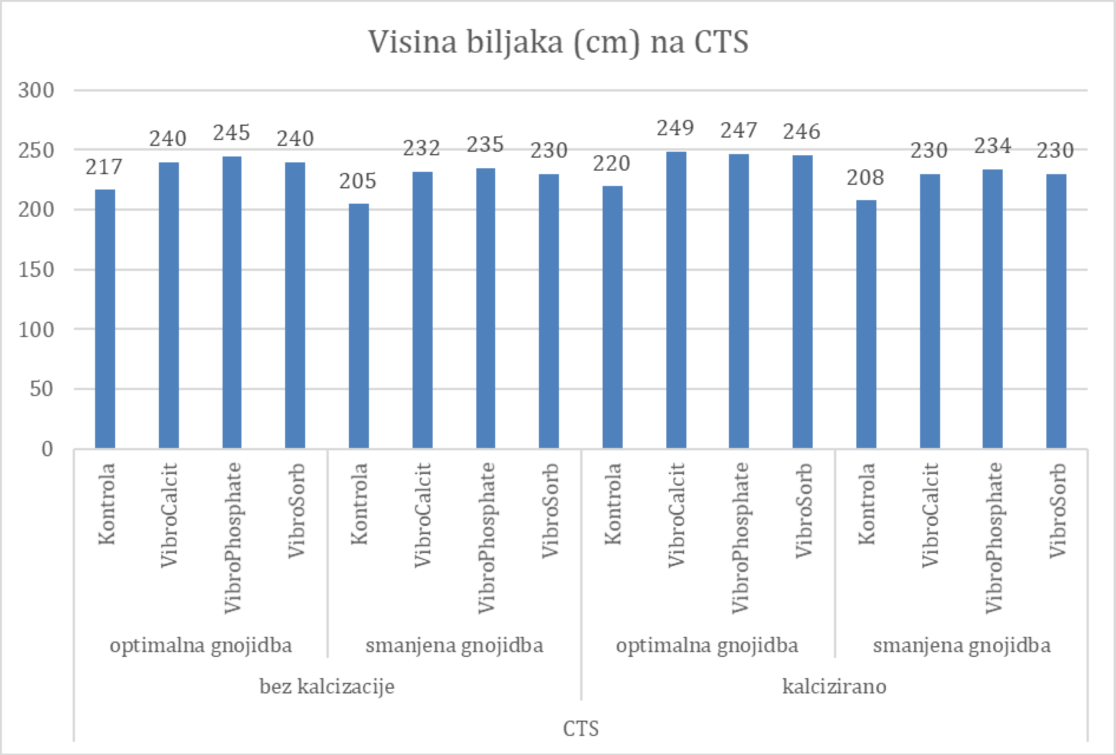


Figure 30. Height of maize plants in the R6 phenological phase (in harvest) on conservation shallow tillage.

Piston Weight

Corn cob weight is one of the key indicators of crop productivity. Heavier cobs not only suggest higher grain density and improved grain yield, but also reflect favorable growing conditions and efficient crop production practices. There are several key points:

- Correlation with yield: The weight of the cob directly affects the overall grain yield, as it reflects the number and quality of grain per cob.
- Factors affecting the weight of the piston:
  - Nutrient availability
  - Water supply
  - Successful pollination
  - Plant health: disease-free and pest-free plants allocate more resources to the development of the cob.
- Breeding implications: Cob weight is a key feature in maize breeding programs, as it provides a measurable goal for improving yield potential.
- Environmental impact: Stress factors such as drought, nutrient deficiencies, or extreme temperatures can reduce the weight of the cob, highlighting the need for adaptive agronomic practices.
- Commercial relevance: Optimizing the weight of the cob is essential to meet the demands of commercial corn production, where both quantity and yield quality are crucial.

Farmers and growers should prioritize practices and traits that increase the weight of the cob, as this is key to achieving sustainable and profitable corn cultivation.

The average weight of maize cob was 331.48 g with Sd = 29.443 and a coefficient of variation of 8.88 %. The highest weight of the cob was for maize on ST-Y-FR-VibroCalcit (390.87 g), and the lowest weight was for maize on ST-N-FD-Control (239.33 g).

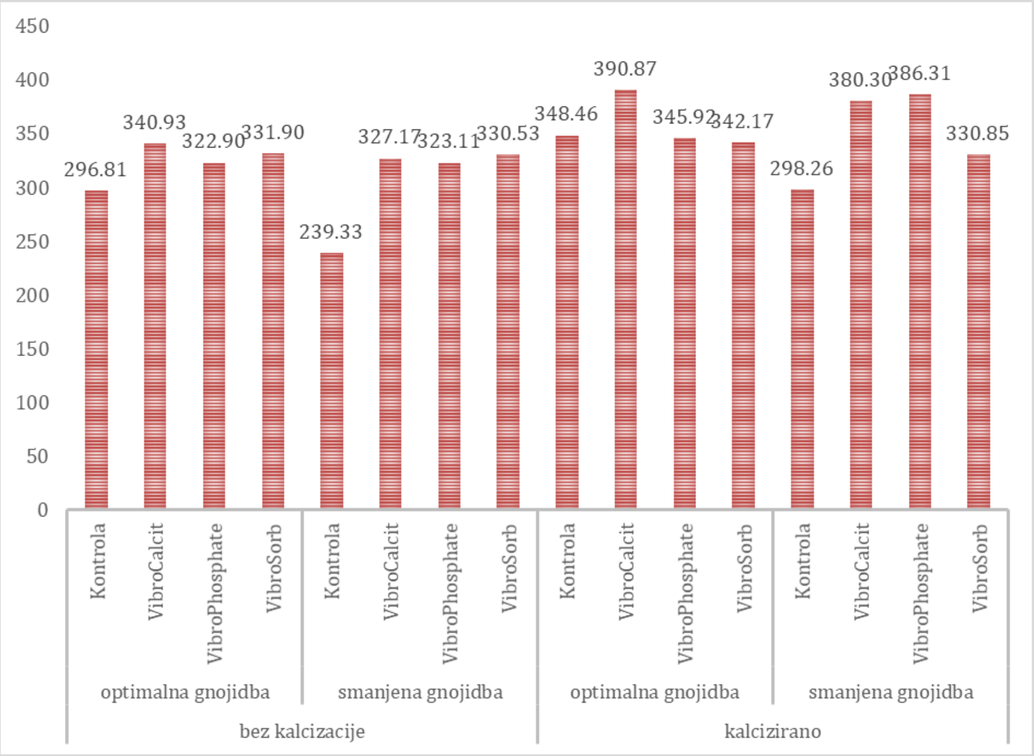


Figure 31. Weight of cob (g) of maize on ST treatment

The average weight of maize on the cob at ST treatment was 333.49 g with a standard deviation of 36.981 and a coefficient of variation of 11.09%. The heaviest cobs (390.87 g) were measured at optimal fertilization with liming with VibroCalcit, and the lowest weight (239.33 g) was measured at the treatment without liming with reduced fertilization on the control treatment (without the application of any of the tested products)

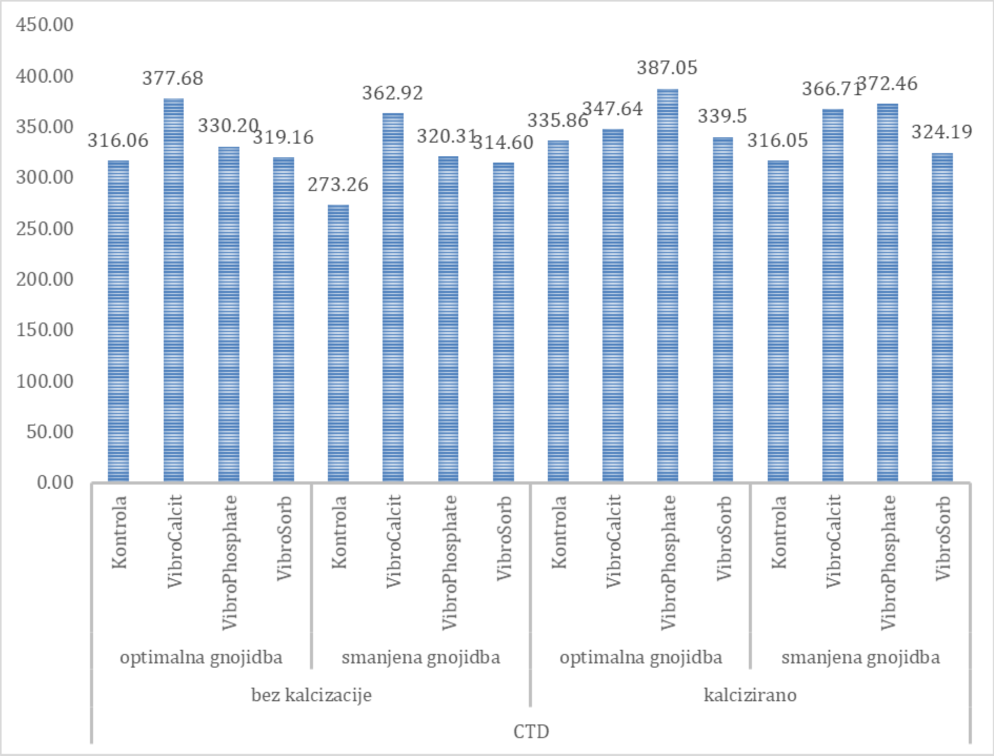


Chart 32. Mass of corn cob (g) on CTD treatment

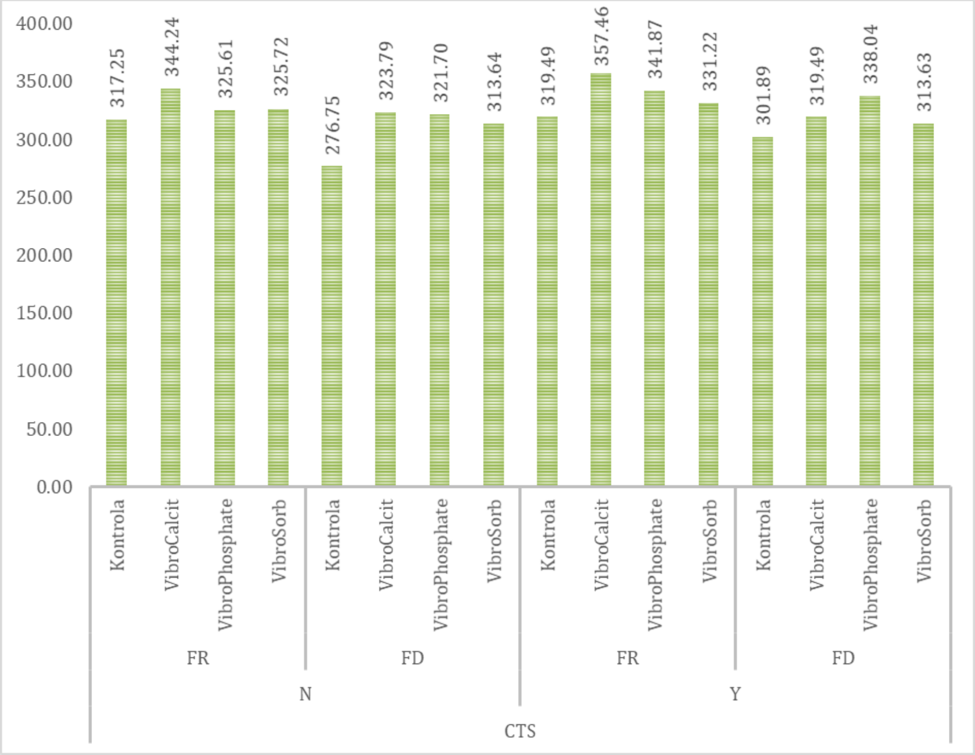


Figure 33. Weight of maize cob (g) on CTS treatment

On CTD treatment, the average weight of maize on the cob was 337.73 g with Sd = 29.814 and Cv = 8.83 %. The maximum value of the cob weight was 387.05 g on the liming treatment with optimal fertilization with VibroPhosphate, and the lowest cob weight was maize grown on the control treatment, without liming with reduced fertilization (273.26 g).

On CTS, the highest weight of the cob was measured on the liming treatment, with optimal fertilization and with VibroCalcit (357.46 g), while the smallest weight was measured on the cob of maize on the control treatment, without liming with reduced fertilization (276.75 g). The average weight of the piston on CTS machining was 323.24 g.

Grain yield

The amount of corn yield is a key indicator of production success and largely depends on the genetic characteristics of the variety, growing conditions and applied agrotechnical measures. Yield is defined as the total amount of grain obtained per unit area, and the factors that most affect it include soil quality, water supply, nutrient availability, protection against pests and diseases, and pollination conditions.

- Genetics and variety selection play a decisive role, as hybrids with high yield potential can significantly increase production. However, even varieties with high genetic potential cannot achieve optimal yields without proper growing conditions.
- Soil and nutrients are the basis of high yields. Fertile soils rich in organic matter and proper fertilization with nitrogen, phosphorus and potassium ensure that the plant has enough resources for growth and development. Lack of nutrients can lead to reduced development of the cob and a smaller number of grains.
- Irrigation is essential in regions with dry periods. Corn is especially sensitive to a lack of water during the flowering phase and pouring of grains, which can significantly reduce the yield.
- Protection against diseases and pests is also important because an infestation or pest attack can weaken the plant, reduce grain quality and reduce the overall yield. Timely application of pesticides and fungicides can prevent large losses.

Finally, agrotechnical measures, such as timely sowing, optimal assembly density and proper tillage, contribute to the maximum use of the genetic potential of the variety. The optimal combination of all these factors ensures high and stable yields, which is crucial for the sustainability and profitability of corn cultivation.

The average yield of maize grain was 13.06 t/ha with Sd = 1.199 and Cv = 9.18 %. The highest yield was achieved at ST-Y-FR-VibroCalcit (15.07 t/ha), and the lowest at ST-N-FD-Control (9.34 t/ha).
On ST processing, the average yield was 13.08 with Sd=1.427 and Cv=10.91%. The maximum yield was achieved on calcified treatment with optimal fertilization and with the application of VibroCalcite (15.07 t/ha), and the lowest on non-calcified treatment with reduced fertilization at the control (9.34 t/ha).

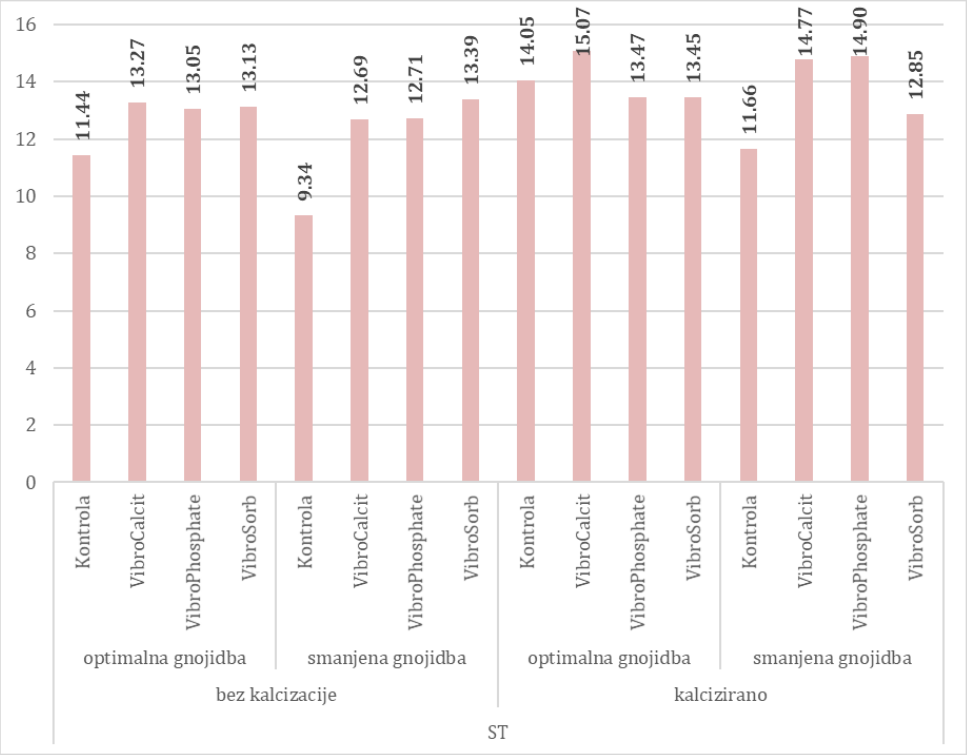


Chart 34. Maize grain yield (t/ha) on ST tillage treatment

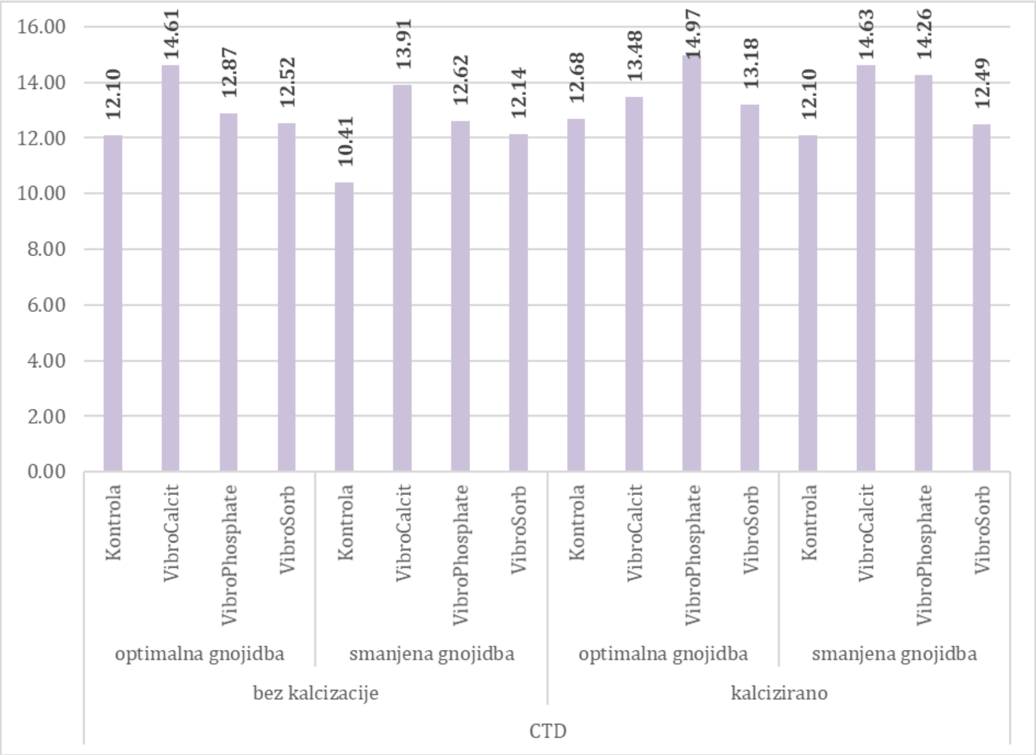


Figure 35. Maize Grain Yield (t/ha) on CTD Tillage Treatment

The average yield on CTD tillage was 13.06 t/ha with Sd = 1.199 and Cv = 9.18 %. The maximum yield was achieved on the liming treatment with optimal fertilization and the application of VibroPhosphate (14.97 t/ha), and the minimum yield was achieved on the treatment without liming with reduced fertilization at the control (10.41 t/ha).

On CTS tillage, the average yield was 12.65 t/ha with a standard deviation of 0.810 and a coefficient of variation of 6.40%. The highest yield was measured on maize grown on liming treatment with optimal fertilization and application of VibroCalcite (14.56 t/ha), and the lowest on treatment without liming with reduced fertilization and control (10.83 t/ha).

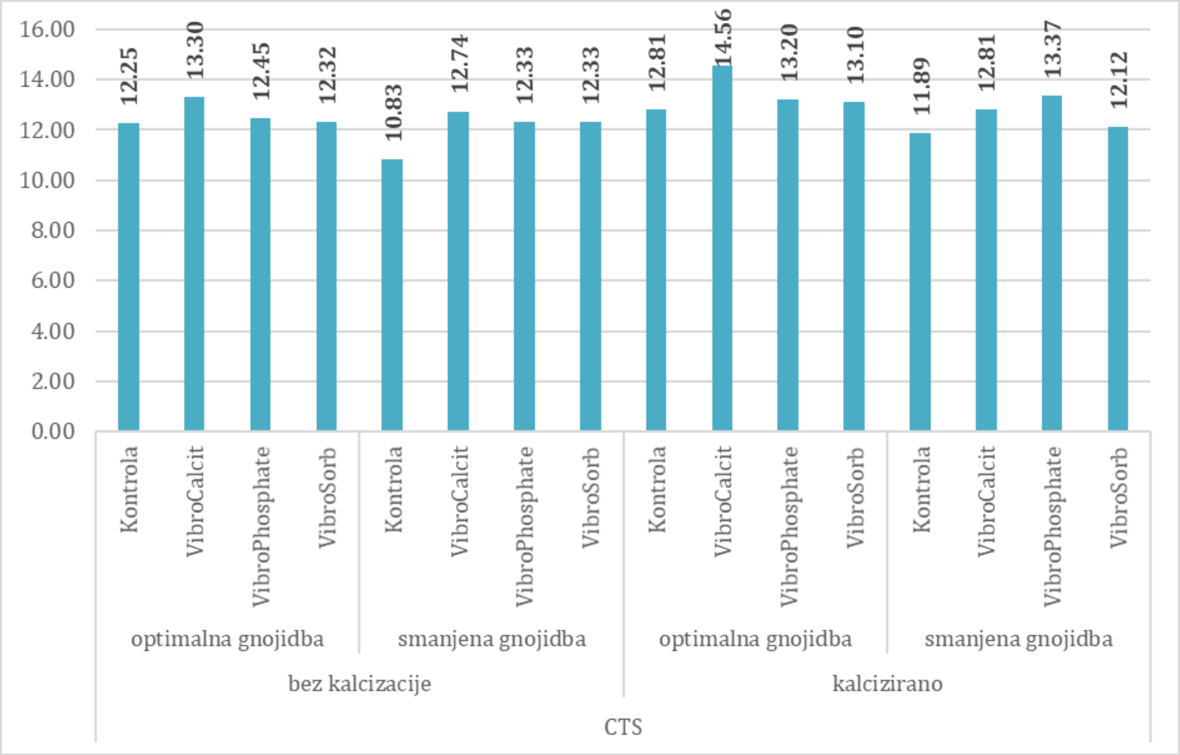


Figure 36. Maize Grain Yield (t/ha) on CTS Tillage Treatment

<u>Biological yield</u>

Biological yield of maize refers to the total amount of dry biomass that a plant produces during its life cycle, and is a key indicator of a plant's productivity in agricultural and environmental terms. Although commercial maize production primarily focuses on grain yield, biological yield has a broader meaning, especially in the context of animal feed production, energy, and agricultural sustainability.

Factors affecting biological yield are:

- Genetic potential of the variety: choosing a hybrid with a high biomass production capacity is key to achieving a high biological yield. Hybrids with stronger vegetative growth often have a higher biological yield, but the genetic balance between grain production and biomass is important for optimal results.
- Growing conditions and environmental factors:
  - light: a sufficient amount of solar energy allows for efficient photosynthesis, which directly increases the accumulation of dry matter,
  - Water and nutrients: Lack of water and essential nutrients such as nitrogen, phosphorus, and potassium limits plant growth and reduces overall biomass production.
  - Soil: High-quality tillage and an optimal structure ensure deeper root development and more efficient absorption of water and nutrients.
- Agrotechnical measures: timely sowing and optimal seeding density are key to achieving maximum biomass. Plants that are too dense compete for resources, while too low density reduces the overall yield per unit area. Maintaining the production area through weed, pest, and disease control allows the plant to focus its energy on growth and development.
- Stress factors: Adverse conditions such as drought, extreme temperatures, pest infestations and diseases can reduce biological yield. Stress is most affected during key stages of plant development, such as flowering and pouring the beans.

In addition to grain, corn biomass has a wide range of applications. The stems and leaves are used for the production of silage as high-quality animal feed. Also, post-harvest residues can be used for mulching, improving soil quality, or in bioenergy production.

Increasing biological yield is key to sustainable agriculture, as it allows for maximum use of resources and reduction of waste. With the right selection and application of production practices, biological yield can be increased, ensuring economically and environmentally sustainable corn production.

The biological yield of maize was on average 36.99 t/ha with Sd = 5.425 and Cv = 14.67 %. The highest biological yield (48.52 t/ha) was achieved by maize on CTD-Y-FR-VibroPhosphate, and the lowest on CTD-N-FR-Control (23.71 t/ha).

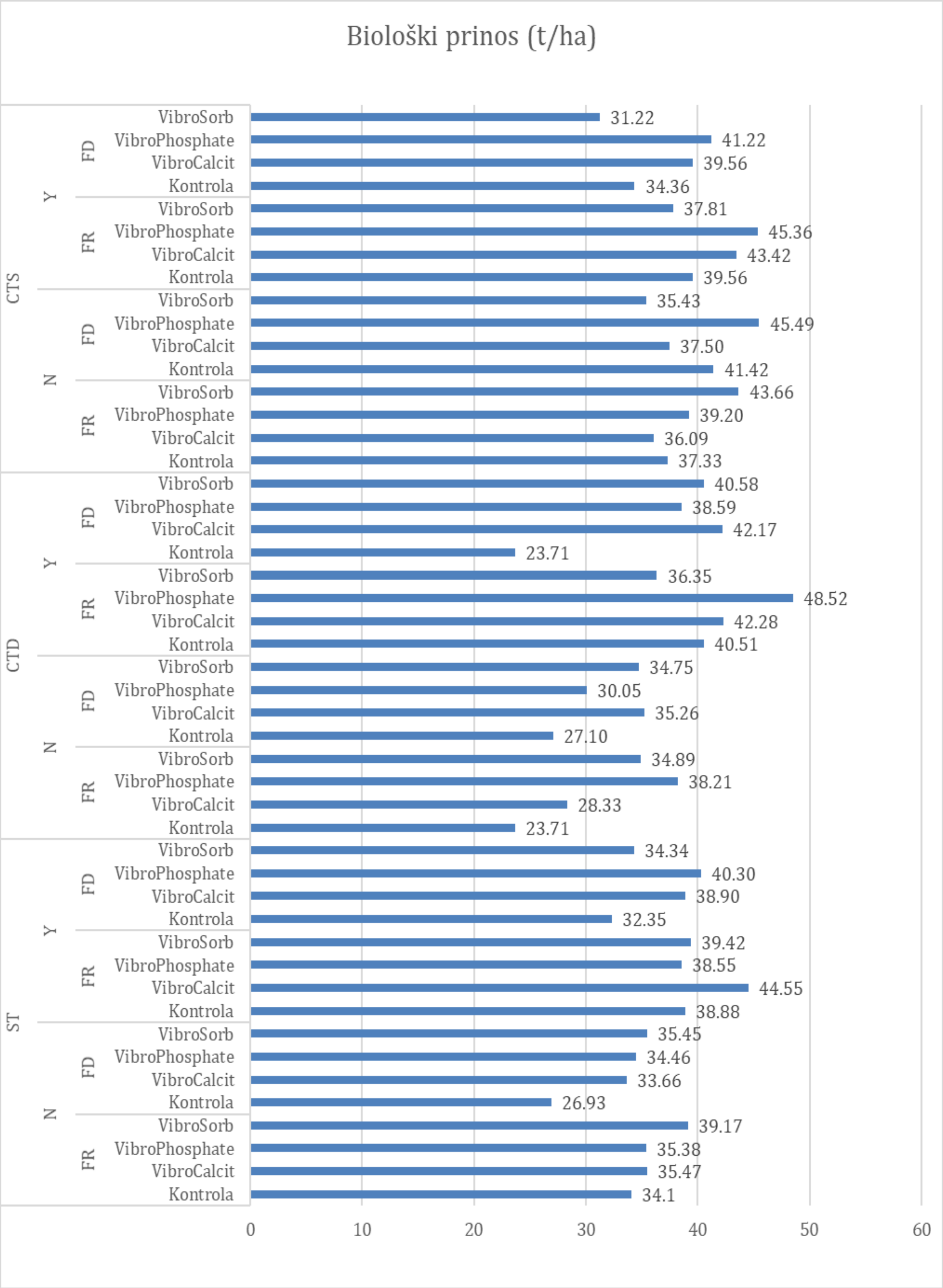


Figure 37. Biological yield (t/ha) of maize

Harvest index

The yield index (GI) of maize represents the ratio between grain yield and total plant biomass (including stem, leaves, and cob). It is expressed as a percentage and is used as an indicator of the plant's efficiency in converting the total biomass produced into an economically viable grain yield.

Maize hybrids selected for high grain yields usually have a higher yield index, as they are optimized for more efficient transfer of assimilates (products of photosynthesis) to the grain. The typical harvest index in commercial hybrids ranges between 45% and 55%.

Stress caused by drought or a lack of essential elements such as nitrogen can reduce the plant's efficiency in translocating assimilates to the grain. Temperature extremes during flowering and grain pouring can lead to weaker grain pouring, which reduces the harvest index.

Timely sowing and optimal density of the plant assembly provide better conditions for the development of cob and grain. Pest and disease control ensures plant health and increases the proportion of grain in the total biomass. The harvest index is an important tool in agriculture and corn breeding, as it helps to assess the effectiveness of the variety and adapt breeding practices. A high ŽI indicates a higher economic profitability of production, while a low index suggests that a significant part of the resource is spent on vegetative mass and not on grain yield. Balancing the total biomass and harvest index is crucial for sustainable and profitable production.

The average harvest index is 35.43% with Sd=5.221 and Cv=14.74%. The highest harvest index had maize on CTD-N-FR-VibroCalcit (51.59%), and the lowest on CTS-N-FD-Control (25.97%). All values of the harvest index are shown in Figure 38.

SPAD

The SPAD values of maize are an indicator of the relative chlorophyll content in the leaves of the plant, which is closely related to its photosynthetic capacity and nutritional status, especially nitrogen levels. The SPAD (Soil Plant Analysis Development) device is used to quickly and non-invasively measure the leaf color green index, thereby assessing the health and productivity of the plant.

SPAD values allow farmers and researchers to assess nitrogen availability, as lower values often indicate a deficiency of this key nutrient. Optimal SPAD values for corn vary, but typically range between 30 and 55, depending on the growth stage and growing conditions. Higher SPAD values indicate a higher chlorophyll content, which is key to efficient photosynthesis and biomass production. This provides the energy needed for plant growth and grain formation. Reduced SPAD values may indicate stressful conditions, such as drought, nutrient shortages, pest damage, or disease.

This makes SPAD measurements a useful tool for early diagnosis of growing problems. SPAD readings help optimize nitrogen fertilizer application, reducing overuse and costs while increasing yield. With regular measurements during the growing season, it is possible to monitor the impact of agrotechnical measures and environmental conditions on the plant.

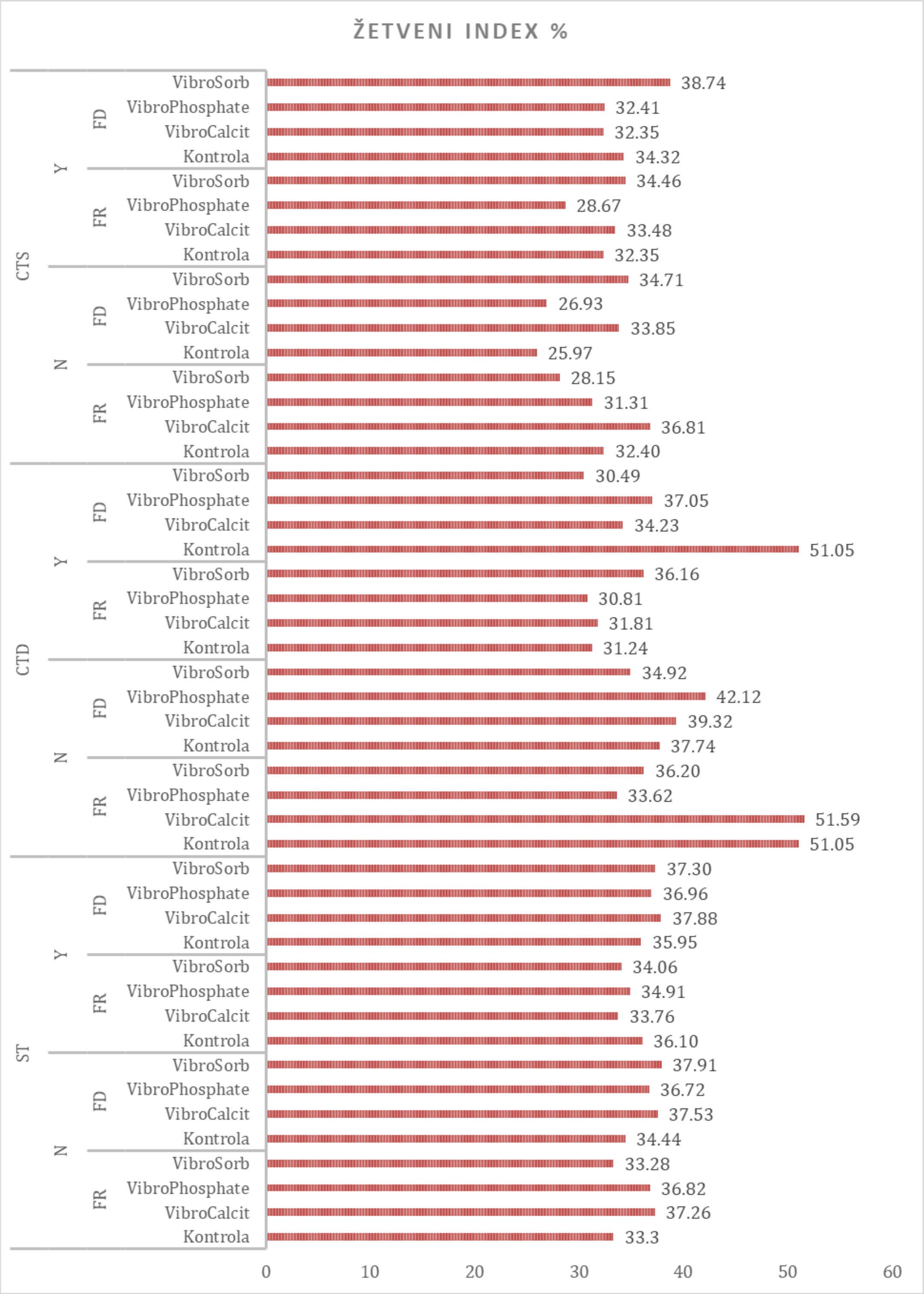
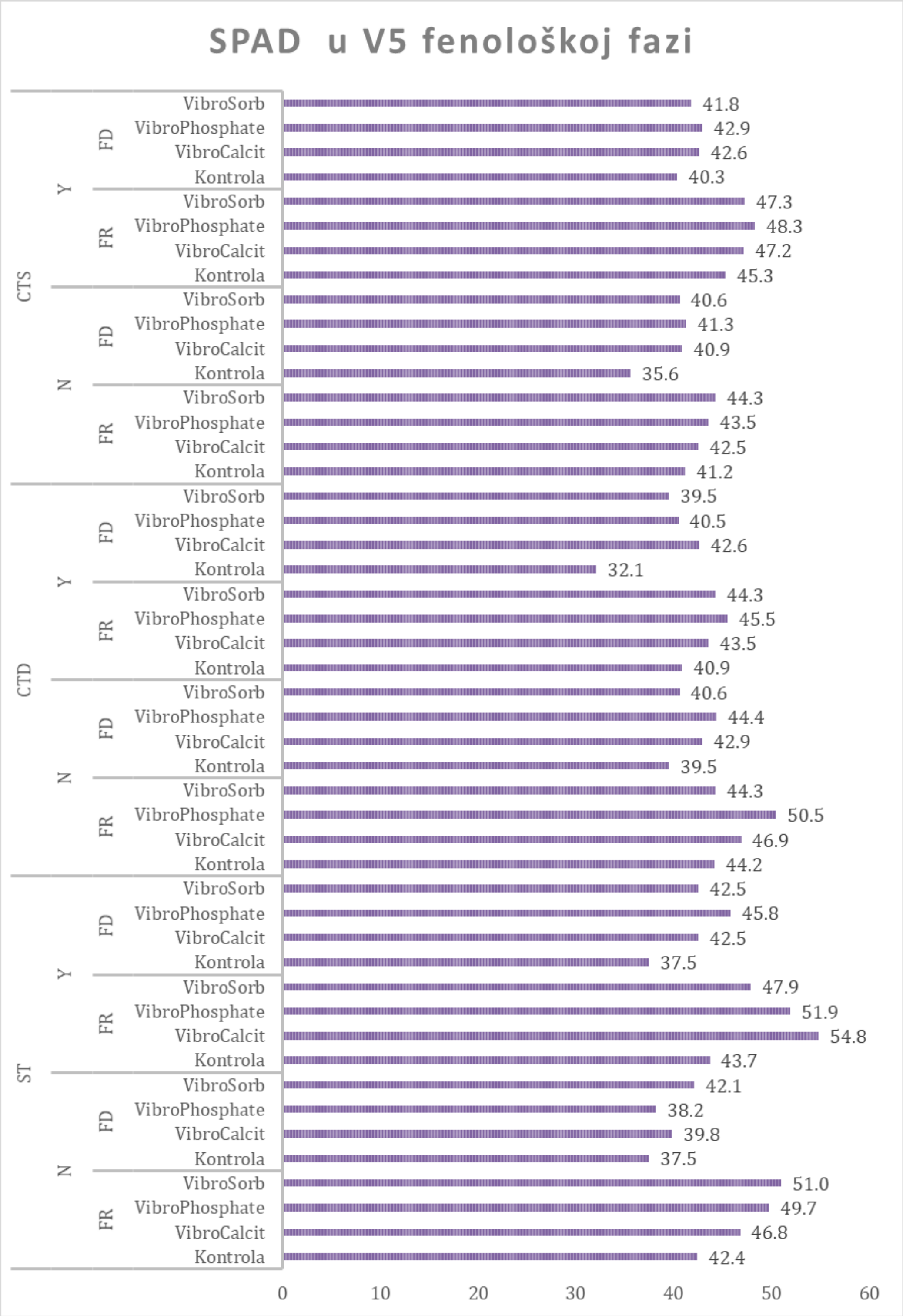
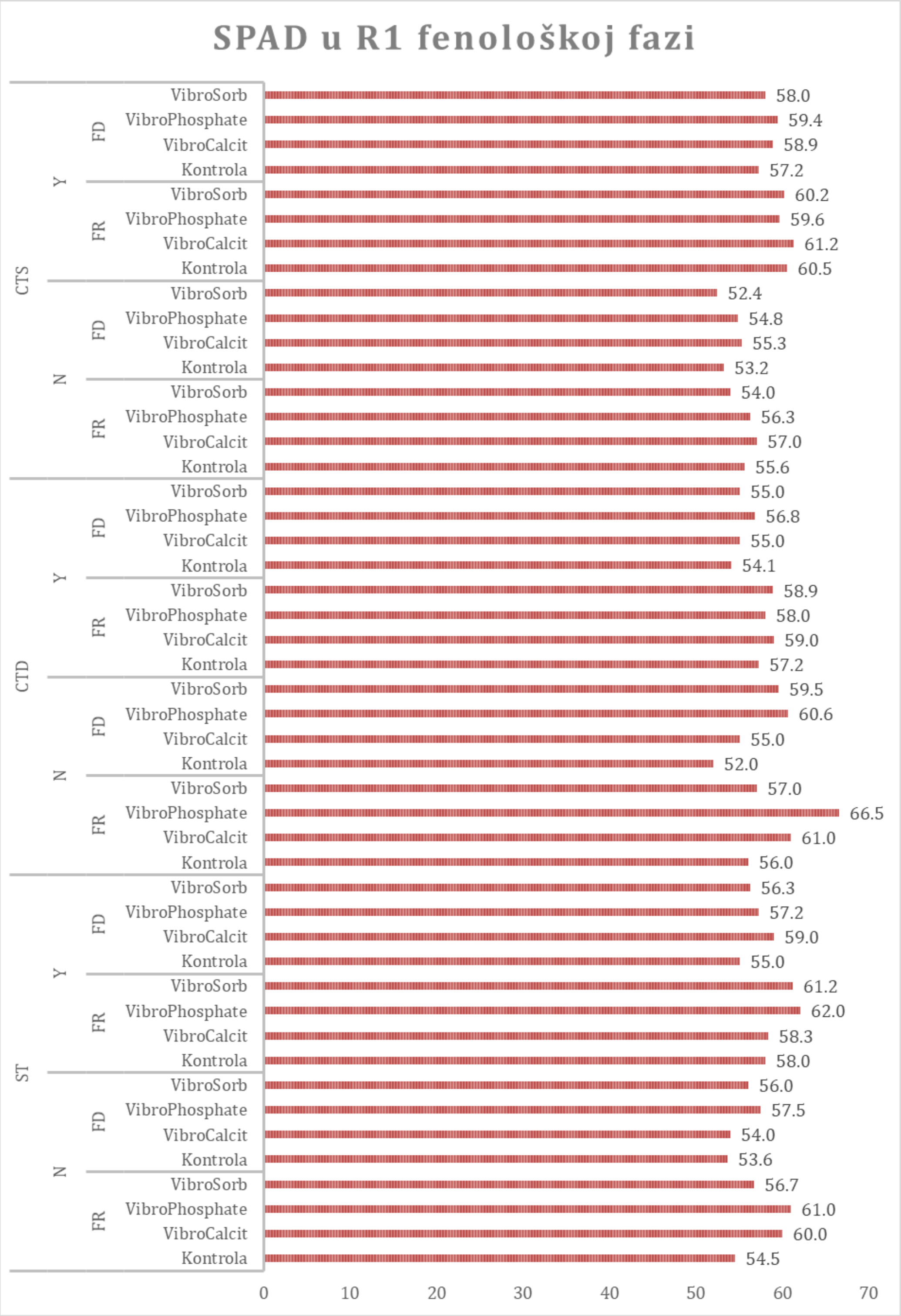


Chart 38 Maize harvest index (%)

In general, SPAD values are a fast, accurate, and reliable indicator of chlorophyll and the nutritional status of corn. Their correct interpretation allows for improved yields, more efficient management of resources and the implementation of sustainable agricultural practices.



Graph 39 SPAD values measured in phenological phase V5 (early growth of maize with 5 visible leaf sleeves)



Graph 40: SPAD values measured in phenological phase R1 (silk phase)

The average SPAD value in the vegetative phase (V 5) was 43.37 with a coefficient of variation of 9.86% and a standard deviation of 4.276. The highest SPAD values measured by the chlorophyll meter were measured in maize leaf at ST-Y-FR-VibroCalcit (54.80), and the lowest at CTD-Y-FD-Control (32.10).

In the silk phase, the average SPAD value was 57.41, with Sd=2.888 and Cv=5.03%. The maximum value was read on CTD-N-FR-VibroPhosphate (66.5) and the lowest on CTD-N-FD-Control (52.0).

LAI (Leaf Area Index)

The Leaf Area Index (LAI) is an agronomic parameter that indicates the ratio of the total area of maize leaves to the soil area covered by the plants. It is expressed as m^2/m2, and its optimal range for maize (in the generative phenological phase of development) is most often between 3 and 6, depending on the hybrid, assembly density and growing conditions. LAI is a key indicator of a plant's photosynthetic activity and its ability to harness the sun's energy, water, and nutrients.

LAI directly affects the amount of solar energy absorbed by the plant. The optimal leaf area index allows for maximum photosynthetic efficiency. If the LAI is too low, the plant cannot absorb enough light to produce the assimilates necessary for growth and development. On the other hand, too high a LAI can cause shading of the lower leaves, a decrease in their photosynthetic activity and an increase in respiration, which reduces the effectiveness of the plant.

Achieving optimal LAI is crucial for high yields. A higher leaf area index is associated with better grain pouring, higher total biomass, and higher grain quality. However, too much LAI can result in increased water loss and reduced resource efficiency.

LAI allows farmers to monitor the efficiency of water, nutrient, and light use. Based on the LAI value, agrotechnical measures such as seeding density, irrigation and fertilization can be optimized to reduce production costs and increase sustainability.

Different corn hybrids have specific leaf growth patterns. Varieties with erect leaves often achieve a higher LAI because they allow for better distribution of light within the assembly. The density of the circuit significantly affects the LAI. Too high a density can cause competition among plants for resources, while too low a density reduces the total leaf area per unit soil. The optimal density allows for a balance between the leaf area and the available resources.

Lack of water, nutrients, or the onset of stress due to high temperatures or disease attacks can reduce leaf development and reduce LAI. Maintaining plant health is key to achieving optimal values. Timely sowing, proper fertilization and plant protection ensure proper leaf development. Weed control prevents competition for resources, thereby supporting leaf growth and maintaining optimal LAI. Tracking LAI helps optimize resources, reducing the environmental footprint of production while increasing yields.

The maize leaf area index is a crucial tool for understanding the interaction between plants, the environment and agrotechnical measures. Its monitoring makes it possible to optimize cultivation, increase yields and use resources sustainably, making it an indispensable indicator in modern agriculture.

The average leaf area index was 3.96 with Sd=0.356 and Cv=8.98%. The highest LAI had maize on CTS-Y-FR-VibroPhosphate (4,447) and the smallest on CTS-Y-FD-Control (2,689).

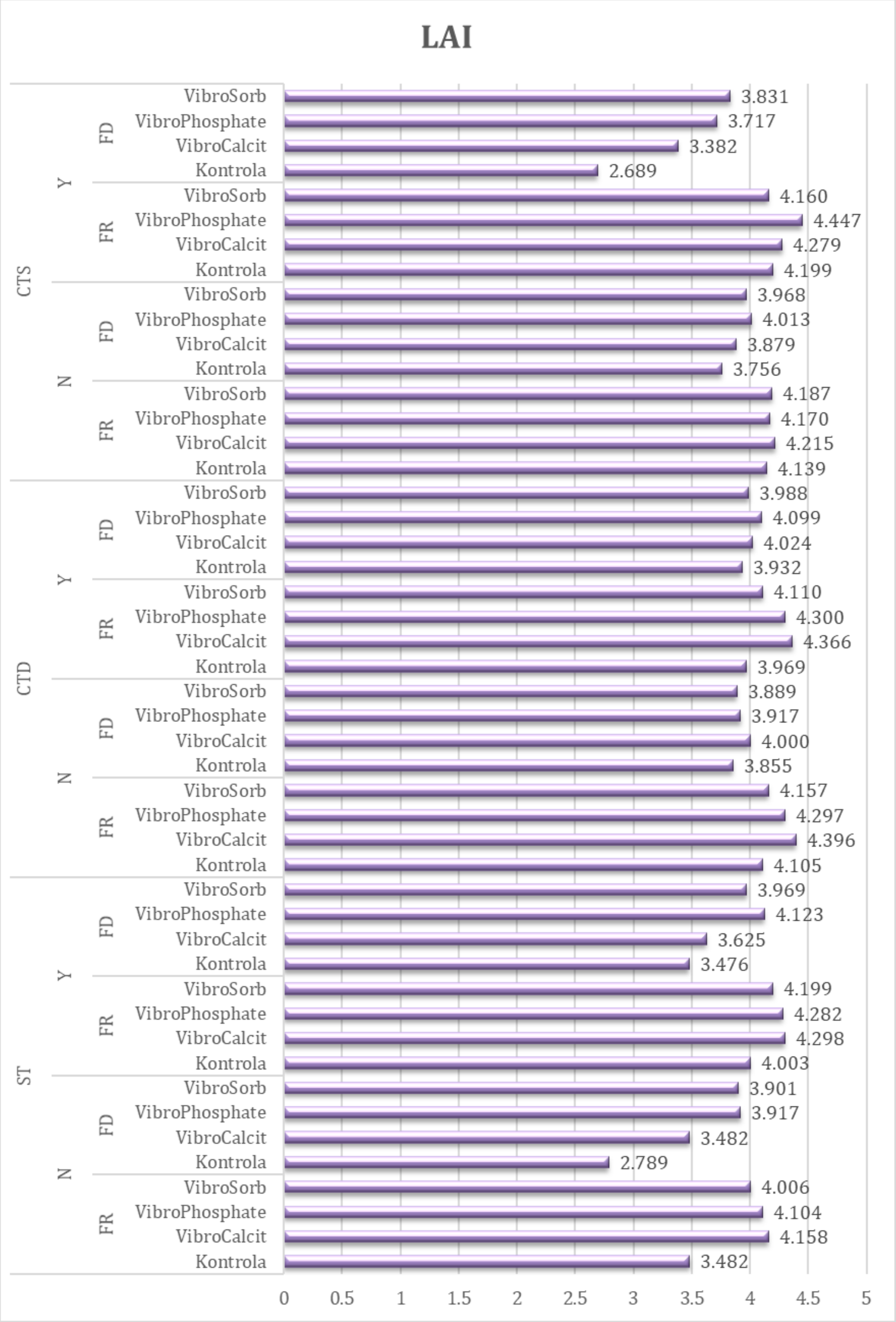


Figure 41. Index of maize leaf surface in the silk phase (R1 phenological phase)

Magnesium

Magnesium belongs to the group of alkaline earth metals. Magnesium is essential for plants and due to the amount that plants absorb to perform its physiological role, it belongs to the macroelements. Magnesium is a crucial mineral for plant and human health, and its presence in corn leaves plays a significant role in the process of growth and development of this crop.

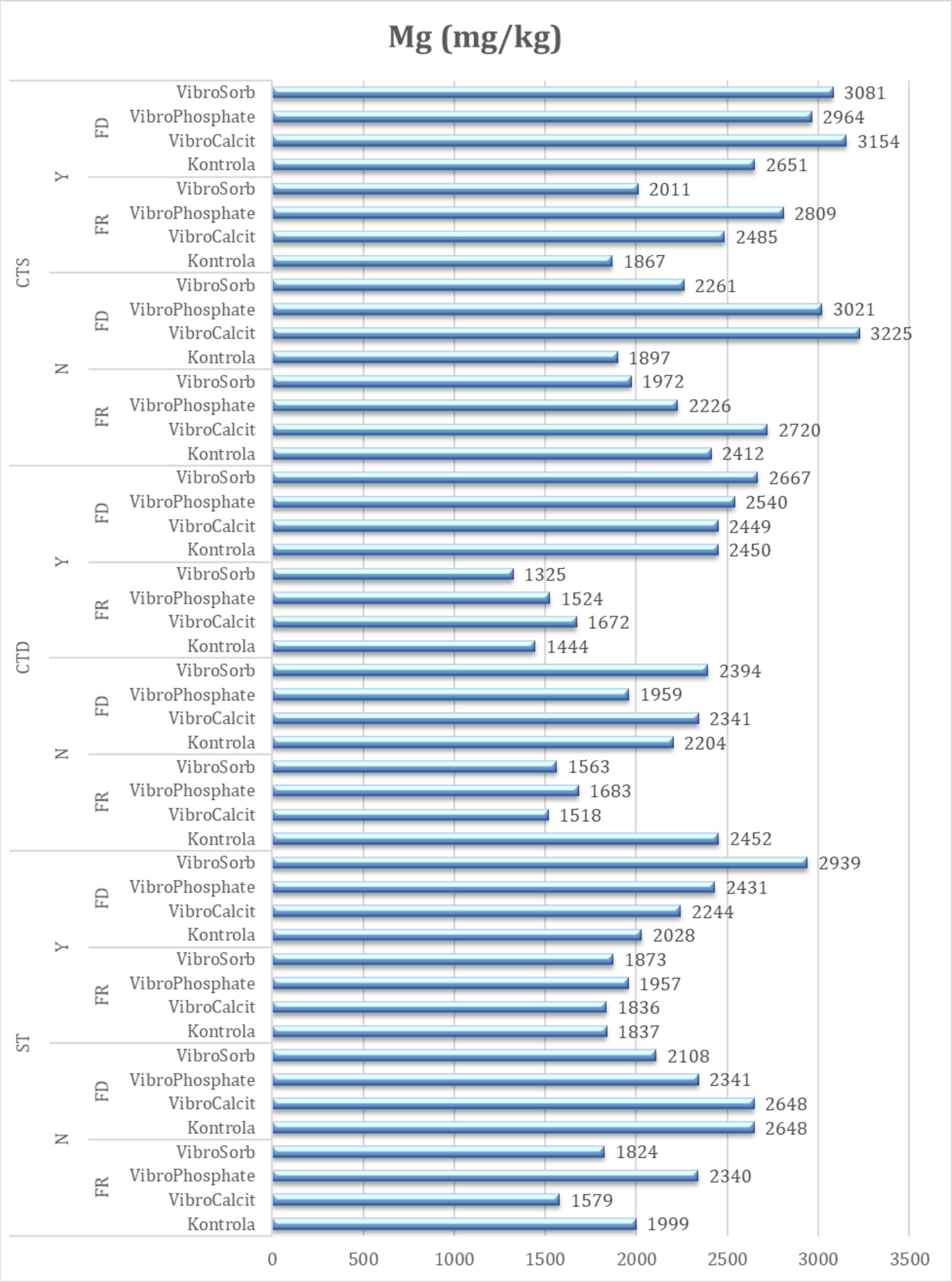


Figure 42. Magnesium concentration in maize leaf in the silk stage

This element is a central part of the chlorophyll molecule, which means it is essential for photosynthesis, the process by which plants convert solar energy into glucose. Without enough magnesium, corn leaves can turn yellowish, especially between the leaf veins, while other parts of the leaf remain green. This phenomenon, known as interveinal chlorosis, is one of the first signs of its deficiency, and appears on older leaves as a result of the breakdown of chlorophyll, of which magnesium is an integral part.

In addition to supporting photosynthesis, magnesium participates in the activation of enzymes that are crucial for protein synthesis, energy transfer and carbohydrate metabolism. Its balance in the soil directly affects the quality and yield of corn. If it is present in insufficient quantity, plants become weaker, less resistant to stressful conditions such as drought, and are more susceptible to diseases.

The average concentration of magnesium in maize leaf was 2241.10 mg/kg (0.2241%) with Sd=486.096 and Cv=21.69%. Maize had the highest concentration of magnesium on CST-N-FD-VibroCalcit (3225 mg/kg), and the lowest on CTD-Y-FR-VibroSorb treatment (1325 mg/kg).

Phosphorus

Phosphorus is one of the essential elements for the growth and development of corn, especially in its leaves, where it plays a key role in the processes that support the plant's energy, metabolism, and growth. This mineral is essential for photosynthesis, respiration and DNA synthesis, making it indispensable for the proper development of corn. Phosphorus is found in plants in the form of phosphate and participates in the transfer of energy within cells, ensuring the effective action of ATP, the molecule that drives most biochemical processes. Corn leaves serve as the primary site for photosynthesis, and phosphorus ensures that this process runs optimally. When a plant has an adequate intake of phosphorus, photosynthesis is more efficient, and thus more sugars and other organic compounds necessary for growth and development are produced. Phosphorus deficiency in corn leaves can cause a variety of problems, including stunted growth and poorer metabolism. The leaves turn dark green with reddish to purplish tones, indicating disturbances in energy transfer and in carbohydrate metabolism.

In the early stages of corn growth, phosphorus is especially important for root development and initial leaf growth. Although phosphorus often accumulates in the roots first, its deficiency quickly becomes noticeable on the leaves. Healthy leaves with enough phosphorus contribute to the development of the plant, ensuring better absorption of light and the formation of nutrients. If phosphorus is not available in sufficient quantity, the plant consumes energy to mobilize reserves from other parts, which can negatively affect growth and yield.

Phosphorus-rich soil is essential for the successful cultivation of corn. However, phosphorus is often poorly mobile in the soil, which means that it is difficult for plants to reach this element if it is not evenly distributed. Plants that have optimal levels of phosphorus in their leaves show better resistance to stressful conditions such as drought or low temperatures, since this element also supports cell renewal processes.

The role of phosphorus in corn leaves does not end only at the level of energy and photosynthesis. Its presence also contributes to the proper maturation of the plant, ensuring that corn reaches its full genetic potential. At the end of the growing season, leaves with a healthy phosphorus content support the full development of the cobs, ensuring high quality and quantity of yield.

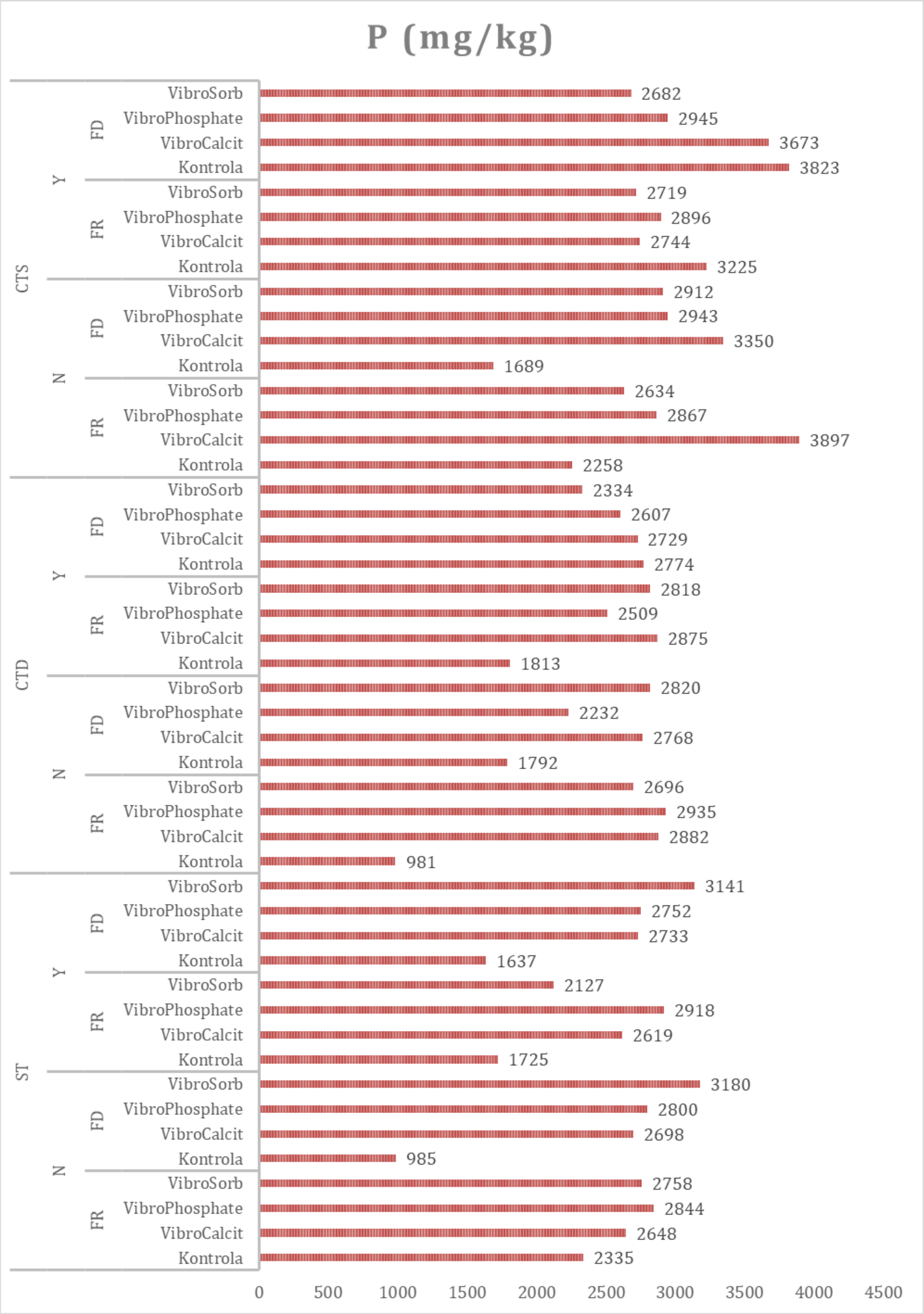


Figure 43. Phosphorus Concentration in Maize Leaf in the Silk Stage

The average concentration of phosphorus in maize leaf was 2640 mg/kg (0.2640%) with a coefficient of variation of 22.61% and Sd=596.875. The highest phosphorus was measured in maize leaf at CTS-N-FR-VibroCalcit (3897 mg/kg), and the lowest at CTD-N-FR-Control (981 mg/kg).

Potassium

Potassium is an essential macroelement for the growth and development of corn, and its role in the plant extends through almost all physiological processes. In corn, potassium especially contributes to the health and functionality of the leaves, ensuring optimal metabolism, water regulation and resistance to stressful conditions.

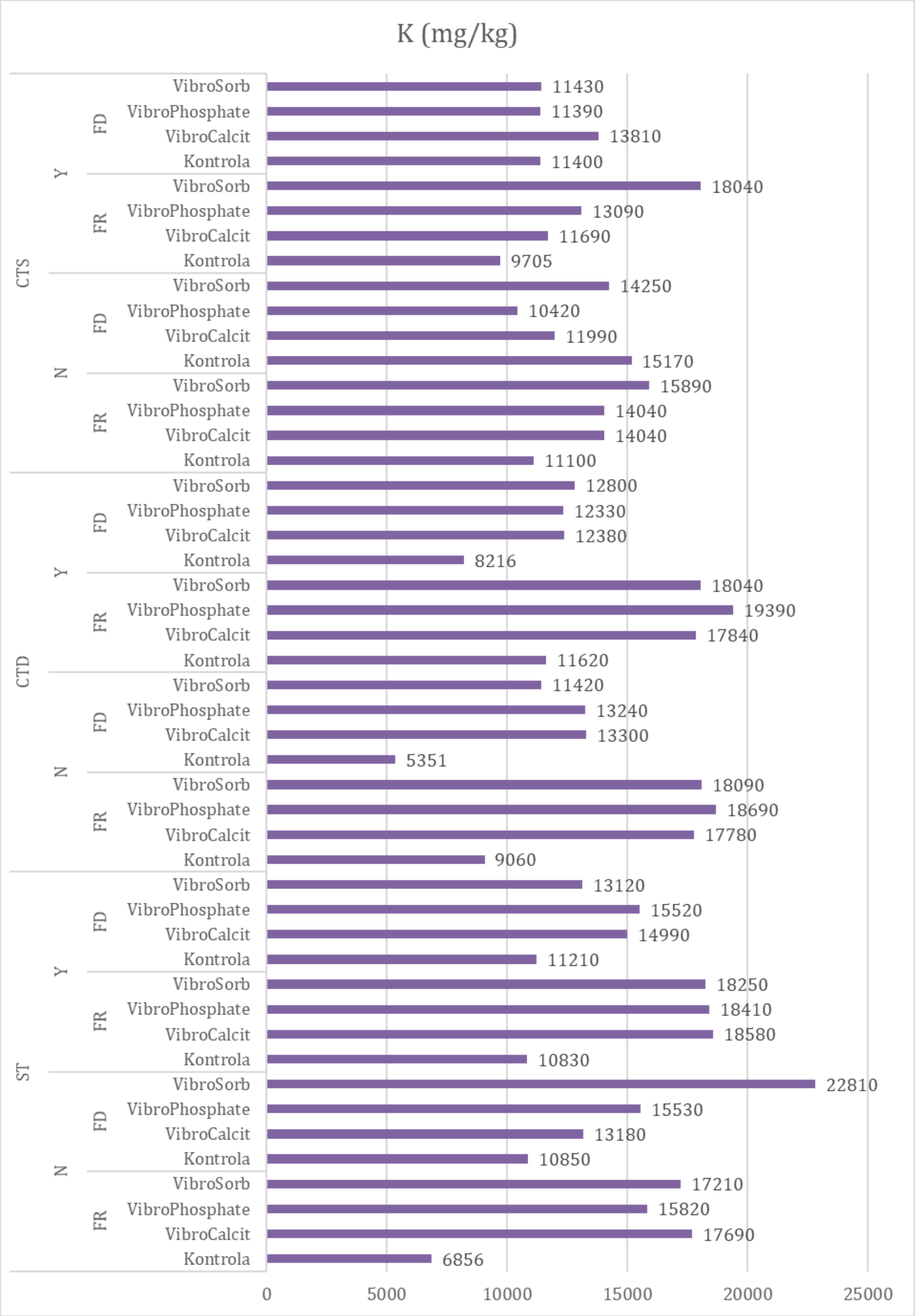


Figure 44. Potassium concentration in maize leaf in the silk stage

Although it is not a component of organic molecules such as proteins or chlorophyll, potassium is vital for enzyme regulation, nutrient transport, and maintaining osmotic balance within cells.

One of the key roles of potassium in corn leaves is to support photosynthesis. Potassium is involved in the opening and closing of buds, microscopic openings on the leaf surface, which control gas exchange and water loss. When the plant has enough potassium, the shoots effectively regulate the flow of CO_2, which increases the efficiency of photosynthesis and sugar synthesis. On the other hand, potassium deficiency can cause a decrease in photosynthesis, which negatively affects the growth of the plant and the development of the cobs.

Potassium also helps transport the products of photosynthesis from the leaves to other parts of the plant, such as the roots and cob. This transport ensures the proper distribution of energy and nutrients needed for growth and development. Without a sufficient amount of potassium, sugars and other metabolites can accumulate in the leaves, interfering with normal metabolism and reducing corn yield. In addition, potassium improves the plant's ability to store carbohydrates, which is crucial for the formation of healthy grains.

In conditions of stress, such as drought, high temperatures or pathogen attacks, potassium plays a protective role. It helps plants maintain cell turgor, which allows the leaves to remain firm and functional even when water availability is limited. This ability to conserve water in the leaves allows corn to continue photosynthesis and growth even under adverse conditions. In addition, potassium strengthens cell walls, increasing the plant's resistance to diseases and mechanical damage.

Visual signs of potassium deficiency in corn leaves include marginal necrosis (yellowish or brown leaf edges), which can spread inward over time. These symptoms, known as "edge burn," are the result of disruptions in water and nutrient transport and weaker resistance to stress. To avoid these problems, proper potassium fertilization is essential to preserve the health of the leaves and achieve high yields.

The average concentration of potassium in maize leaf was 13,913.71 mg/kg (1.39%) with Sd=3591.672 and Cv=25.81%. The highest potassium (22,810 mg/kg) was measured in maize leaves at ST-N-FD-VibroSorb and the least at CTD-N-FD-Control (5351 mg/kg).

Calcium

Calcium is an essential mineral for corn, although it is often less mentioned compared to phosphorus, potassium, and nitrogen. Its role in the plant is varied and irreplaceable, especially when it comes to the health and functionality of leaves, roots and young tissues.

Calcium is not only a building block of cell walls, but also plays a key role in regulating cellular functions and signaling, making it vital for plant growth and resistance to stressful conditions. One of the most important functions of calcium in corn is to maintain the integrity and stability of cell walls. Calcium binds pectin molecules in cell walls, which ensures the strength and elasticity of plant tissue. Healthy leaves allow optimal light intake and gas exchange, which contributes to greater efficiency of photosynthesis.

In addition to its structural role, calcium plays a key role in signaling within plant cells. When a plant experiences stress, such as drought, extreme temperatures, or pathogen attacks, calcium acts as a secondary messenger that carries information through cells. This signaling helps the plant to react quickly to stress, activate defense mechanisms, and adapt to adverse conditions. In corn leaves, this may mean improved drought resistance or a better ability for tissue to heal after damage.

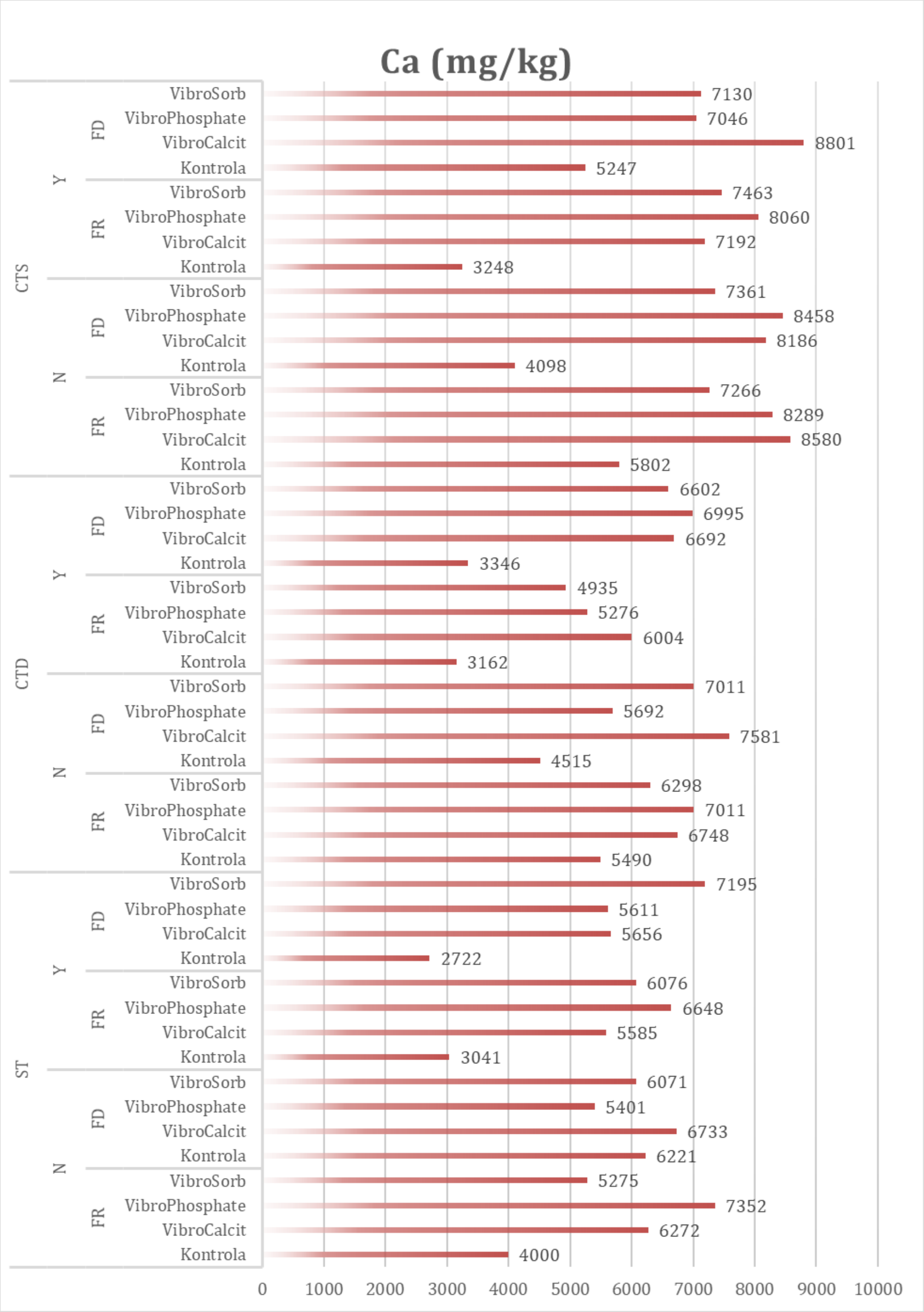


Figure 45. Calcium concentration in maize leaf in the silk stage

Calcium is also crucial for the normal growth and development of young leaves and meristem tissues. In these parts of the plant, cells divide and grow rapidly, which requires a constant supply of calcium. Without enough calcium, leaf deformities, growth arrest and increased susceptibility to diseases occur. Symptoms of calcium deficiency in corn often include necrosis of the tips of young leaves, which indicates tissue death due to a lack of this essential element.

It is important to note that calcium in the soil moves poorly, so plants depend on constant uptake through the roots. Soil with a low calcium content or poor structure can limit its availability, which negatively affects the health of corn. The application of liming can significantly improve the availability of this mineral and allow proper nutrition of plants. In addition to structure and growth, calcium also has a positive effect on the resistance of corn to diseases. Calcium-rich cell walls become less permeable to pathogens, thereby reducing the risk of infections. This protective function is especially important in high-stress conditions, when the plant needs additional support to maintain health and productivity.

Ultimately, calcium is a fundamental element for the health and vitality of corn. Its role in the structure, signaling and resistance of the plant makes it indispensable for obtaining a high and high-quality yield. Maintaining an adequate level of calcium in the soil is the key to the successful cultivation of this important crop. The average calcium concentration, measured in maize leaf, was 6155.08 mg/kg (0.616%) with a standard deviation of 2722 and a coefficient of variation of 24.89%. The highest concentration of calcium (8801.00 mg/kg) was measured on CTD-Y-FD-VibroCalcit (8801 mg/kg), while the lowest concentration of calcium was measured on ST-Y-FD-Control (2722 mg/kg).

Micronutrients

Micronutrients are essential for optimal growth and development of maize, although they are needed in smaller quantities compared to macroelements. These essential elements include iron, zinc, copper, manganese, boron, nickel, molybdenum, and chlorine. Each of them has a specific function in physiological and biochemical processes, and their deficiency can significantly impair the health of the plant and reduce the yield.

Iron is a key microelement for photosynthesis, as it participates in chlorophyll synthesis and electron transfer processes in chloroplasts. Iron deficiency usually manifests itself in the form of intercostal chlorosis on younger leaves, which reduces the plant's ability to produce the energy it needs to grow. Zinc plays an important role in the synthesis of growth hormones such as auxin and participates in the stabilization of enzyme structure. Its deficiency can cause stunted plant growth and leaf deformation. Copper is needed for the synthesis of lignin, which strengthens the cell walls and increases the plant's resistance to pathogens. The leaves of copper-deficient plants become curled, and the stems become weaker. Manganese participates in photosynthetic reactions, especially in the process of water degradation during photosynthesis, and in nitrogen metabolism, which affects the health of the leaves and the overall development of the plant. Boron is essential for proper cell division, flower development and pollination. Its deficiency can cause deformation of the pistons and improper grain development. Molybdenum is crucial for nitrate metabolism and nitrogen fixation. Without enough molybdenum, corn cannot efficiently use the available nitrogen, leading to reduced growth. Chlorine, although often neglected, plays an important role in osmotic balance and regulation of cell turgor, which helps the plant cope with drought.

A deficiency of any microelement can lead to a number of problems, including stunted growth, deformation of the plant, a decrease in resistance to disease and stress, and lower yields. Given that microelements are often poorly mobile in the soil, their availability depends on the pH of the soil, organic matter and the presence of other nutrients. Proper soil analysis and precise application of micronutrient fertilizers are key to achieving optimal conditions for maize growth. Maintaining the balance of microelements ensures the health of the plant, higher yields and better resistance to adverse conditions.

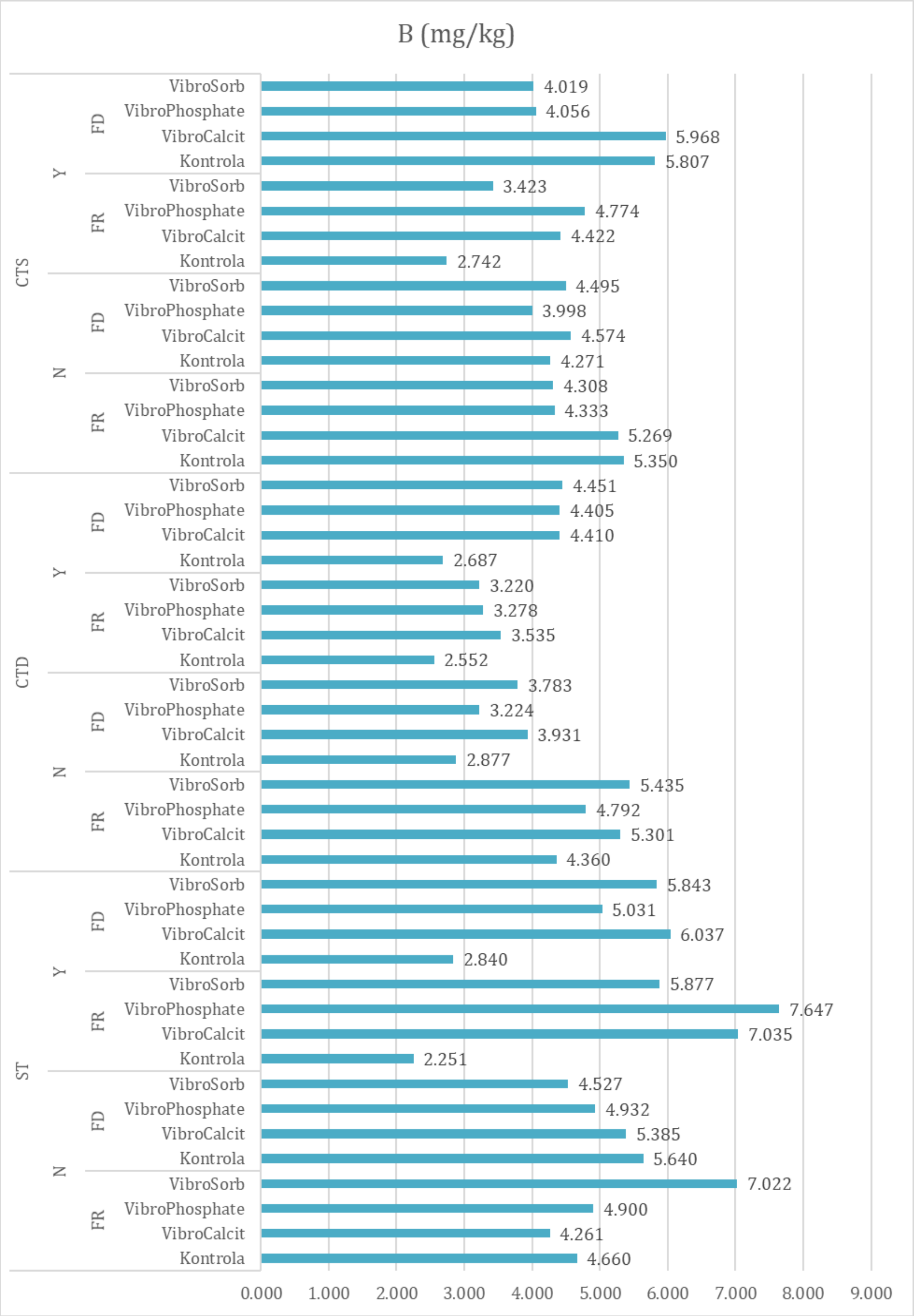


Figure 46. Concentration of boron in maize leaf in silk stage

Proper fertilization is key to ensuring adequate amounts of micronutrients. Soil analysis makes it possible to identify potential deficits, while foliar fertilization can be effective for quickly correcting deficiencies. Providing a balanced diet with micronutrients helps corn reach its genetic potential, increases resistance to stressful conditions and ensures stable yields.

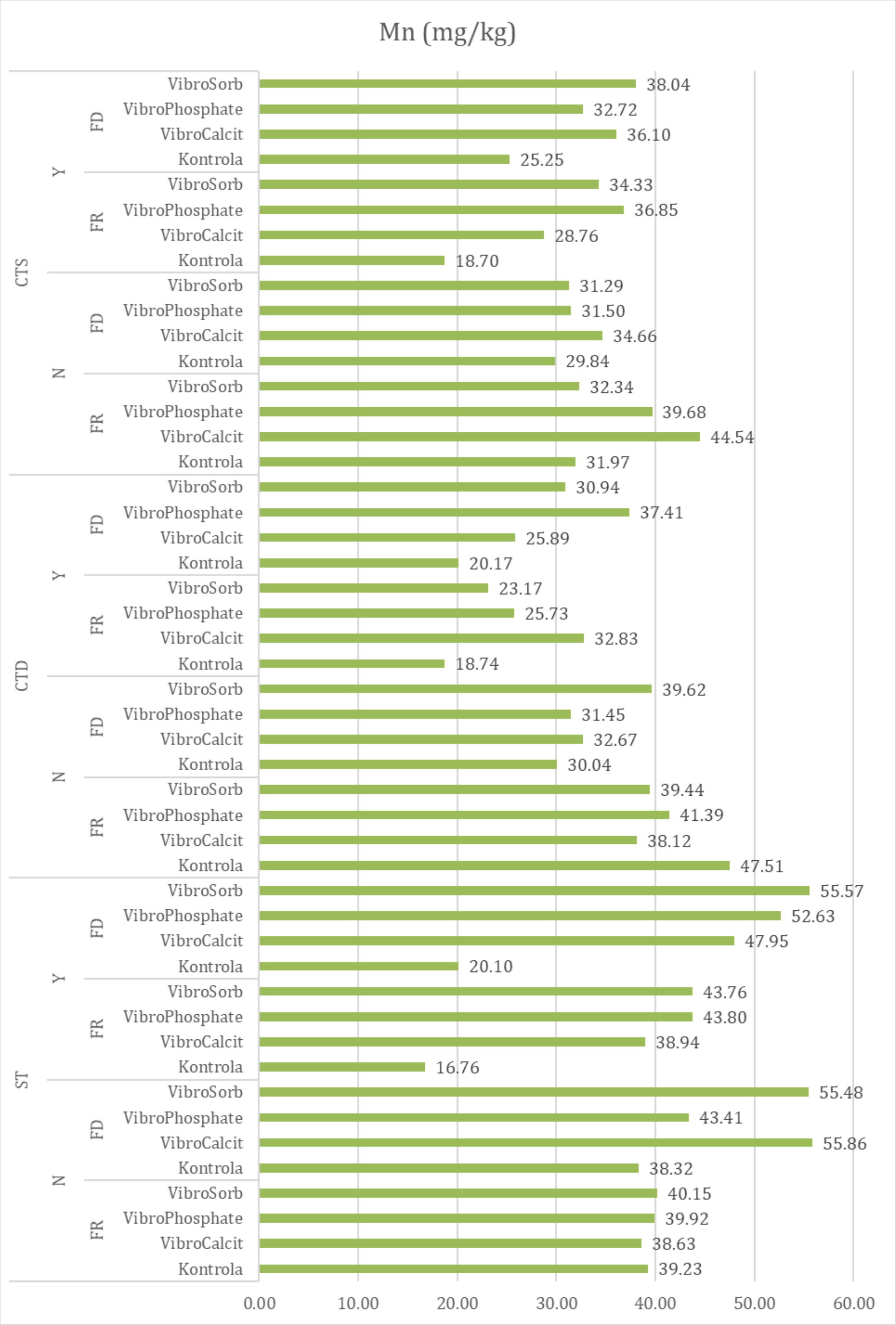


Figure 47. Concentration of manganese in maize leaf in the silk stage

Ultimately, microelements, although necessary in trace amounts, play an indispensable role in the health of corn. Their presence allows the normal course of key metabolic processes and contributes to the quality and quantity of the crop. A systematic approach to micronutrient management ensures sustainable and profitable maize production.

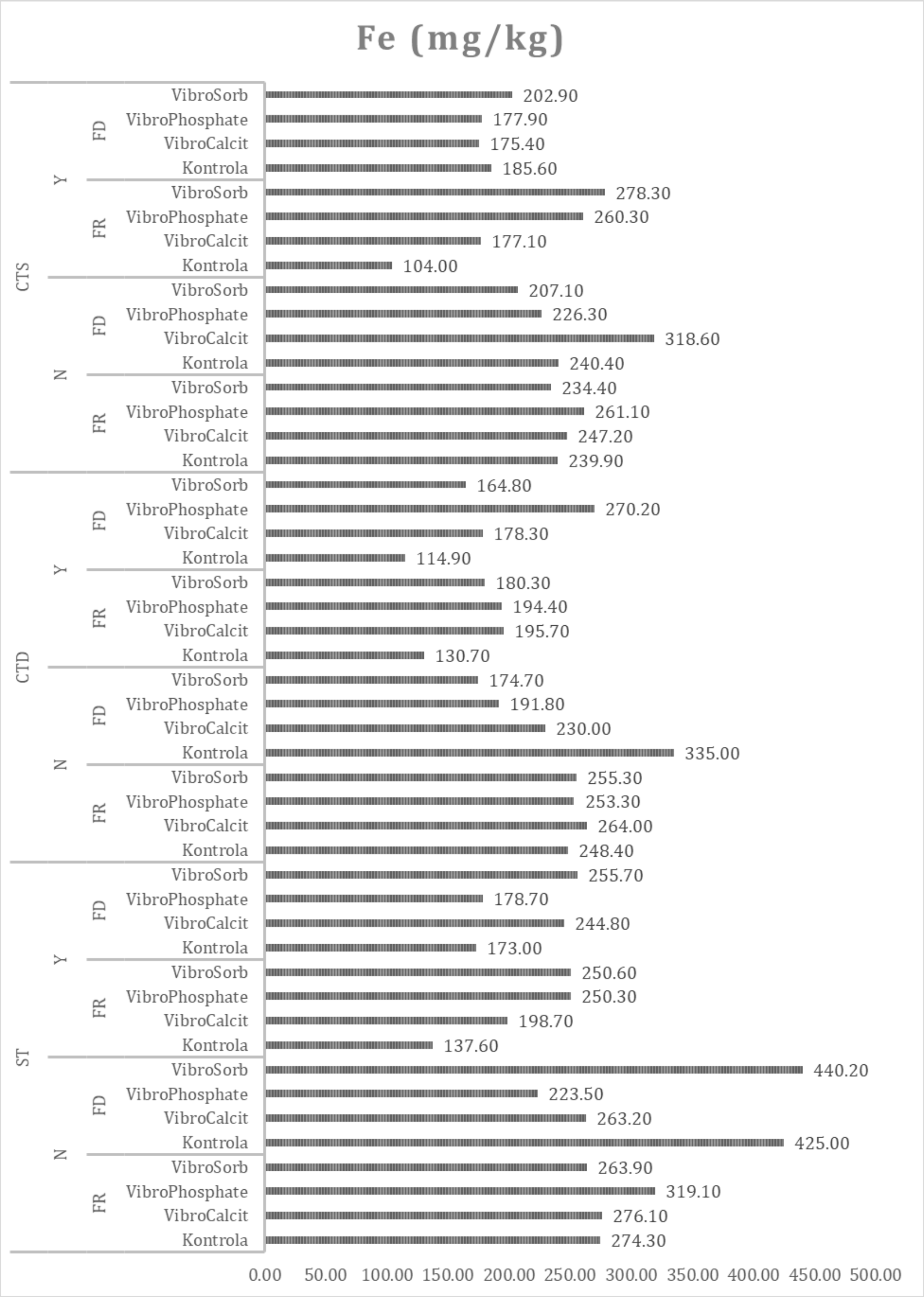


Figure 48. Concentration of iron in maize leaf in the silk stage

The average boron concentration was 4.54 mg/kg with SD=1.198 and Cv=26.39%. The highest concentration was measured at ST-Y-FR-VibroPhosphate (7.647 mg/kg) and the lowest at ST-Y-FR-Control (2.251 mg/kg).

The mean concentration of manganese was 35.67 mg/kg with SD=9.603 and Cv=26.92%. The highest concentration was measured at ST-N-FD-VibroCalcite (55.86 mg/kg) and the lowest at ST-Y-FR-Control (16.76 mg/kg).

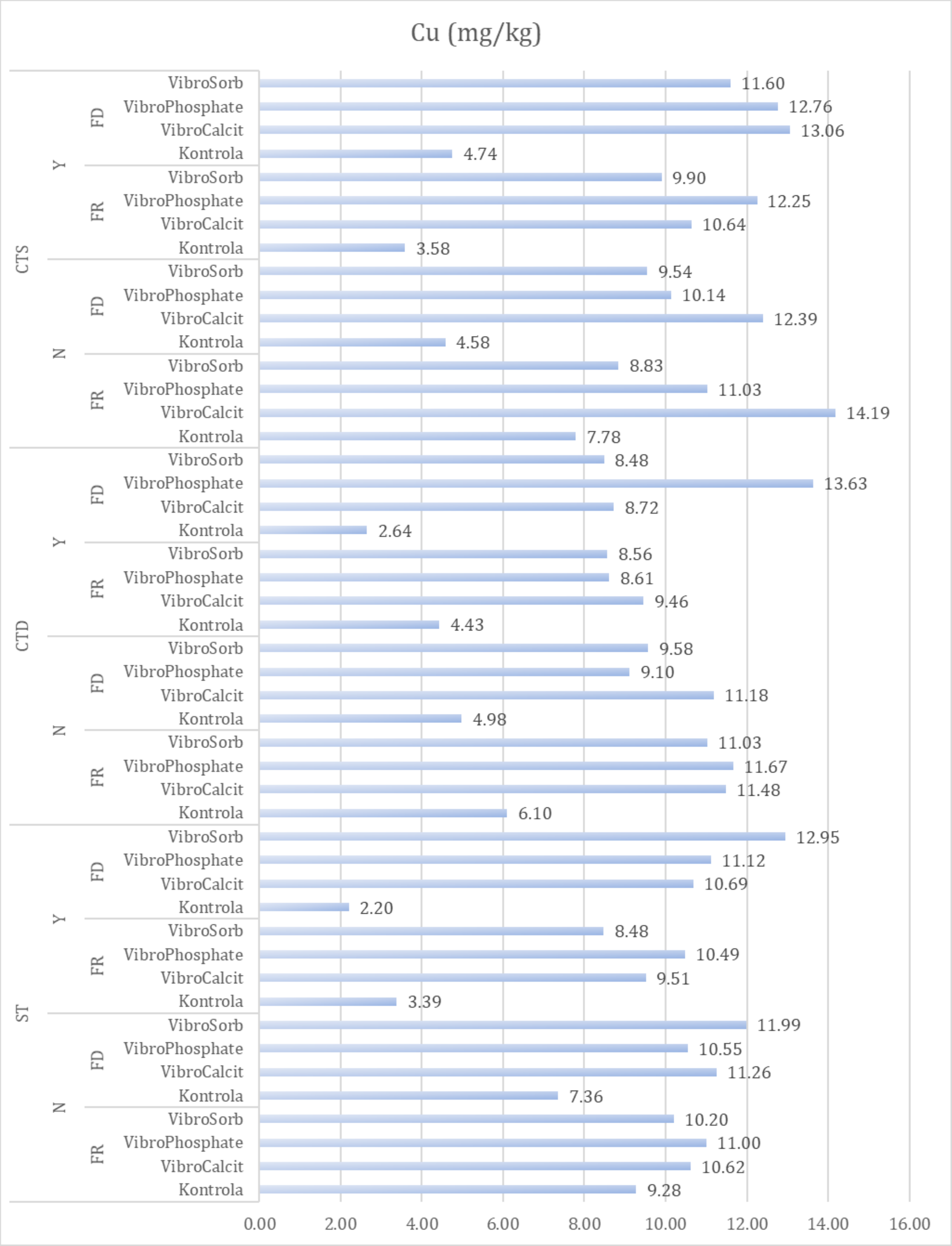


Figure 49. Concentration of copper in maize leaf in silk stage

The average iron concentration was 231.10 mg/kg with Sd=80.972 and Cv=31.03. The maximum iron concentration was achieved in maize on ST-N-FD-VibriSorb (440.20 mg/kg), and the minimum on CTS-Y-FR-Control (104.00 mg/kg).

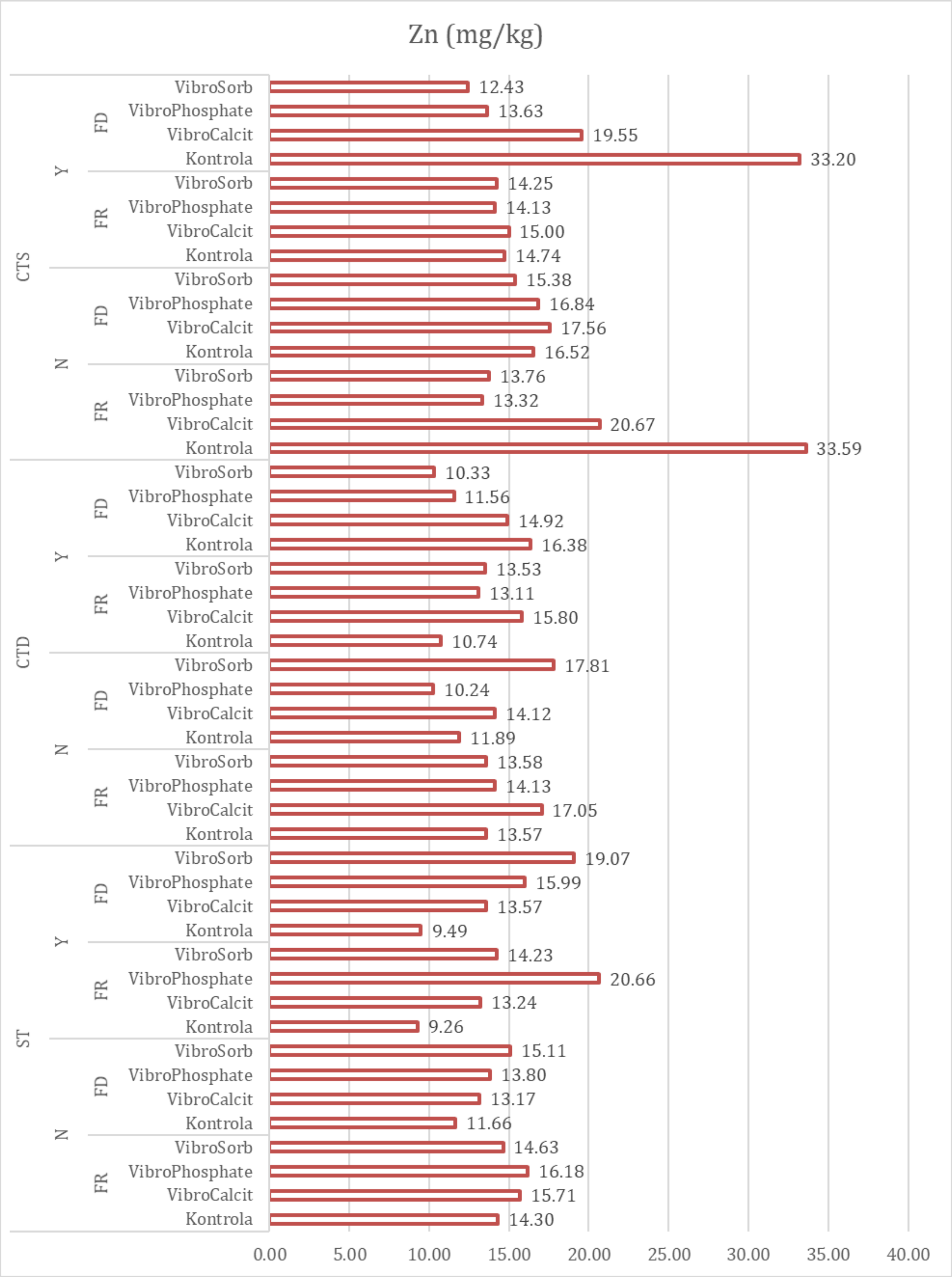


Figure 50. Concentration of zinc in maize leaf in the silk stage

The average copper concentration was 9.33 mg/kg with Sd = 2.991 and Cv = 32.06 %. The highest concentration was measured at CTS-N-FR-VibroCalcit (14.19 mg/kg) and the lowest at ST-Y-FD-Control (2.20 mg/kg).

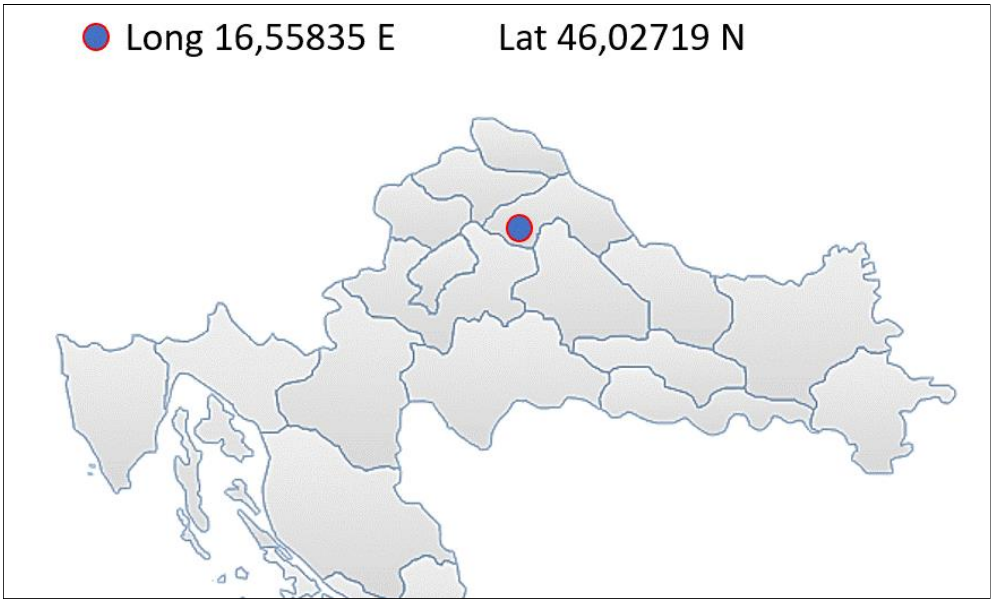
The concentration of zinc on average for all treatments was 15.28 mg/kg with Sd = 4.612 and Cv = 30.19 %. The highest concentration of zinc was measured in maize leaf at the CTS-N-FR-Control (33.59 mg/kg), and the lowest at the ST-Y-FR-Control (9.26 mg/kg).

Conclusion

Based on the conducted research according to this methodology, a positive impact of the applied Viridisfarm foliar preparations on the investigated indicators in maize is observed. As is common in scientific and/or professional research, for greater accuracy and more reliable confirmation of the stated facts, it is necessary to conduct research over a number of years, as well as at different production sites. This is especially important to emphasize since the success of the research largely depends on the weather conditions during the vegetation period, as well as on the characteristics of the agroecological growing area, i.e. the results achieved largely depend on the above factors.

Also, it should be noted once again that this 2024 growing year was extremely demanding in the production of winter and especially spring crops, since the weather conditions were extremely variable. In the spring, they were first recorded below the average in the amount of precipitation and below the average low temperature, and in the later course of the growing season, above the average temperature and below the average amount of precipitation. This has significantly affected the achievement of yields, and these extremely unfavorable growing conditions can "mask" the real value of the tested treatments.

Location of the experimental field, Križevci, 2024.



Scheme of the experimental field, Križevci, 2024.

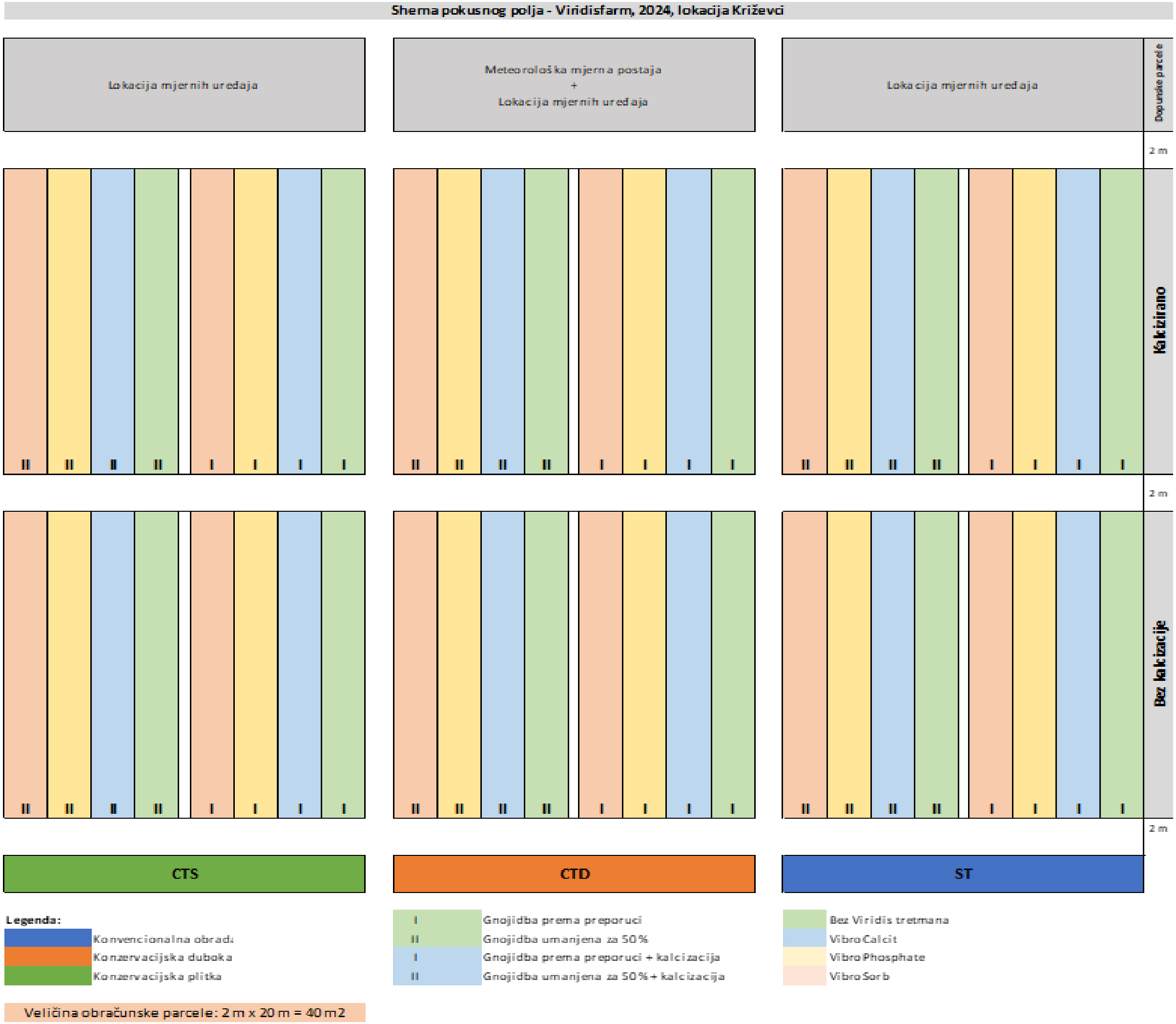


Photo attachment from the experimental surface, Križevci, 2024