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TILLAGE SYSTEMS AND THEIR IMPACT ON THE QUALITY OF AGRICULTURAL SOIL

Brenda Ponce Lira
Universidad Politécnica de Francisco I. Madero. Agrotechnology Engineering Department. Hidalgo, Mexico. Zip code: 42660.
ORCID: 0000-0002-4326-6242

Prisciliano Hernández Martínez
Universidad Politécnica de Francisco I. Madero. Energy Engineering Department. Hidalgo, Mexico. Zip code: 42660.
ORCID: 0000-0002-9009-4746

Patricia López Perea
Universidad Politécnica de Francisco I. Madero. Department of Agroindustrial. Hidalgo, Mexico. Zip code: 42660.
ORCID: 0000-0002-4663-9577

Karina Aguilar Arteaga
Universidad Politécnica de Francisco I. Madero. Department of Agroindustrial. Hidalgo, Mexico. Zip code: 42660.
ORCID: 0000-0002-6289-4682

Abstract: The objective of the present investigation was to compare the effects of the conservationist and conventional tillage system on the physical and chemical properties of the soil. Two soil samples were taken at different depths from 0 to 5 cm and from 5 to 30 cm. The apparent density (Da), electrical conductivity (EC), pH, cation exchange capacity (CEC), carbonates, organic matter (OM), nitrate (NO3-), available phosphorus and potassium (P and K) and bases were evaluated. interchangeable (Ca^{2+}, Mg^{2+}, K^{+} y Na^{+}). It was observed that the conservation tillage system neutralizes the pH, regulates the concentration of exchangeable bases and reduces the concentration of carbonates. The evaluations of the aforementioned parameters allow us to conclude that the conservation agriculture system is an alternative to favor soil quality.
Keywords: conservation agriculture, characterization, conventional tillage, soil fertility.

INTRODUCTION

The type of agricultural system to be used for primary production is a key element in the agri-food sector because it is closely related to soil fertility, sustainability, yields, and crop quality (Solano et al., 2022). ; Yu et al., 2022). Modern (or conventional) agriculture does not cover the food demand of the Mexican population, on the contrary, it has caused a dependence on mechanization and agro-inputs; In addition, the establishment of monocultures and the intensive preparation of the soils have generated an imbalance in the agroecosystems, favoring the vulnerability of the planting to pests and diseases; wind has eroded much of the agricultural land as it is unprotected from crop residues, and groundwater scarcity is becoming more evident (Jamil et al., 2021; Canwat and Onakuse, 2022).

In Mexico, conventional agriculture is beginning to be associated with negative implications, including the affectation of soils, due to its intensive exploitation in an attempt to increase productivity with the excessive use of machinery and agrochemicals (Mishra et al., 2022).

Currently producers from the Mezquital Valley, Hidalgo, Mexico; They have had serious soil problems, not only from implementing conventional agriculture; but by carrying out erroneous practices, such as removing organic matter (stubble), causing compaction, erosion, nutrient depletion, decreased water retention and generally poor soil quality. As if this were not enough, the use of wastewater, indebtedness to make the payment of agricultural machinery and investments to obtain agricultural chemical products, fossil fuels, and other inputs used are added. The foregoing has generated high production costs and, consequently, profits have been low, leading to bankruptcies, disinterest in the field, and on some occasions even the abandonment of cultivated land (Lesser et al., 2018; Fonteyne et al., 2021).

This series of adverse effects have generated the need to make a change in the field, some farmers have opted for conservation agriculture, by using tools and techniques to furrow, fertilize and degrade the stubble without the need to apply chemical products or heavy machinery. Conservation agriculture is characterized by three principles. The first, the minimum movement of soil, which preserves the structure of the soil, saves fuel and wages, there is greater production at a lower cost and the micro and macrobiota are preserved. Another of the principles consists of leaving a plant cover on the soil, which brings as an advantage the increase in fertility and microorganisms, decreases water evaporation, mitigates the germination of weeds in the plots, reduces erosion and salinity and increases the stability of aggregates. The third principle consists of performing a crop rotation, which reduces the risk of pests and diseases, likewise, with plant diversity there is a greater distribution of roots and nutrients, as well as a better balance between N, P and K (Fonteyne et al., 2021; Golub et al., 2021). Therefore, the purpose of this study is to compare the effects of the conservationist and conventional tillage system on the physical and chemical properties of the soil under flood irrigation conditions with wastewater in the Mezquital Valley, Hidalgo, Mexico.

MATERIALS AND METHODS

The study was carried out within the Mezquital Valley, Hidalgo, Mexico, in one of the demonstration plots of the Francisco I. `` Universidad Politécnica de Madero ``located on the Tepatepec-San Juan Tepa highway km 2, Francisco I. Madero, Hidalgo, at 20° 13' 46.9" NL and 99° 05' 21.23" SW and at an altitude of 2,300 masl.

The conventional tillage system (SC) was used as control; where stubble is commonly removed from the plots, subsoil and harrowing practices are implemented with a depth of 30 cm; followed by furrowing (0.75 m), sowing and fallow. In the treatments with the conservationist system (AC), maize was planted leaving 25 cm of the oat stem and the remaining 100 % of the stubble of said crop was previously trimmed and left on the surface.

A randomized complete block experimental design with two repetitions was used, of which three random samplings were carried out. The data obtained were analyzed by analysis of variance (ANOVA) for each experiment, individually and combined, using R version 4.2.3.

Parameters were tested for significance between treatments (Tukey $p \leq 0.05$). When significant differences were found, the honest least significant difference (DMSH) was used to determine the difference between means.

After the corn harvest, random soil sampling was carried out at depths of 0 to 5 cm and 5 to 30 cm based on NOM-021-RECNAT-2000. To determine apparent density (Da), electrical conductivity (EC), pH, cation exchange capacity (CEC), carbonates, organic matter (OM), nitrate (NO3-), phosphorus and available potassium (P and K) and exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} y Na^{+}).

RESULTS AND DISCUSSION

PHYSICOCHEMICAL PROPERTIES OF THE SOIL

Despite the fact that no significant difference ($p > 0.05$) is reported in the bulk density between sampling depths and evaluated tillage systems, it is the AC systems that report the lowest bulk density. It is necessary to consider that when the Da of the soil increases, compaction increases and affects moisture retention and root development of the DFBDBF crop (Romero et al., 2015). Based on NOM-021-RECNAT-2000, the soils of both tillage systems are of mineral origin, rich in organic matter (Table 1).

Another of the evaluated variables was the EC, which in both systems and both depths values are reported: < 2 dS m^{-1}, which classifies them as very slightly saline soils (NOM-021-RECNAT-2000). It is worth mentioning that, in the depth of 0 to 5 cm, the AC system reports a significant difference in the CE ($p \leq 0.05$) in relation to the SC; The value of the conservation system is attributed to the surface layer as a product of the mineralization of organic matter. Despite not reporting a significant difference in depth from 5 to 30 cm, the AC system presented lower EC, which would indicate a low concentration of exchangeable cations such as Ca^{2+}, Mg^{2+}, K^{+} y

Na^+.

In conservation practices carried out in Sinaloa, Mexico, it is reported that the amount of soluble cations in the soil decrease as time passes with said practice (Sifuentes-Ibarra et al., 2018).

The pH is statistically the same (Tukey $p > 0.05$) in tillage systems and between sampling depths. For both systems the pH ranges from 7.8 to 8.4; Said values according to NOM-021-RECNAT-2000 refer to moderately alkaline soils. It must be noted that, for the sampling from 0 to 5 cm, the pH of the AC system is lower than that of the SC, the same trend is observed in the sampling from 5 to 30 cm, this can be related to the incorporation or removal of organic matter in the properties (Table 1).

Other studies carried out in Chiapas, Mexico, have shown that SC increases the pH value due to excessive soil movement and the use of agrochemicals and fertilizers (Martínez-Aguilar et al., 2020).

Regarding the CIC, the values reported in the depth from 0 to 5 cm show a statistical difference between systems ($p \leq 0.05$), with the SC reporting the highest CIC; however, in both systems the CEC at this depth is classified as high (Table 1). For depths from 5 to 30 cm, there is no significant difference (Tukey, $p > 0.05$) and the CIC values obtained are classified as very high (NOM-021-RECNAT-2000). It is important to note that the SC reports higher CEC at both depths; a possible explanation is the use of wastewater for agricultural irrigation in the area and the organic components that it has (Mendoza-Escalona et al., 2021). It is reported that after 20 years with the conservation agriculture system, the CEC is increasing steadily over time (Luiz-Partelli et al., 2018).

In relation to the percentage of carbonates in the depth from 0 to 5 cm, the systems are statistically different ($p \leq 0.05$); in the AC system, 43.84% less is reported than in SC. This same trend occurs in the depth of 5 to 30 cm, where 45.04 % less is obtained in the AC system compared to the SC (Table 1). On the contrary, in the SC the percentage of carbonates increases over time, consequently, it generates a high EC, pH and high salinity, favoring soil erosion, slow plant development and yield loss (Imadi et al, 2016).

In general, the AC system contains a higher percentage of OM due to the incorporation of stubble on the surface and the minimum movement of the soil, which brings with it the aforementioned benefits. However, it is necessary to point out that the OM value reported in the SC is due to the quality of the irrigation water that is used, which also contains some metals such as Pb2+ in a concentration of 0.054 mg L-1 in the Endho dam. and Cd2+ concentrations above the permissible limit, as well as other volatile and semi-volatile compounds (Lesser et al., 2018; García-Salazar and Lara-Figueroa, 2020).

In Sinaloa, Mexico, sampling was carried out under two planting systems; direct (SD) and conventional tillage (LC). Both treatments started with 0.78 % OM in a period from 2009 to 2012, in this last year 1.47 % OM was reported in direct sowing soils while in conventional tillage only 1 % was reported. Although both treatments started with the same percentage, the incorporation and transformation of crop residues has a positive effect because the minimum movement of the soil improves the OM content, microbial activity and the level of fertility, favoring optimal development of the crop (Sifuentes -Ibarra et al., 2018). This project ratifies the benefits derived from incorporating OM, which favors the soil to be fertile for agricultural production, benefiting the environment in the same way (Yáñez-Díaz et al., 2018).

Parameters	Sampling depth and tillage system			
	0 a 5 cm		5 a 30 cm	
	AC	SC	AC	SC
apparent density (g cm^{-3})	0.787(0.02)^{a}	0.968(0.02)^{a}	0.789(0.03)^{a}	0.973(0.00)^{a}
electric conductivity (dS m^{-1})	1.520(0.03)^{a}	1.110(0.36)^{ab}	1.110(0.33)^{ab}	1.360(0.12)^{ab}
pH	7.885(0.11)^{a}	8.194(0.04)^{a}	8.249(0.25)^{a}	8.429(0.10)^{a}
cation exchange capacity ($cmol_c$ kg^{-1})	33.250(2.47)^{b}	39.450(3.46)^{a}	40.200(4.52)^{a}	41.550(4.87)^{a}
carbonates (%)	1.252(0.21)^{b}	2.230(0.14)^{a}	1.355(0.50)^{b}	2.436(0.00)^{a}
organic material (%)	5.391(1.29)^{a}	3.516(0.04)^{ab}	3.000(0.37)^{ab}	2.711(0.11)^{ab}
nitrates (mg Kg^{-1})	20.710(9.08.)^{c}	20.507(0.55)^{c}	17.269(0.66)^{c}	19.765(1.48)^{c}
available phosphorus (mg Kg^{-1})	97.410(0.53)^{b}	103.375(3.00)^{b}	92.920(5.71)^{b}	95.645(5.71)^{b}
available potassium (mg Kg^{-1})	1521.057(44.91)^{a}	1594.874(41.82)^{a}	1352.451(33.67)^{a}	1321.508(30.18)^{a}
exchangeable sodium (mg Kg^{-1})	485.629(4.71)^{d}	962.214(0.66)^{c}	877.209(0.23)^{c}	975.143(0.63)^{c}
exchangeable magnesium (mg Kg^{-1})	1214.162(1.63)^{b}	1329.809(0.11)^{b}	1397.924(2.20)^{b}	1384.088(0.26)^{b}
exchangeable calcium (mg Kg^{-1})	3453.948(3.29)^{a}	4060.508(1.11)^{a}	4276.160(2.78)^{a}	4522.149(0.71)^{a}

AC: Conservation agriculture system. SC: Conventional system. The standard deviation results appear in parentheses. Means with different letters between rows are significantly different (Tukey, $p \leq 0.05$).

Table 1. Physical and chemical parameters of a soil at different depths.

NITRATE, PHOSPHORUS AND POTASSIUM IN THE SOIL

The concentrations of nitrate (NO3-), phosphorus (P) and potassium (K) available for the depth of 0 to 5 cm are classified as high (Table 1). It must be mentioned that the concentration of NO_3^-, P and K in the soil is very important because they are macronutrients required for the growth of any crop; promoting the formation of amino acids and proteins, the development of plants and their performance, the absorption of nutrients, the transfer of energy, the differentiation of cells and the development of tissues that form the growth points of the plant, the activation of more than 60 enzymes for the synthesis of proteins and carbohydrates, improving the water regime of the plant and increasing tolerance to drought, frost and salinity (Santiago-Mejia et al., 2018., Quispe, 2018).

SOIL SALINITY

The SC presents high concentrations of Na^+, Mg^{2+} y Ca^{2+} compared to the AC system (Table 1). Just the concentration of Na^+, nonessential ion, at a depth of 0 to 5 cm, only reports a significant difference ($p \leq 0.05$), where the SC had 476.58 mg kg-1 more sodium than the AC system. With the above, it is suggested to be careful with the agricultural management used in the area, such as the continuous use of high irrigation sheets, to avoid salinity of the properties. It is relevant to note that sodium can reduce the productivity of a crop by 50 % (Delgado-González, 2022). It must be noted that, at both mentioned depths, the conservation system belongs to a low salinity according to NOM-021-RECNAT-2000, this is because it has a slightly alkaline pH and the presence of salts is low. On the contrary, in conventional tillage there was a high content of sodium, calcium and magnesium, favoring sodium environments (Delgado-González, 2022).

Another study carried out in the state of Nuevo León, Mexico under four systems (grassland, scrubland, plantation and agricultural) reported 1.68 mg Mg kg^{-1} in grassland, 3.08 mg Mg kg-1 in scrub, 2.45 mg Mg kg^{-1} in plantation and 2.14 mg Mg kg^{-1} in agriculture at a depth of 0 to 5 cm. Given this depth, it is reported 0.11 mg Na kg^{-1} in grassland, 0.14 mg Na kg^{-1} in scrub, 0.11 mg Na kg^{-1} in plantation and 0.15 mg Na kg^{-1} in agriculture, highlighting the treatment of grassland. The mentioned study, compared to the present project at a depth of 0 to 5 cm, reports that the systems with the highest OM content have low salinity (Yáñez Díaz et al., 2018).

The results presented denote that the conservation agriculture system represents a sustainable management, which producers in the region are beginning to adopt to mainly reduce the salinity of their properties and increase soil fertility.

CONCLUSIONS

Despite the fact that there was no statistically significant difference in some parameters; the use of the conservation tillage system improves the pH, regulates the concentration of calcium, magnesium and calcium; increases the amount of organic matter and with it the availability of nutrients and water retention. Likewise, a lower presence of carbonates was reported in this system. It is concluded that numerically the conservation system is an alternative to favor the fertility of agricultural soil and to ensure proper soil management and make comprehensive and sustainable use of resources for the benefit of future generations.

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