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Evaluation of Change on the Structural Quality and Organic Matter the Soil Induced by No-till Chronosequence under Semi-arid Climate in Algeria

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ABSTRACT

Background: The no-till system is increasingly accepted as an alternative to conventional tillage because of its agronomic and environmental advantages. The evaluation of soil quality during the transition to no-till phases is very important to allow better soil management, especially in semi-arid regions.

Methods: This study was carried out during 2017. The objective of this research is to evaluate change of soil structure (morphological and analytical) and organic matter (total and labile) at two different depths (0-10 and 10-20 cm). No-till system chronosequence was carried out in four phases in cereal cultivation. Soil samples were collected, then different carbon forms (total, particulate and microbial) and soil structure (morphology, structure stability and bulk density) were analyzed.

Result: The best soil quality was obtained during the two chronosequence phases 9 and 6 years, at both soil depths studied. However, this soil quality change is limited at 0-10 cm soil depth in the 3 years chronosequence phase.

Key words: Conventional tillage, No-till, Structure soil, Organic matter.

INTRODUCTION

Degradation of soil quality by anthropological and climatic processes lead not only to a decrease in agricultural productivity of the soil, but also to the deterioration of water and air qualities as well human health (Bünemann *et al*., 2018; Guo, 2021; Selvakumar *et al*., 2021). The conventional tillage, which consists of soil fragmentation and reversing using ploughs, often leads to the incorporation of culture residues into the soil, to a rapid mineralization of organic matter, compaction of soil, affect agricultural productivity and induces soil erosion (FAO, 2018). The no-till farming is considered as an alternative to conventional tillage system, in which residue is left on the soil surface, thus allow to enhance soil organic matter, reduces mineralization and improves soil structure, consequently prevent soil erosion (FAO, 2018). The transition from conventional tillage to no-till can provide gradual changes in soil quality before reaching a new balance. This balance is related to soil depth, soil texture, culture and climate (Vian *et al*., 2009; Roger-Estrade *et al*., 2011; Blanco-Canqui and Ruis, 2018; Kool *et al*., 2019).

Evaluation and surveillance of soil quality is very important for better management and sustainability of soils in order to conserve natural resources and ensure food security in developing countries (FAO, 2021). The studies have shown the importance of several indicators for evaluation of soil quality, namely soil structure and organic matter (Bünemann *et al*., 2018; Guo, 2021). The soil structure is studied and evaluated indirectly using some physicals soils proprieties, as for example bulk density, total porosity, structural stability and hydraulic conductivity (Kribaa *et al*., 2001; Vian *et al*., 2009; Jemai *et al*., 2013; Plaza-Bonilla *et al*., 2013). Actually, authors consider the soil structure as an important morphological indicator for soil quality evaluation due to its simplicity, reliability and low cost. It is easily measured in situ using morphological and visual estimation (Guimarães *et al*., 2013; Boizard *et al*., 2017; Celik *et al*., 2020). The total organic matter is widely used for soil quality evaluation. The active or labile fractions (particulate and microbial fractions, respectively) are generally more sensitive to soil perturbation than the total organic matter of agricultural soil (Bünemann *et al*., 2018 ; Naragund *et al*., 2022). They both provide a better indication for temporally and spatially changes in soil (de M. Sá *et al*., 2001; Vian *et al*., 2009; Roger-Estrade *et al*., 2011; Guimarães *et al*., 2013; Debska *et al*., 2020).

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Objective of our study was to quantify the change on soil structure and organic matter between different phases of no-till transitions under semi arid climate. In order to select at which no-till transition phase and at what soil depth showed the best improvement in soil quality. In fact, it will provide better support for farm management.

MATERIALS AND METHODS

The study was conducted during 2017 in Setif provence, which is located at the Northeast of Algeria (36°09'N, 5°21'E). This region is characterized by a semi-arid climate type with an annual rainfall of 380 mm and mean temperature of 13.7°C (Kribaa *et al*., 2001). Several no-till trials have been conducted in this region under the responsibility of the Technical Institute of Great Cultures (ITGC) in order to increase wheat production and protect soil against erosion (Ali *et al*., 2017). Four plots were selected on the basis of homogeneity the climate, slope, soil texture and wheat cultivation. These plots are characterized by a silty clay texture and a low slope (<2%). The NT0 plot was maintained in conventional plowing which consists of turning over the surface horizon using a plow at 25 cm depth. While, in NT9, NT6 and NT3 plots, no-till system was used with transition periods for 3, 6 and 9 years. In all chronosequence phases wheat was sown directly on the previous harvest residues. At the time of seeding, all plots were subjected to fertilization in a dose of 150 kg/ha using ammonium phosphate (12% N, 52% P et 0% K). Otherwise, at the beginning of tillering 100 kg/ha of urea were used (46% N). Only No-till plots were weeded prior to seeding using glyphosate (2.5 L/ha).

Soil samples, disturbed or undisturbed, were collected from two soil layers (H1 : 0 to 10 cm and H2 : 10 to 20 cm). Total organic carbon (TOC) was analysed according to Walkley method described by Nelson and Sommers (1996). Particulate organic carbon (POC) was measured following Cambardella and Elliott (1992) method. Whereas, microbial biomass carbon (MBC) was estimated using fumigation-extraction method. All these parameters were analysed on disturbed soil samples. However, Soil structure (SS), aggregate stability (AS), soil bulk density (BD) were determinated on undisturbed soil samples. The soil struture (SS) was evaluated by visual observations and scoring method of Ball *et al*. (2017), from good structure quality (score 1) to bad structure quality (score 5). The (AS) was determined according to Le Bissonnais (1996) method and (BD) was estimated using cylinder (100 cm^3).

Analysis of variance was performed and Tukey's test was used to compare the effect of transition phases at p <0.05 in each depth. A Principal Component Analysis (PCA) was performed in order to provide information on the correlation between soil indicators, transition phases and depths, then after Hierarchical Cluster Analysis (HCA) was performed to obtain different clusters. Statistical analysis was performed by using R 4.02 software with graphical interface (Rcmdr).

RESULTS AND DISCUSSION

Soil structure, aggregate stability and bulk density

The results showed a significant variation (p<0.05) between the mean values of the structural indicators in chronosequence of no-till on the two depths (Table 1).

At 0-10 cm depth, the best results SS, BD and AS were observed at the transition phase NT9 with value of 1, 1.41 g/cm and 1.86 mm, respectively. Otherwise, values detected for the transition phase NT0 were 3, 1.58 g/cm and 1.14 mm, for SS, BD and AS, respectively. Indicators SS and BD allowed to differentiate transition phases into two groups (NT9-NT6-NT3) and (NT0). During phases NT9, NT6 and NT3 soil compaction (BD) decrease by -11% and morphostructural degradation (SS) by -67%, for each phase compared to NT0. The (AS) indicator can classify phases into several groups (NT9> NT6> NT3> NT0). Furthermore, (AS) increase during the chronosequence phases in comparison to NT0 phase, with values of 39, 32 and 25%, for NT9, NT6 and NT3, respectively. In addition, NT9 and NT6 have changed (AS) with 19 and 10%, respectively, compared to NT3. The phase NT9 increased by 9% compared to NT6. The amelioration of morphological and analytical indicators of soil structure (SS, BD and AS) by the no-till system has been observed in most agro-pedo climatic contexts (Kribaa *et al*., 2001; Vian *et al*., 2009; Roger-Estrade *et al*., 2011; Jemai *et al*., 2013; Plaza-Bonilla *et al*., 2013; Celik *et al*., 2020). According to these authors, this amelioration is due to the decomposition of organic residues allowing an increase of organic matter content and biological activity.

At 10-20 cm soil depth, NT9 phase had the best SS, BD and AS values 1.3, 1.48 g/cm and 1.55 mm, respectively. However, the worst values were recorded in NT3 phase 4, 1.65 g/cm and 0.94 mm, respectively. The SS and BD indicators can differentiate the transition phases in the next order: NT3> NT9-NT0-NT6 and the indicator AS grouped phases as follows NT9-NT6> NT0> NT3. The phases of transitions NT9, NT6 and NT0 can improve by -150%, 100% and -68 % the indicator SS, -11%, 10% and -7% of BD and 65, -22 and 35% of the AS, compared to NT3 phase. Thereby NT9 and NT6 phases improve AS indicator at 30 and 21%, respectively, in comparison to NT0. At this depth (10-20 cm) and in comparison to NT0, the transition phases NT9 and NT6 allow a morphological and analytical amelioration of soil structure, while the NT3 phase offers a deteriorated morphological structure, soil compaction and a less stable structure. This is due to the short transition period (3 years) which does not allow a good biological evolution of soil (Roger-Estrade *et al*., 2011; Jemai *et al*., 2013; Plaza-Bonilla *et al*., 2013; Celik *et al*., 2020).

Change in total organic matter (TOC) and labile fractions (POC and MBC)

The carbon values of total organic matter and its labile fractions show a significant variation on two depth (p<0.05) (Table 1).

Table 1: Comparison of mean soil indicators between different transition phases (in pairs) in H1 (0-10 cm) and H2 (10-20 cm) soil layers at p<0.05.

	BD (g/cm)	SS (scor)	AS (mm)	TOC (g/Kg soil)	POC (g/100 g C)	MBC (g/100 g C)
H1 (0-10 cm)						
NT9	1.41 a	1 a	1.86 d	17.4 b	67.2 c	1.78 d
NT6	1.42 a	1 a	1.66 c	16.6 b	66.2 c	1.44 c
NT3	1.43 a	1 a	1.51 b	16.4 b	55.4 b	1.34 b
NT0	1.58 b	3 b	1.14 a	10.2 a	33.3 a	0.98 a
(NT6-NT3)	ns	ns	10%	ns	17%	10
(NT9-NT3)	ns	ns	19%	ns	18%	25
(NT3-NT0)	-11%	-67%	25%	38%	40%	27
(NT9-NT6)	ns	ns	9%	ns	ns	20
(NT6-NT0)	-11%	-67%	32%	39%	50%	32%
(NT9-NT0)	-11%	-67%	39%	42%	51%	45%
H2 (10-20 cm)						
NT9	1.48 a	1.3 a	1.55 c	12.8 c	45.7 c	1.26 c
NT6	1.55 a	2 a	1.45 c	11.8 bc	42.4 bc	1.15 b
NT3	1.65 b	4 b	0.94 a	9.7 a	25.3 a	0.92 a
NT0	1.50 a	1.6 a	1.21 b	11.1 b	38.8 b	1.18 b
(NT6-NT3)	-7%	-68%	35%	18%	41%	20%
(NT9-NT3)	-11%	-150%	65%	25%	45%	27%
(NT3-TN0)	10%	100%	-22%	-13%	-35%	-23%
(NT9-NT6)	ns	ns	ns	ns	ns	9%
(NT6-NT0)	ns	ns	21%	ns	ns	ns
(NT9-NT0)	ns	ns	30%	8%	16%	7%

BD= Bulk density, SS= Soil structure, AS= Agregation stability, TOC= Total organic carbon, POC= Particulate organic carbon, CMB= Carbon microbial biomass, NT0= Conventional tillage system, NT3= Phases of no-till transitions 3 years, NT6= Phases of no-till transitions 6 years, NT9= Phases of no-till transitions 9 years, ns= No significant.

At a depth of 0-10 cm, the soil at NT9 records the highest TOC with 17.4 g / Kg of which 67% was in the form of POC and 1.78% in the form of MBC. So, the lowest TOC value was found in NT0 soil with 10.2 g/Kg of which 33.3% as POC and 0.98% as MBC. This variation in the concentration of different forms of carbon can classify the phases of transitions as NT9-NT6-NT3> NT0 for TOC, NT9-NT6> NT3> NT0 for POC and NT9> NT6> NT3> NT0 for MBC. Compared to NT0, the NT9, NT6 and NT3 phases changed TOC with 42, 39 and 38%, POC with 51, 50 and 40% and MBC with 45, 32 and 27%, respectively. Thus, the NT9 and NT6 phases offer an improvement in the POC compared to the NT3 soil, with 18 and 17% respectively. Additionally, MBC was on average higher in NT9, compared to NT6 and NT3 levels were improved by 20 and 25%, respectively.

At a depth of 10 to 20 cm, NT9 records the best organic carbon concentration (12.8 g / Kg soil) and their labile POC and MBC fractions with values of 45.7 and 1.26%, respectively. The lowest amount of TOC was (9.7 g / Kg soil), including POC (25.3%) and MBC (0.92%) in NT3 phase. The evolution of organic matter followed the order: NT9≥NT6≥NT0> NT3 for TOC, NT9≥NT6≥NT0> NT3 for POC and NT9> NT6-NT0> NT3 for MBC. Compared to NT3, the phases NT9, NT6 and NT0 increase TOC by 25, 18 and 13% and POC by 45, 41 and -13%, respectively. In addition, NT9 improved the MBC in the NT6, NT0 and NT3 phases, with 9, 7 and 27% respectively. In addition, NT6 and NT0 improved the MBC over NT3 by 20 and -23%, respectively. The results showed in the two soil layers that the organic fraction MBC is more sensitive to the change induced by chronosequence followed by POC and TOC. However, the longer a transition phase between the conventional tillage system and no tillage, the more crop residues accumulate in the soil, which is an important source of energy for microorganisms. (Vian *et al*., 2009); Debska *et al*. (2020) pointed out that labile fractions (particulate and microbial) play a very important role in improving structural stability.

Correlation analysis

The variance of the first two principal components (Dim 1 and Dim 2) explains a good data variation and accounted 92 and 04%, respectively. Therefore, the total variance accounted 97% of the original data (Fig 1 and 2). All soil indicators are well projected and correlated on the Dim 1 axis. The indicators AS, TOC, POC and MBC were located positively and they are closely associated, while SS and BD are located negatively on the Dim1 axis (Fig 1).

Fig 1 and 2 show that there is an association between transitions phases and soil indicators, (H1NT9, AS, TOC, COP and MBC) and (H2NT3, SS and BD). This means that the transition phase NT9 increased AS, COT, COP and MBC, but decrease SS and BD, in soil depth H1 (0-10 cm). On the

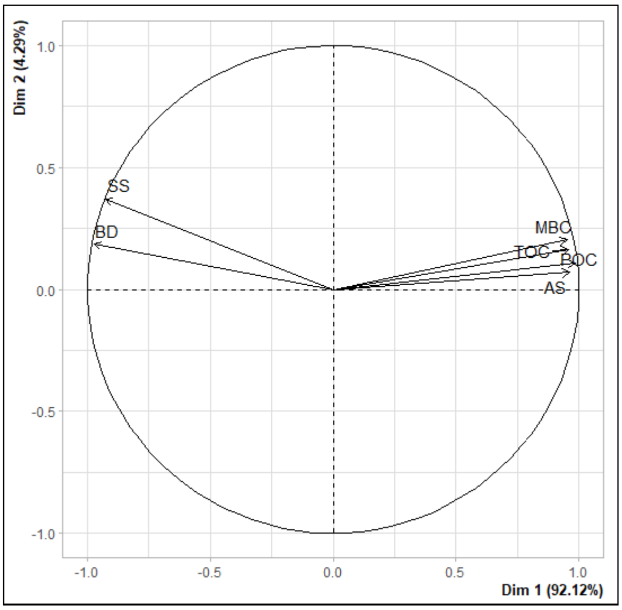

Fig 1: Principal Component Analysis (PCA) correlation circle of the soil indicators studied.
SS= Soil structure, BD= Bulk density, AS= Aggregates stability, TOC= Total organic carbon, POC= Particulate organic carbon, MBC= Microbial biomass carbon.

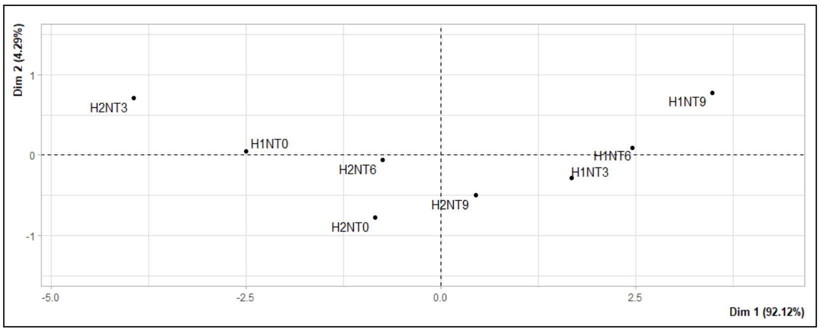

Fig 2: Presentation of the correlation between the soil depths (H1 and H2) and no-till transition phases (NT0, NT3, NT6 and NT9) on the factorial plane (Dim1, Dim2).

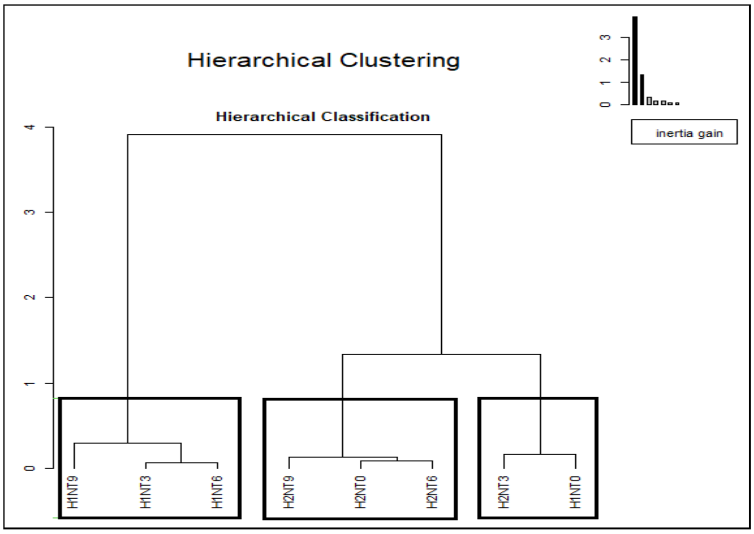

Fig 3: Classification dendrogram of correlation between soil depths (H1 and H2) and no-till transition phases (NT0, NT3, NT6 and NT9) on the basis similarity of soil indicators.

other hand, NT3 showed decrease (AS, COT, COP and MBC) and an increase (SS and BD) in depth H2 (10-20 cm). Depending on the degree of similarity with soil indicators, the others transition phases set between these two groups. Hierarchical cluster analysis indicated three main groups. The first cluster included (H1NT9, H1NT6 and H1NT3), the second one contained (H2NT9, H2NT6 and H2NT0, while the third included (H2NT3 and H1NT0) (Fig 3).

CONCLUSION

Our results show that the change on soil indicators of chronosequence the no-till in the context semi arid climate from Algeria is important between the transition phases of no tillage and between soil depths. The transition phases 9 and 6 years offered the best changes of structural quality (SS, BD and AS) and organic matter (TOC, POC and MBC) at both depths. These advantages are limited to the first soil depth in the transition phase (3 years).

The labile fractions (MBC and POC) and structural stability (SA) are the most sensitive indicators to changes between transition phases and between soil depths compared to other indicators as TOC, SS and BD.

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