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Evaluation of short-term conservation tillage systems by enzyme activity assessment

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ABSTRACT

Aims: There are few studies on the effectiveness of this type of management on the soil properties of Golestan Province, the main agricultural pole in Iran. This study aims to investigate tillage types on microbial enzymes as quality indicators of Fertile soils.
Materials & Methods: Three types of operations which include No Tillage (NT), Minimum or Occasionally Tillage (OT or MT), and Conventional Tillage (CT) were selected. In 0-30 cm of soil depth, samples were taken with 30 replications. Microbial respiration, microbial biomass, urease, acid and alkaline phosphatase, dehydrogenase, and cellulase activity were measured.
Findings: Conservation tillage (ST) which includes both MT and NT, increased acid and alkaline phosphatase by 1.6 to 2.5 times. The reverse trend for cellulase decreased from 37.5% in MT to 25% in NT. Urease and dehydrogenase increased by 14 and 18% in MT and decreased by 5.7 and 10% in NT. Microbial biomass and microbial respiration increased by 1.8 and 2.5 times in MT, and no-tillage operation decreased by 15 and 44%.
Conclusion: The emphasis is on the advice of ST. However, some points related to promoting this method in agricultural lands should be considered. In short-term operation (transitional phase), MT has a better condition for enzyme activity than NT. Low enzyme activity in NT conditions may reduce the availability of nutrients and thus reduce the yield, and then extension experts should inform the Farmers.

Keywords: Enzymes Activity; Conservation Agriculture (ST); Tillage; Soil Quality..

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Introduction

Land-use management has a significant effect on soil properties. Tillage is one of the essential parts of soil management in farmlands, which plays a vital role in providing proper seedbed, weed control, and mixing fertilizer, pesticide, and other additives to soil[1]. The plowing operation affects the physiochemical and faunal properties of the soil and changes the water storage capacity. Mitigation from drought and climate change depends on soil and water conservation. Moldboard plowing, as a conventional method in developing countries, accelerates the soil structure and erosion rate breakdown. Maintaining a sufficient amount of residue as an effective solution for promoting soil quality has been emphasized in many cases [2]. Residues are suitable for forming new aggregates and protecting them against raindrops [3]. In conservation agriculture farmer combines minimum or no tillage (NT) with permanent soil cover (at least 30%) with diversified crops [4]. The input of organic materials increases in conservation farming by crop rotation system and limitation in tillage [5]. Tillage management affects the index of quality [6]. It has also been reported that ST, in comparison with CT, increases the amount of nutrients and water in the soil. Therefore, it is suitable to be introduced as optimal soil management in sustainable agriculture [7].

The quality of soil depends on the soil's physicochemical properties and fauna properties [8]. Harasim et al. [9] mentioned that the tillage system affects soil quality by changing soil properties. According to Motta et al. [10], maintaining the residues can affect soil indicators such as acidification (pH). Larson et al. [11] mentioned that soil stirring in conventional tillage methods results in the degradation of residues, and nutrients, including carbon and nitrogen, were removed by decomposition.

Soil fauna is more sensitive than other indicators in response to management. Conservation agriculture also improves biological processes, and non-plowing treatments increase the population of fauna, bacteria, actinomyces, fungi, earthworms, and nematodes [12]. Microbial diversity makes the ecosystem stable when exposed to environmental stresses [13]. Microbial biomass, respiration, and enzyme are functional indices to evaluate the biological quality of soil [14]. Measuring these indicators are a helpful method for expressing biochemical reactions, nutrient circulation, and their availability by the fauna. Nannipieri et al. [15] reported that Enzymes are functional indices to analyze land-use impacts on soils because there are simple, rapid, and accurate. Researchers mentioned the positive effects of conservation tillage practices and organic conditioners on soil enzymes [16].

Besides all the results, there are some challenges. The production process of organic components and decomposition in the soil is slow and may take several years to increase the positive activities in the soil. Researchers reported that eight years of no-tillage may not increase the amount of organic carbon or nitrogen in some regions and decrease yield [17]. This decrease in yield can discourage the farmer from this protection operation.

Based on crop production, the Golestan province is ranked first to fourth for strategic crops. Because of the specific topography of the province, which varies from 27 to 3750 meters, there are diverse weather conditions, and various crops are planted. Rainfall, temperature, and humidity were annually 300mm, 17.8 ˚C, and 75%, respectively. Considering the introduction, the purpose of the research was to determine the effect of conservation tillage systems on soil biological and enzyme activities of Golestan province. We hypothesized that the conservation tillage system would improve the soil's biological aspects of soil quality. Nevertheless, different results may be obtained due to the diversity of climate, soil, and topography in this region, which will effectively promote this method in the future.

Materials & Methods

Description of Region and Sampling

This study evaluated the effect of different tillage systems on soil biological activities in the Bandar-e-Gaz region, west of Golestan province (Figure 1). Three tillage systems contain conventional tillage (CT), Occasional or Minimum tillage (OT or MT), and without or No-tillage (NT) are implemented in this area. The CT consisted of moldboard plowing for four years. The MT was the state where the farmer had plowed twice in 4 years, and in the NT, the plowing tool was not used. Conservation tillage in the study area was a short-term operation involving a relatively short period of time and was called a transitional phase. The main crops in the study area were wheat, canola in autumn, and soybean in summer. In 0-30 cm of soil depth, samples were taken with 30 replications.

Soil Experimental Analyses

A pH meter measured the pH value in a 1:2.5 substrate water. Salinity (EC) was analyzed in a 1:5 substrate water with EC-meter. Walkley–Black method was used for organic carbon (SOC) determination. To measure Basal soil microbial respiration, soil samples were maintained in closed containers at 25°C, and the amount of carbon dioxide produced was adsorbed by sodium hydroxide and determined by titration [18]. Microbial biomass was conducted by chloroform fumigation method [19]. Dehydrogenase activity was evaluated by the colorimetric method informed by Antonious et al. [20] using TTC as a substrate. The activity of alkaline phosphatase was analyzed by the sodium phosphate colorimetric method. In this method, buffer(2cc) and substrate(0.5cc) were used and incubated at 30°C for 90 min, and the amount of $NH4^+$ was determined [21]. For urease measurement, in incubated soil for 2 h, added urea and borate in 37°C. Then KCl solution was added and Shaked for 30 min. Ammonium detected by spectrophotometer (UV 330). The activity of cellulase was measured by Deng and Tabatabaei [22]. In this method, incubated soil was added to toluene and Na-acetate (50 mM), and carboxymethylcellulose (CMC). After that, the suspension was centrifuged. K-saturated was added, and Shaked and the supernatant were analyzed. Acid phosphatase was measured using PNPP as substrate [23].

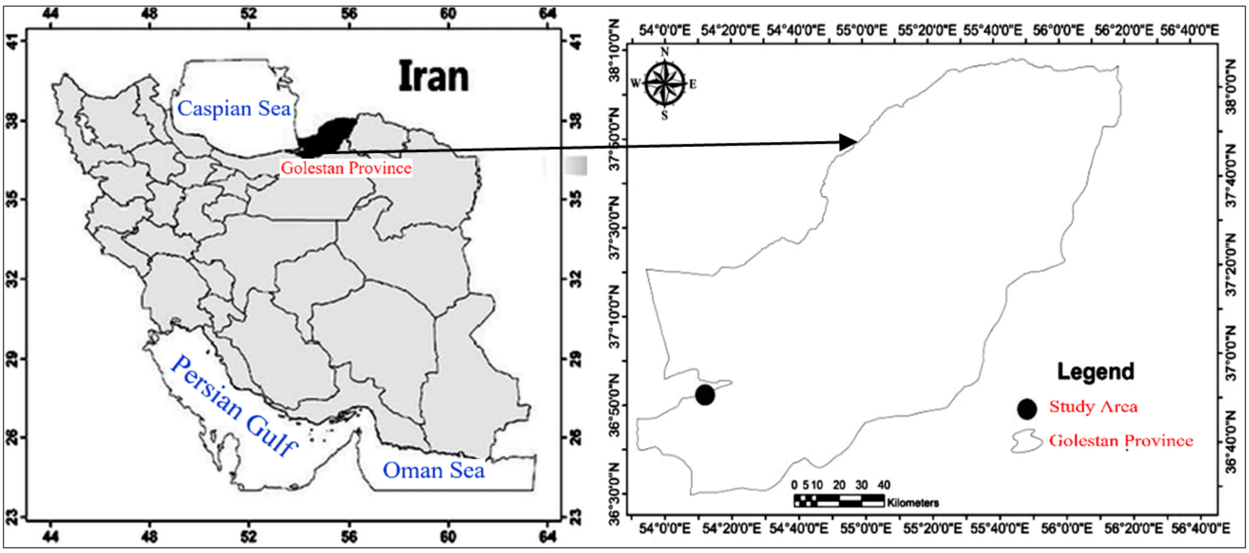

Figure 1) Map of the study area.

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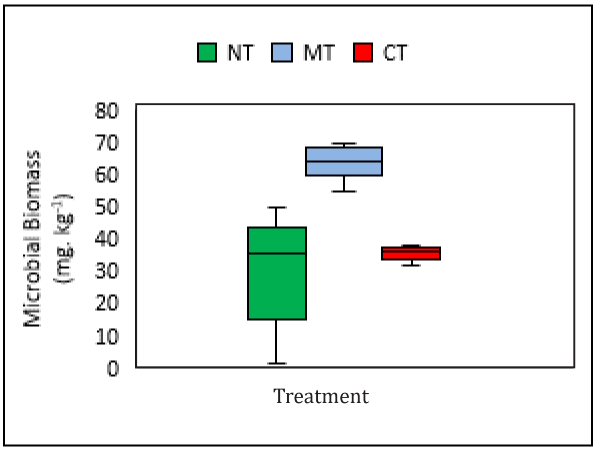
Findings

The results obtained from the analysis of the area under study showed that the texture of the soil was silty loam. The pH of the soils varied from 7.6 to 7.9 (mean 7.8), and EC values were in the range of 0.6–1.5 $dS.m^{-1}$. Organic matters were 1.4, 1.2, and 1% in NT, MT, and CT, respectively. The analysis results in the study area showed that tillage treatment has an essential effect on Basal respiration and microbial biomass (Figure 2). The results showed that the rate of respiration in the conventional plowing system (25 $mgCO^2$-C. m^{-2} soil. d^{-1}) was higher than the NT (14 $mgCO^2$-C. m^{-2} soil. d^{-1}), and the minimum plowing system had the highest respiration rate (60 $mgCO^2$-C. m^{-2} soil. d^{-1}). However, the amount of microbial biomass in the three plowing systems had a trend similar to respiration.

The NT system had the highest value of the other two systems in the amount of alkaline phosphatase (0.75 mM PNP. H^{-1}.kg^{-1}.DM)) in the study area; thus, there was no significant difference with the non-plowing system. NT and MT systems showed an increasing trend in alkaline and acid phosphatase activity. Urease enzyme in the MT system was higher than other systems (4 mM $N\text{-}NH^4$. h^{-1}. Kg^{-1}soil), while the non-plowing system had the lowest activity of the enzymatic activity (3.3 mM $N\text{-}NH^4$. h^{-1}. Kg^{-1} soil). Moreover, the results suggested that conservation tillage in both MT and NT decreased the enzymatic activity of cellulase, which showed a decrease from 37.5% in MT to 25% in NT (Figure 3). In addition, conservation tillage had the highest activity of dehydrogenase in MT (4.5 µg TPF. gr^{-1}.h^{-1}), but NT decreased the value

Discussion

Microbial biomass and respiration increased by 1.8 and 2.5 times in MT and decreased by 15 and 44% in NT. Vasquez-Murita [25] introduced the effect of soil type and its characteristics as the reason for the difference in the amount of microbial biomass of carbon in the soils. Variety in soil organic matter through different tillage changes fertility and consequences on soil microbial biomass [26]. Decomposition intensity was high when macrofauna contributed to the process, and the participation of two other sizes of organisms (micro and meso) decreased it [27, 28, 29]. Due to the tillage in the soil, more oxygen reached soil macrofauna in the conventional plowing systems of this study. When soil organic matter was exposed to air, conditions were provided to increase the materials' decomposition and respiration [30]. Dominquez et al. [31] stated that macrofauna activity in NT is affected by compaction and low de-



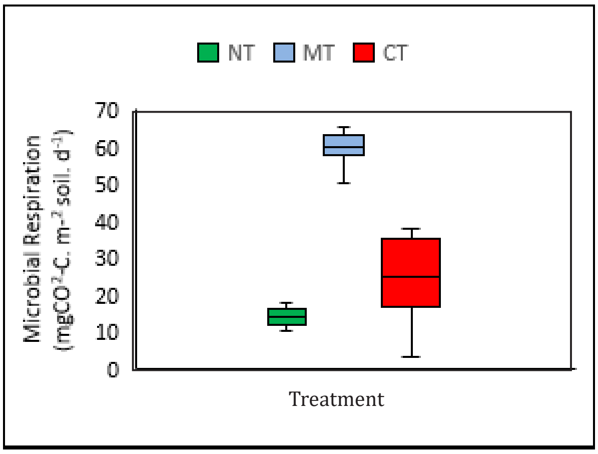


Figure 2) Effects of different tillage systems on microbial biomass and basal respiration at 0-30 cm layer of soil. CT, conventional tillage, MT, occasional tillage, NT, and no-tillage are treatments.

composition of organic components. In this management, toxic agrochemicals affected the quantitative aspect of earthworms. In Dominquez et al. [31] study area, limiting tillage increased bulk density by about 0.11 g.cm^{-3}, OM from 3.5% changed to 2.5%, and acidity decreased by 0.73 units. Decreased decomposition and earthworm activity by limiting tillage strongly correlated with the authors' idea. Fuentesa et al. [32]. However, it should be noted that the increased carbon degradation is the main reason for the increase in respiration. The highest respiration rate was observed in the occasional tillage system, and non-plowing and conventional systems had less respiration due to the amount of carbon and rate of carbon decomposition. Hamzei and Borbor [33] stated that the carbon decomposition rate increased in the conventional tillage system, followed by increased respiration. Microbial activity increased in the conventional plowing system, which was caused by exposure to degradable decomposed materials. Plowing systems affected the level of decomposition of materials by influencing the C/N ratio of soils, thereby increasing the degradability of organic matter. According to Bosta et al. [34]. Microbial respiration study as an indicator for determining mineralization of organic carbon. Conservation tillage increased acid phosphatase and alkaline phosphatase by 1.6 to 2.5 times. The reverse trend was in cellulase activity, which showed a decrease from 37.5% in MT to 25% in NT urease, and dehydrogenase increased by 14 and 18% in MT and decreased by 5.7 and 10% in NT. The results showed a correlation between enzyme activities, microbial biomass, and respiration. In general, MT has a better condition for enzyme activity than NT. Merini et al. [35] mentioned that soil type and physical properties significantly impact all enzyme activities. Speir et al. [36] mentioned that 10 years of land-use changes caused variation in soil enzymes by about 4-20%.

According to the results, acid and alkaline phosphatase in the conservation plowing system were more than in CT. Tabatabaei [37] found that the increased organic compounds in the soil lead to an increase in the phosphate compounds and, consequently, induces the production of alkaline phosphatase enzyme in the soil. The amount of alkaline phosphatase in the soil is affected by factors, including soil moisture [38]. Since ST in the area enhanced residues on the soil surface and thus promoted soil moisture content, it increased the amount of acid and alkaline phosphatase. Gianfered and Bollidge [39] also found that increasing soil organic matter promotes the enzyme's activity. Studies indicated that soils treated with a conservation plowing system have the least amount of soil acidity [40], which can be one of the reasons for increasing phosphatase activity under these conditions. Venkatesan and Senthurpandian [41] indicated that the depth of the soil sample, pH, temperature, ionic balance, and inhibitory parameters affect enzyme activities.

Dehydrogenase and urease activity responded to the treatments increasing with the adoption of occasional tillage. The urease enzyme plays an essential role in the mineralization of nitrogen in organic compounds and the supply of nitrogen to plants and microorganisms from natural sources and fertilizers in the soil. The extracellular activity of urease in the soil provides information about soil biochemical processes that affect soil function [42]. Peixoto et al. [43] mentioned that OT had better physical conditions than NT. They showed that OT reduced soil bulk density by 6.9%, penetration resistance by 54.8%, and increased Microporosity by 45.4% and total porosity; by 10.6% at a depth of 0–0.20 m. It seems that aeration and physical quality in OT promote the activity of enzymes.

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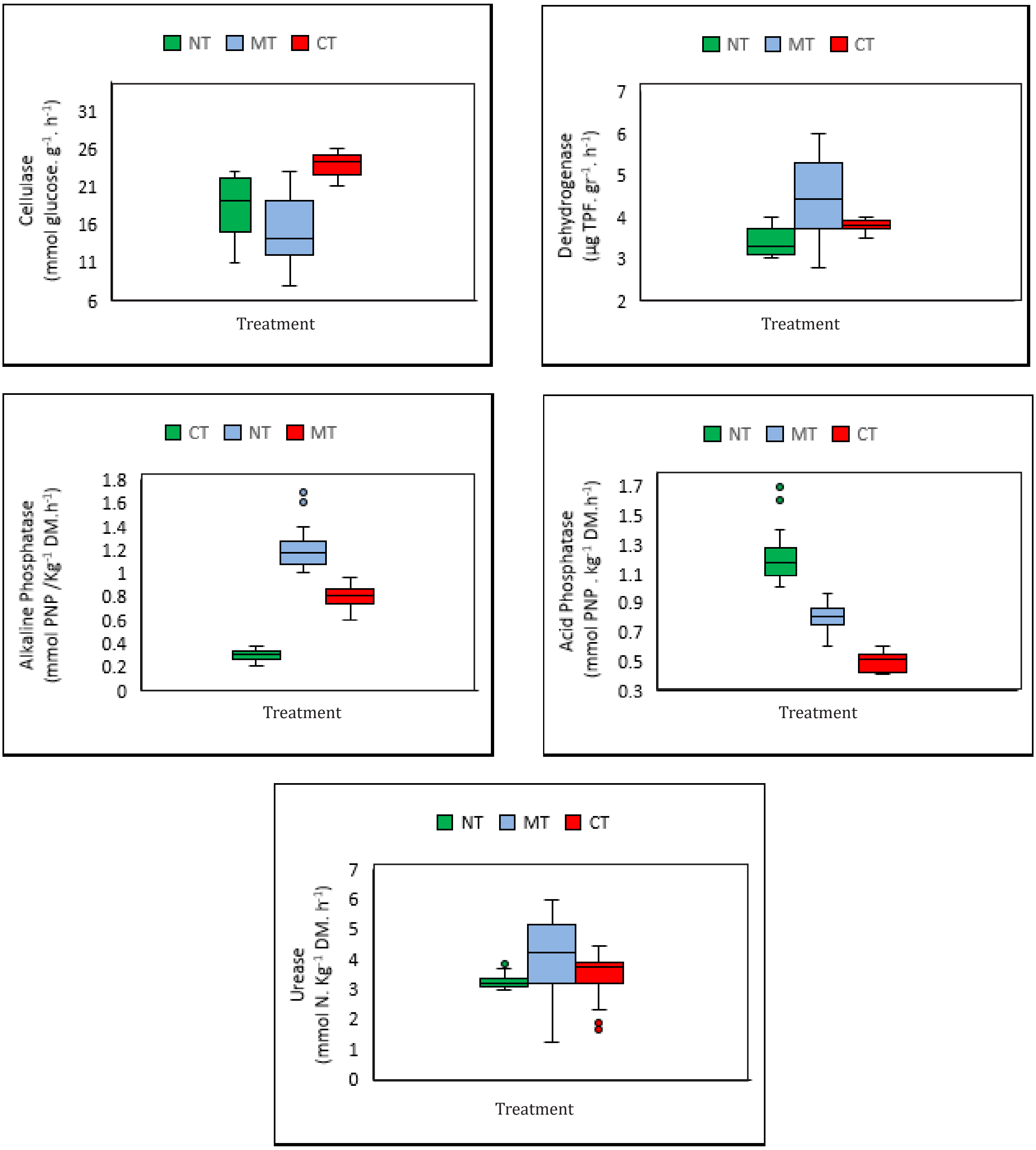

Figure 3) Effects of different tillage systems on enzyme activity at 0-30 cm layer of soil. CT, conventional tillage, MT, occasional tillage, NT, and no-tillage are treatments.

The highest activity of cellulase was related to the CT system. According to Johansson et al. [44], soil compaction in ST tillage harmed soil bio-activity. These results are different from Balota et al. [45] research findings. Balota et al. [45] showed that limiting tillage increased by about 54% for amylase, 16% for cellulase, 53% for arylsulfatase, and 48% for acid phosphatase. Derpsch et al. [46] and Brouder and Gomez Macpherson [47] concluded that types of analyzing methods, verities in species of plants, and location conditions make the research results inconsistent. Domınguez et al. [17] showed that no-till, in

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the way it was used in that area, cannot be accepted by the farmer. The amount of pH and organic matter was decreased, and this operation increased soil compaction. No-till and agrochemical input caused adverse effects on the edaphic environment that threatened macrofauna community health; therefore, moving the soil to increase decomposition and aeration seems useful.

Conclusion

This study investigates tillage types' effects on microbial enzymes as quality indicators of Fertile soils. The results showed that the conservation tillage (ST), which includes both MT and NT, increased acid and alkaline phosphatase, and cellulase had an opposite trend. MT showed higher Microbial biomass, respiration, urease, and dehydrogenase. There needs to be more research concerning the influence of short-term conservation tillage on crop yield in this area, especially at the beginning of the operation when farmers expect a positive result. This study again emphasizes the importance of conservation agriculture in promoting the physical quality of the soil. However, by comparing the results of this research with other studies, we find that the operation of NT in these soils and in a short time (transitional phase) should be done with more consciousness. The increase of organic matter without attention to its decomposition processes does not have enough positive quality effects. Prevention of tillage might reduce the physical quality of some soils. Therefore, intermediate-intensity methods such as OT can be environmentally friendly practices. So, further field-based investigations about crop yields are needed. The extension of NT in such areas and short-term operation (transitional phase) should be done with government support. This can encourage the farmers to continue and prevent financial loss.

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