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EFFECTS OF DIFFERENT TILLAGE PRACTICES ON SOIL FERTILITY PROPERTIES: A REVIEW

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ABSTRACT

Soil tillage is an important factor affecting soil fertility properties and crop yield. Tillage impact certain soil physical and chemical properties such as bulk density, soil porosity and water-holding capacity, infiltration rates, hydraulic conductivity, soil temperature, soil organic carbon, pH, CEC, available nitrogen, phosphorus and exchangeable potassium amongst others. The main objective of the present work was to compare the effect of no-tillage systems and the conventional tillage systems. Tillage systems can be generally categorized into plow tillage (conventional tillage), reduced tillage using chisel plow, disc plow, harrow disc or cultivators and no-till systems. Conservation tillage and its various types generally improve the soil quality indicators including soil organic carbon (SOC) storage. Whereas, conventional tillage practices give birth to a finer and loose-setting soil structure with a modified soil bulk density and soil moisture content, hence, causing loss of soil organic carbon and deterioration in other soil properties. Generally, soil fertility properties are more favourable with no-till than tillage-based systems. However, some researchers observed no significant effect of tillage methods (no-tillage and plow till) on bulk density (BD), pH and total porosity, while others found otherwise. The magnitude of these discrepancies could be due to the differences in crop species, soil properties, climatic characteristics and their complex interactions as well as tillage system adopted.

Keywords: Tillage, Soil Fertility Properties, Crop Yield

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

1. INTRODUCTION

Tillage is a major agricultural practice in sustainable farming. The best known early assumptions as to the reason for tillage were made in the early part of 18th Century byan English Farmer, Jethro Tull who is regarded as the father of tillage. Tull asserted that tillage improves the productiveness of soil because it causes a breakdown of the large soil particles into smaller ones which increase the surface from which plant roots obtain their food (Baver, 1956). Yoder (1937) described the ultimate goal of tillage as a high state of tilth and the attainment of this goal rests in the art of tillage. The soil is tilled to improve air, water and nutrient relationships for overall better crop performance.

Tillage is defined as the mechanical manipulation of the soil for the purpose of crop production affecting significantly the soil characteristics such as soil water conservation, soil temperature, infiltration and evapotranspiration processes. Tillage creates an ideal seedbed condition for plant emergence, development, and unimpeded root growth. This further suggests that tillage exerts impact on the soil purposely to produce crop and consequently affects the environment (Mutiu *et al.,* 2015). This is because soil inversion and pulverization by repeated tillage accelerates decomposition of organic matter which in turn affects soil physical, chemical and biological properties. Tillage impact is noticeable on soil physical and chemical properties though in different magnitudes.

Therefore, tillage may cause a variety of undesirable outcomes, for example, soil structure destruction, accelerated erosion, loss of organic matter and fertility, and disruption in cycles of water, organic carbon, and plant nutrient (Lal, 1993). Thus, continuous tillage and exploitation of soils ultimately leads to soil properties breakdown.

Tillage systems can be generally categorized into plow tillage (conventional tillage), reduced tillage using chisel plow, disc plow, harrow disc or cultivators and no-till systems using direct drilling in untilled soil (Reinhard *et al.,* 2014). These various tillage operations create lots of impact at different intensities on soil physical and chemical properties, such as bulk density, soil porosity and water-holding capacity, infiltration rates, hydraulic conductivity, soil temperature and organic matter content, nutrient distribution amongst others.

So many researches have been carried out on the impacts of different tillage techniques on soil physical and chemical properties and there is a substantial interest and emphasis on the shift to conservation and no-tillage methods. Thus, the objective of this study was to review the various works done on the impacts of different tillage practices on soil fertility properties and compare the no-tillage to the conventional tillage system.

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

2. REVIEW OF DIFFERENT TILLAGE SYSTEMS

Reinhard *et al.* (2014) categorized tillage systems into plow tillage (conventional tillage), reduced tillage using chisel plow, disc plow, harrow disc or cultivators and no-till systems using direct drilling in untilled soil. Tillage systems are classified generally into conservation tillage and conventional tillage based on the amount of surface residues left on the soil surface after tillage operation. Conservation tillage is further classified into five as shown below:

2.1 Conventional Tillage (CT)

Conventional tillage practices cause change in soil structure by modifying soil bulk density and soil moisture content. In addition, repeated disturbance by conventional tillage gives birth to a finer and loose-setting soil structure while conservation and no-tillage methods leave the soil intact (Rashidi and Keshavarzpour, 2007). This difference results in a change of characteristics of the pores network. The ability of the soil to store and diffuse air, water, and agricultural chemicals and, thus, in turn, regulate erosion, runoff, and crop performance is controlled by the network ofpores (Khan *et al*., 2001). Onwualu and Anazodo (1989) mentioned a higher porosity of soils under conventional treatments (52.9%) than under no-till (40.3%) as tillage loosens the soil. But the larger pore volume of tilled soils is only temporary and collapses rapidly under the impact of rainfall and runoff during the rainy season.

2.2 Conservation Tillage

Soil conservation concept entails all measures and techniques employed to maintain soil fertility at the lowest cost possible without significant decrease in crop yields. Conservation tillage is any tillage system that leaves at least 30% of the soil surface covered with crop residue after planting to reduce soil erosion by water (CTIC, 2004). This tillage practice therefore, involves seedbed preparation in the presence of residue, mulch and an increase in surface roughness. The practices therefore range from reduced or no-till to more intensive tillage depending on several factors, such as climate, soil properties, crop characteristics, and socioeconomic factors.

Conservation tillage is the most important aspect of conservation agriculture thought to take care of the soil health, plant growth and the environment (Mutiu *et al.*, 2015).

2.2.1 Types of conservation tillage

Conservation tillage practices range from zero tillage (No-till), reduced (minimum) tillage, mulch tillage, ridge tillage to contour tillage.

2.2.1.1 Minimum (reduced) tillage

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

Minimum tillage means reduced level of soil manipulation involving ploughing using primary tillage implements. Minimum tillage describes a practice where soil preparation is reduced to the minimum necessary for crop production and where 15 to 25% of residues remain on the soil surface (Morgan, 1995).

Several studies showed that reduced and zero-tillage systems contribute to long-term maintenance of the soil structure as pores from root growth and the activity of the soil fauna and the soil aggregates from the previous years are less or not at all disturbed (Lal, 1993). Soils with reduced tillage are characterized by less total pore space but have more stable fine pores and fewer air-filled pores than tilled farmland soils (Osunbitan *et al.*, 2005).

2.2.1.2 Ridge tillage and ridge tying

Ridge tillage is the practice of planting or seeding crops in rows on the top, along both sides or in the furrows between the ridges which are prepared at the beginning of every cropping season. Tied ridging or furrow diking includes the construction of additional cross-ties in the furrows between neighbouring contour ridges (Lal, 1990). Eziakor (1990) recommends ridge tillage for shallow soils, where hardpan seriously restricts root development and crop production. The accumulation of soil material increases the rooting zone and the mixture of the topsoil with nutrients and moisture from the subsoil facilitates the growth of crops in addition.

2.2.1.3 Mulch tillage

In mulch tillage, the soil is prepared or tilled in such a way that the plant residues or other materials are left to cover the surface to a maximum extent.

2.2.1.4 Contour tillage

When tillage is done at right angles to the direction of the slope it is referred to as contour tillage. Contour ridging, the preparation and cultivation across the slope, is a simple approach to erosion control in areas with small slope gradient but its effectiveness decreases with an increase in slope gradient, slope length, and increasing rain intensity. Soils with high erodibility factor that are characterized by a high percentage of fine sand and silt tend to be problematic soils for ridge tillage as they are more susceptible to water erosion if not covered with residues or crops (Lal, 1993).

2.2.1.5 No Tillage (NT) or Zero tillage

No-till or zero-tillage is characterized by the elimination of all mechanical seed bed preparation except for the opening of a narrow strip or hole on the ground for seed placement. The surface of the soil is covered by crop residue or mulch. Many studies have shown that with continuous no-tillage soil organic matter increases, soil structure improves, soil erosion is controlled, and in

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

time crop yields increase substantially from what they were under intensive tillage management (Papendick and Parr, 1997). As a result of reduced soil disturbance, zero tillage improves soil organic carbon and benefits the overall soil quality. There is overwhelming evidence from several scientific studies that continuous no-tillage is the most effective and practical approach for restoring and improving soil quality, which is vital for sustained food production and a healthy environment.

3. DISCUSSIONS

3.1 IMPACTS OF TILLAGE ON SOIL PROPERTIES

It has been established that different tillage practices affect soil physical and chemical properties. Table 1 shows the effects of different tillage strategies on soil properties as reported by Shahbaz *et al*. (2017).

Table 1: Effect of different tillage strategies on soil properties

Treatment	Soil bulk Density ($Mg\ m^{-3}$)	Soil organic carbon ($g\ kg^{-1}$)	Infiltration rate ($mmhr^{-1}$)	Percent porosity (%)	Soil saturated hydraulic conductivity ($mm\ hr^{-1}$)
Minimum Tillage	1.48	3.57	22.95	43.943	48.95
Conventional Tillage	1.40	3.56	25.35	46.773	57.71
Deep Tillage	1.41	3.57	25.27	46.39	57.92
LSD (0.05)	0.0507	NS	NS	1.3531	4.4836

Source: Shahbaz *et al*. (2017).

3.1.1 Impacts of Tillage on Soil Physical Properties

According to Lal (1997a), soil physical properties are generally more favourable with no-till than tillage-based systems. Conservation tillage improves soil quality indicators including SOC storage (Sharma *et al.*, 2013). Effects of conservation tillage on soil properties vary, and these variations depend on the particular system chosen. No-till (NT) systems, which maintain high surface soil coverage, have resulted in significant change in soil properties, especially in the upper few centimetres (Anikwe and Ubochi, 2007).

3.1.1.1 Soil structure

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

Tillage practices modify soil structure by changing its physical properties such as soil moisture content, soil bulk density and soil penetration resistance. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation tillage, which leaves the soil intact. The difference results in number, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water, agricultural chemicals and crop growth. This in turn controls erosion, runoff and crop performance. Changes in soil physical properties affect the seedling emergence, plant population density, root distribution and crop yield (Khurshid *et al.*, 2006). The pore network in conservationally tilled soil is usually more continuous, because of earthworms, root channels and vertical cracks. Therefore, conservation tillage may reduce disruption of continuous pores. Whereas, conventional tillage decreases bulk density of soil (Khan *et al.*, 1999) and soil penetration resistance.

This also improves porosity and water holding capacity of the soil. Continuity of pore network is also interrupted by conventional tillage, which increases the tortuousity of soil. Among the crop production factors tillage contributes up to 20% and the most effective way to reduce soil compaction is tillage (Khurshid *et al.*, 2006).

Mechanization of agriculture and intensive tillage operations are the main causes of soil compaction. Soil compaction adversely affects soil structure, reduces crop production, increase runoff and erosion.

3.1.2 Bulk density

Bulk density is the ratio between soil dry mass and volume. It is a very important soil property influencing soil water retention, aeration, trafficability, and infiltration rate, and is extremely sensible to soil management operations such as tillage. The bulk density is used to evaluate tillage and crop management effects on soil properties and this information are useful for seedbed properties assessment.

Soil bulk density is probably the most frequently measured soil quality parameter in tillage experiments (Rasmussen, 1999). The bulk density of a soil gives an indication of the soil's strength and thus resistance to tillage implements or plants as they penetrate the soil. Thus, soils with higher proportion of pores to solids have lower bulk densities than those that are compact and have fewer pores.

Shahbaz *et al*. (2017) recorded highest values for bulk density (1.48 Mg m^{-3}) from minimum tillage plot followed by deep tillage treatment and lowest bulk density (1.40 Mg m^{-3}) from conventional tillage plot. So conventional treatment represented increased bulk density up to 5.40% than Minimum treatment (Table 1). Some researchers (Puget and Lal, 2005) observed

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

no significant effect of tillage methods (no-tillage and plow tillage) on bulk density (BD) and total porosity.

Bulk density is inversely related to soil porosity and is an indicator of the capacity for air and water transport in the soil. One of the goals of tillage is to alleviate soil compaction by reducing bulk density.

Studies on the bulk density of surface soil layers showed differences according to the tillage methods. The results of Rahman *et al.* (2008) showed that bulk density of soil under CT was at the beginning lower than NT in 0–75 cm depth, and inversely after the harvesting. This result could be as a result of combined influence of greater wheel traffic, decrease in OC concentration and reduction in soil aggregation. Aikins and Afuakwa (2012) in a study compared the effect of different tillage practices on soil penetration resistance, dry bulk density, moisture content, and total porosity and reported that tillage practices significantly affected soil dry bulk density. The No Tillage treatment recorded the highest dry bulk density significantly higher than that of the disc ploughing followed by disc harrowing treatment, which produced the lowest dry bulk density. Similarly, Rashidiand Keshavarzpour (2008) reported than bulk density is higher in NT than in conventional tillage.

3.1.3 Total porosity

Soil porosity and organic matter content play a critical role in the biological productivity and hydrology of agricultural soils. Pores are of different size, shape and continuity and these characteristics influence the infiltration, storage and drainage of water, the movement and distribution of gases and the ease of penetration of soil by growing roots (Kay *et al.*, 2002). Hasinur *et al.* (2008) found that conventional tillage increased the total porosity of soil, but the macropores (effective pores) decreased in number, stability and continuity compared with no-till soil.

On the contrary, Shahbaz *et al*. (2017) recorded highest value of percent porosity (Φ) (46.77) from where the conventional tillage plot followed by deep tillage plot and minimum percent porosity (Φ) (43.94) from minimum tillage plots. So the conventional tillage treatment showed 6.05% more percent porosity than minimum treatment. Therefore, Table 1 shows significant results. Aikins and Afuakwa (2012) also reported that the disc ploughing followed by disc harrowing treatment produced the highest total porosity while the No Tillage treatment gave lowest total porosity.

3.1.4 Soil moisture

In order for a soil to function as a medium for plant growth, it must contain a certain amount of water. Soil structure studies have shown that soil is a porous medium which contains various

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

sizes of pores (Baver, 1956). Water which enters the soil either remains in the pores or percolates through them to lower depths. The character of the soil pore space has a great influence on the disposition of soil water. Soil moisture content is influenced by tillage of the soil since tillage influences the soil structure.

Studies on the influence of different tillage methodologies on the soil moisture content were made by Olaoye (2002); Rashidiand Keshavarzpour (2008); Aikins and Afuakwa (2012) among others. Aikins and Afuakwa (2012) reported that plots with disc ploughing followed by disc harrowing tillage had the highest soil moisture contents and the lowest soil moisture contents were located in the No Tillage plots. In contrast, Olaoye (2002) found higher soil moisture content in No Tillage plots compared with that of disc ploughed followed by disc harrowed plots. However, differences in the trend in soil moisture content may be attributed to weather (Aikins and Afuakwa, 2010). Rashidiand Keshavarzpour (2008) reported that different tillage treatments significantly affected soil moisture content and that the soil moisture content was higher in the CT treatment than the NT treatment. Rashidi and Keshavarzpour (2007) also studied same results; they reported that conventional tillage also has impact by producing loose and finer soil structure as compared to no-tillage and conservation tillage systems and results in decreased water movement into the soil profile thus decreased nitrate leaching.

3.1.5 Water infiltration and Hydraulic conductivity (mm h^{-1})

Water infiltration into the soil profile, surface runoff and soil erosion in arable lands depend on the conditions of the top layer. The tillage treatment of the top layer plays a key role in changes of the hydro-physical properties, mainly saturated hydraulic conductivity Ks of the surface layer (Kamenickova *et al*., 2012). Tillage operations affect the infiltration capacity and hydraulic conductivity of soils which has an impact on the amount of runoff and, hence, of soil loss. Lal (1997a) observed the highest infiltration rate for no-till treatments and lower rates for plowing. Contrariwise, Shahbaz *et al*. (2017) recorded highest value for infiltration rate from conventional tillage plot followed by deep tillage treatment and lowest infiltration rate from minimum tillage plot. So the conventional treatment showed an increase of 9.46% for infiltration rate than minimum treatment.

Many researchers have found that NT significantly improved saturated and unsaturated hydraulic conductivity owing to either continuity of pores (Benjamin, 1993) or flow of water through very few large pores. Shahbaz *et al*. (2017) recorded maximum soil saturated hydraulic conductivity (mm h^{-1}) (57.92) from deep tillage plots followed by conventional tillage treatment and minimum soil saturated hydraulic conductivity (48.95) from minimum tillage plot. So the deep tillage treatment showed 15.48% more soil saturated hydraulic conductivity than minimum treatment.

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

3.1.6 Soil penetration resistance

Penetration resistance measures the energy that must be exerted by the young seedling to emerge from the soil. It indicates resistance that must be overcome by the young rootlets in their search for nutrients and water in the soil (Olaoye, 2002). Soil compaction is routinely determined by measuring the penetration resistance, which is a measure of soil strength or resistance to deformation.

Penetrometer resistance measurements of soil can be used to assess the need for tillage operations, which help maintain effective plant rooting and facilitate good water and nutrient uptake (Veenstra *et al.*, 2006). Aikins and Afuakwa (2012) reported that tillage practice significantly affected soil penetration resistance under No Tillage as compared with that in the tilled soil treatments. Similarly, Olaoye (2002) reported higher soil penetration resistance in the No Tillage treatment in comparison with the disc ploughing followed by disc harrowing treatment for Ferric Luvisol in the rain forest zone of Akure in Nigeria.

Shahbaz *et al.* (2017) reported similar results to the findings of Khan *et al.* (1999) who studied the effect of different tillage practices on soil physical properties and concluded that conventional tillage affected soil bulk density and also caused decrease in soil penetration resistance which resulted in increased drainage and nitrate leaching. Jabro *et al.* (2010) also found similar results; they studied that deep tillage resulted in lowering soil penetration resistance by manipulating and loosening of the deeper soil layer and ultimately resulted in more absorption of mobile nutrients from deeper soil depth.

Rashidiand Keshavarzpour (2008) also reported a significant effect of different tillage treatments on soil penetration resistance. They reported a higher soil penetration resistance for the NT treatment than for the CT treatment.

3.1.7 Soil temperature

Tillage practices often influence soil temperature and, consequently, affect plant growth during the early part of the growing season. Soil temperature determines the rates of physical, chemical, and biological reactions in soils. Studies on the influence of different kinds of tillage operations on the soil temperature showed contrasting results. Lal (1995) found reduced soil temperatures on the field with conservation tillage as the surface was covered with mulch. The more favourable moisture and temperature conditions in plots with reduced or no tillage also have beneficial effects on the activity of the soil fauna, such as earthworms. These soil organisms reduce compaction and crust formation, construct macropores, and contribute to an improved soil structure by the formation of stable aggregates.

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

Veronica *et al.* (2015) after an experiment on a typical rain-fed Mediterranean Vertisol to determine the effects of the tillage system and the crop on soil temperature reported that soil temperature was higher in the system with conventional tillage than with no tillage.

Soil temperature was strongly related to air temperature and was also slightly lower under NT due to crop residues that accumulated on the surface of the NT treatment (Liu *et al.*, 2013).

Similarly, Wang *et al.* (2009) reported that higher soil temperature in the CT treatment than in the NT treatment.

In addition, the higher soil temperature under CT may be due to a surface difference: under NT, the soil surface is partially covered by remnants of straw from the previous crop, causing the soil to absorb less solar radiation during the day (Wang *et al.*, 2009). The tillage depth under CT makes the soil more porous, and as a result, the soil likely has lower thermal conductivity. This change leads to greater heat retention under CT. Overnight, the cause of the lower temperature in the NT treatment may be that the soil (especially in the upper profile) is loose and easily loses the energy stored during the day (Wang *et al.*, 2009).

3.2 Impacts of Tillage on Soil Chemical Properties

The result of an experiment established in 1996 in Raasdorf (Austria) on chernozem with four tillage treatments (mouldboard ploughing (MP); no-till; deep conservation tillage and shallow conservation tillage) and two crop rotations to determine the soil chemical properties as affected by tillage and crop rotation in a long-term field showed that Soil pH and $CaCO_3$ were not affected by soil tillage. Soil organic carbon (SOC), total nitrogen (Nt), potentially mineralizable Nitrogen (PMN), plant-available phosphorus (P) and potassium (K) increased in the uppermost soil layer with reduced tillage intensity. SOC, Nt, P and K were more evenly distributed in mouldboard ploughing (MP) whereas a generally higher decline downwards the soil profile was observed with lower tillage intensity. Lower tillage intensity resulted in a decrease of P and K in 30–40 cm (Reinhard *et al.*, 2014).

Basamba *et al.* (2006) concluded after an experiment that soil organic carbon and total C, N and P were generally better under no-till as compared to minimum-tilled soils; while P fractions were also generally higher under no-till treatments. According to Lal (1997b) soil chemical properties of the surface layer are generally more favourable under the no- till method than under the tilled soil. Annual no-tillage, implying yearly practice of no-till system over a long period of time, is beneficial to maintenance and enhancement of the structure and chemical properties of the soil, most especially the SOC content. Soil chemical properties that are usually affected by tillage systems are pH, CEC, exchangeable cations and soil total nitrogen.

3.2.1 Soil pH

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

Soil pH determination is a measure of hydrogen ion concentration or the degree of acidity or alkalinity of a soil. Soil pH is the single most important chemical property of the soil. Tillage treatments and associated cropping systems cause variation in pH values of soils and significant difference was found between NT and CT treatments. The lowest value for pH was reported with NT treatment (Rahman *et al.*, 2008).

Kahlon and Singh (2014) reported that the effect of tillage practices on soil pH was not significant in both Sandy Loam and Loamy Sand soils. However, among the tillage practices, the mean highest pH was found under CT followed by NT, RT and the lowest under HS tillage practices for SL and LS soils. Rahman *et al.*(2008) also observed no significant differences in soil pH among NT and CT practices.

Tillage technique is often shown to have zero effect on soil pH (Rasmussen, 1999), though soil pH has been reported to be lower in no-till systems compared to CT (Rahman *et al.*, 2008). The lower pH in ZT was attributed to accumulation of organic matter in the upper few centimeters under ZT soil (Rhoton, 2000) causing increases in the concentration of electrolytes and reduction in pH (Rahman *et al.*, 2008). Conversely, Cookson *et al.* (2008) found that surface soil pH decreased with increasing tillage disturbance and Lal (1997b) reported a significantly higher soil pH in NT plots compared to those in tilled plots. Therefore, tillage may not directly affect soil pH but its effects on pH will depend on the prevailing climatic condition, soil type and management factors.

3.2.2 Cation exchange capacity (CEC)

Exchangeable ions are those weakly adsorbed by soil particles that can be displaced from sorption sites by other ions in the solution. Exchangeable ions are essential for maintaining plant nutrient reserves in the soil.

Cation exchange capacity (CEC) is measured as the amount of cations (equivalents or moles of charge) which can be extracted by a high concentrated cation solution (usually, 1 M K^+ or $NH4^+$). The CEC is usually dominated by Ca, Mg, Na, K, Al, and protons. Rahman *et al.* (2008) reported that exchangeable Ca, Mg, and K, were significantly higher in the surface soil under NT compared to the ploughed soil. Kahlon and Singh (2014) also reported that the effect of tillage practices on CEC (cmol kg^{-1} soil) was higher in NT than under CT. Soil surface accumulation of organic has been reported to increase CEC under NT as compared to CT (David *et al.*, 2006).

3.2.3 Soil organic carbon (SOC)

The loss of carbon (C) from agricultural soils has been, in part, attributed to tillage, a common practice providing a number of benefits to farmers. Kahlon and Singh (2014) observed SOC to be significantly affected by tillage practices. However, NT reduces soil disturbance, improves

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

SOC maintenance and benefits soil quality. During the first 4 years of tillage, Rhoton (2000) determined a 10% loss of initial soil organic matter content with plough tillage. Mann (1986) also estimated the soil organic matter depletion between 16 and 77% caused by tillage. In most instances, increased levels of tillage or increased tillage periods resulted in reductions of soil carbon.

Shahbaz *et al*. (2017) recorded highest values for soil organic carbon (3.57 g kg^{-1}) from minimum tillage and deep tillage plots and lowest value of soil organic carbon were (3.56) from conventional tillage plot. As regards minimum and deep tillage treatments, soil organic carbon was improved 0.28% than conventional tillage. Therefore, Table 1 shows treatments results are non-significant. This problem can be solved by changing preferences as tillage known as reduced and `minimum tillage having less destructive effects as compared to the conventional one. Rasmussen (1999) observed that with annual no-tillage, plant residues left on the soil surface increase the organic matter in the top soil. Similarly, Lal (1997b) reported a significantly higher SOC in soil with NT compared to tilled soil.

In recent years, the promotion of less intensive tillage practices and no tillage (NT) agricultural management has sought to mitigate some of these negative impacts on soil quality and to preserve SOC. Moreover, higher N_2O emissions can occur with reduced or NT, due to moister and denser soil conditions, which may eventually offset positive effects on SOC balances (Basche *et al.,* 2014).

A number of authors have reviewed the impact of tillage on soil C E.g. Alvarez (2005); Sánchez *et al.*, (2012); Powlson *et al.,* 2014). These reviews and meta-analyses have shown both beneficial (Sánchez *et al.,* 2012;) and null (Powlson *et al.,* 2014) effects on SOC due to NT relative to conventional tillage. Furthermore, the efficacy of reduced tillage relative to NT is also unclear (Alvarez, 2005). Discrepancies may depend on whether total SOC stocks are measured or only presented as the SOC concentration, and also whether they are measured only in the upper soil layers or are reported accounting for the full soil profile. Moussa-Machraoui *et al.* (2010) studied that the contents of SOC was slightly greater under NT than under CT. No-till increases soil C stock by an average of 4-7 per cent. The enhancement of SOC and SOM contents in the soil under NT is often accompanied by the enhancement of the cation exchange capacity (CEC). Wang *et al.* (2008) after their 16 years' study reported that continuous long-term conservation tillage practice (NT, straw cover) significantly increased SOM, total N and available P in the surface soil (0 to 10 cm) layer.

3.2.4 Nitrogen (N)

There are several factors associated with reduced tillage that may affect, and likely lower the availability of N to crops. These include the cooler soil temperatures that reduce N

ISSN: 2455-6939

Volume: 08, Issue: 01 "January-February 2022"

mineralization from soil organic matter, increased immobilization in the surface of the soil because of the enrichment of organic C from residue, and denitrification where the soil porosity has been altered by traffic. These factors either independently, or in combination, have been shown to reduce the N uptake by crops no-till compared to conventionally tilled treatments.

Kahlon and Singh (2014) reported that tillage practices significantly affected Available Nitrogen. They recorded higher available N (kg ha^{-1}) than under CT. Moussa-Machraoui *et al.* (2010) also reported more available N under NT due to more organic matter accumulation.

Higher mineralization and/or leaching rate could be implicated for reduction in organic C and total N under tilled plot due to soil structure deterioration following tillage. Tillage increases the mineralization of nitrogen through break down of organic matter which may increase crop yield in short-term but in longer term continuous tillage degrades soil organic matter and reduces soil fertility and structural stability. The surface soil beneath the canopy had higher OM content in both tillage systems, particularly under NT.

3.2.5 Available phosphorus (AV. P)

Kahlon and Singh (2014) reported that tillage and residue management practices had no significant effect on Av. P. However, decaying residues releases nutrients such as phosphorus among others. Moussa-Machraoui *et al.* (2010) observed that some of the chemical parameters of soil were significantly modified under NT when compared to CT system. Thus, the nutrient (N, P, K, P_2O_5 and K_2O) contents were more under NT than CT.

The surface soil accumulation of P in conservation tillage was attributed to the limited downward movement of particle bound P in soils and the upward movement of nutrients from deeper layers through nutrient uptake by roots (Wang *et al.*, 2008).

3.2.6 Potassium (K)

Kahon and Singh (2014) reported that the effect of tillage on potassium was higher in NT plot than CT plot. The top 20 cm of plots managed by CP contained the highest amounts of available K (Sabine *et al.*, 2013). Further, they opined that potassium is more mobile in the soil and differences between tillage systems should become apparent much sooner than for Phosphorus. Similar findings were reported by Lewis *et al.* (2011) who detected higher contents of available K in the top 30 cm of a field trial after three years of conversion to organic farming and reduced tillage (CP 15 cm depth) in a continental climate in the US.

4. SUMMARY AND CONCLUSIONS

Tillage is performed primarily to lose the upper layer of soil in order to create a suitable seedbed for germination and growth of plants. Hence, tillage is a very important practice in agriculture.

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From the review of the various researches done on tillage, literature suggest that different tillage practices exert enormous impacts on the soil physical and chemical properties. Research results have been widely reported on the effects of tillage on soil structure, temperature, penetration resistance, moisture, infiltration rate and hydraulic conductivity, total porosity and bulk density as the main physical parameters affected; and soil organic carbon, pH, CEC, available nitrogen, phosphorus and exchangeable potassium as the main chemical parameters affected. The magnitude of the changes depends on soil types and composition as well as tillage system adopted. Conservation tillage and its various types generally improve the soil quality indicators including soil organic carbon (SOC) storage. On the other hand, conventional tillage causes loss of soil organic carbon and deterioration in other soil properties. Conventional tillage practices give birth to a finer and loose-setting soil structure with a modified soil bulk density and soil moisture content. Conventional tillage operations are the main causes of soil compaction. The response of soil physical properties to soil compaction is manifested in an increase in bulk density, a decrease in total porosity, air permeability, plant-available water and crop yield.

Some researchers observed no significant effect of tillage methods (no-tillage and plow till) on bulk density (BD), pH and total porosity, while others found otherwise. These discrepancies could be due to the differences in crop species, soil properties, climatic characteristics and their complex interactions. Generally, soil physical and chemical properties are more favourable with no-till than tillage-based systems. Many studies have shown that no-tillage enhances the availability of nutrients to the plants and improves different soil properties like soil bulk density, particle density, soil organic carbon, infiltration rate, percent porosity, soil saturated hydraulic conductivity and controls soil erosion but also is considered a phenomenon more appropriate to minimize leaching of nutrients along with water hence enhancing soil chemical properties.

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