International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 189-193

Received: 10-05-2019
Accepted: 12-06-2019

Laxmi
Department of Soil Science and Agricultural Chemistry College of Agriculture, University of Agricultural Sciences, UAS, Raichur, Karnataka, India

SR Balanagoudar
Department of Soil Science and Agricultural Chemistry College of Agriculture, University of Agricultural Sciences, UAS, Raichur, Karnataka, India

Ananda Naik
Department of Soil Science and Agricultural Chemistry College of Agriculture, University of Agricultural Sciences, UAS, Raichur, Karnataka, India

MA Bellakki
Department of Soil Science and Agricultural Chemistry College of Agriculture, University of Agricultural Sciences, UAS, Raichur, Karnataka, India

Pandit Rathod
Department of Agronomy, ZARS Kalaburagi, UAS Raichur, Karnataka, India

Correspondence
Laxmi
Department of Soil Science and Agricultural Chemistry College of Agriculture, University of Agricultural Sciences, UAS, Raichur, Karnataka, India

Physico-chemical and biological properties of soil under conservation agriculture practices in chickpea crop

Laxmi, SR Balanagoudar, Ananda Naik, MA Bellakki and Pandit Rathod

Abstract
A field experiment was conducted at Agriculture Research Station, Kalaburagi, University of Agricultural Sciences, Raichur, conducted during *rabi* 2016-17. To study the "Physical and biological properties of soil as under conservation agriculture practices in chickpea crop". The experiment was laid out in Split plot design with four replications, six treatments, three main plots and two sub plots. The experimental results revealed that Zero Tillage with residue retention significantly recorded higher the physical properties such as porosity (52.50 %), maximum water holding capacity (39.01 %), mean weight diameter (1.11 %) and aggregate stability (75.38 %), and also higher number of soil bacteria, fungi and actinomycetes population higher in zero tillage with residue retention over conventional tillage. Higher bulk density was recorded in conventional tillage with residue.

Keywords: Seed, custard apple, annona squamosa, pre-sowing treatments, seed germination, growth

1. Introduction

Agriculture is the backbone of Indian economy with about two thirds of the population residing in rural areas directly or associated with it for their livelihood and contributing to 13.7% of the Gross Domestic Product (GDP). With the advent of green revolution in late seventies, India has leapfrogged in food security, poverty reduction and per capita income. But, agricultural intensification in the form of intensive tillage based production systems generally had an adverse impact on natural resources such as soil, water, biodiversity and the associated ecosystem services provided by nature. The degradation of the land resource base has resulted in decreased crop yields and increased factor productivity. The above scenario has forced the farmers, scientists and development stakeholders to search for an alternative paradigm that is ecologically sustainable as well as profitable. Soil and water management form the basis for sustainable system of productive agriculture. These natural resources are deteriorating at a faster rate, which necessitates the need of conservation agricultural (CA) practices to restore the soil quality, enrich soil organic carbon (SOC) and also to feed the population of India projected to be about 1.48 billion by 2030. Thus, CA has emerged as a new paradigm to achieve sustainable agricultural production. It has been proposed as a combination of management principles to improve water use efficiency, reduce soil erosion and conserve natural resources such as farmer's time, labour and fossils fuels/diesel. Over the past few decades, rapid strides have been made to evolve and spread resource conservation technologies like zero and reduced tillage system, better management of crop residues and planting system which enhance water and nutrients conservation. it was estimated that CA spreads about 124 m ha, which is aimed to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs.

2. Material and Methods

A field experiment was conducted during *Rabi* 2017 in Agriculture Research Station, Kalaburagi, University of Agricultural Sciences, Raichur to study the "Physiccal and biological properties of soil under conservation agriculture practices in chickpea crop". Chickpea (var. JG-11) was raised as test crop. A composite soil sample was collected from experimental site before the start of experiment and was analysed for physical chemical and biological properties (Table 1).

Experiment consists of six treatments under tillage with and without residue was tested in Split plot design with four replications. 100 per cent recommended dose of fertilizer for chickpea crop is 10:25:0 kg N: P_2O_5: K_2O ha^{-1} was applied in the form of diamonium phosphate (DAP) to RDF treatments while as per package were applied at the time of sowing. The present study was carried under the following treatments, *i.e*. The main plots are M_1: Conventional tillage, M_2: Reduced tillage and M_3: Zero tillage and sub plots are S_1: With residue retention and S_2: Without residue retention and their interaction of both main and sub plots consist of six treatments are M_1S_1: Conventional Tillage (CT) + with residue, M_1S_2: Conventional Tillage (CT) + without residue, M_2S_1: Reduced Tillage (RT) + with residue, M_2S_2: Reduced Tillage (RT) + without residue, M_3S_1: Zero Tillage (ZT) + with residue and M_3S_2: Zero Tillage (ZT) + without residue.

Table 1: Physical-chemical and biological properties of soil of the experiment site

Particulars	Value obtained
I. Physical properties	
1. Sand (%)	48.50
2. Silt (%)	25.00
3. Clay (%)	26.25
4. Textural	Clay loam
II. Chemical properties	
1. Soil pH (1:2.5)	8.12
2. Electrical conductivity (dSm^{-1})	0.36
3. Organic carbon (%)	0.52
4. Available Nitrogen (kg ha$^{-1)}$	212
5. Available Phosphorus (P_2O_5) (kg ha^{-1})	25
6. Available Potassium (K_2O) (kg ha^{-1})	533
7. Available Sulpur (S_{O4}) (kg ha^{-1})	14
III. Available Micronutrients	
1. Zinc (ppm)	0.91
2. Iron (ppm)	5.52
3. Copper (ppm)	2.51
4. Manganese (ppm)	5.21
IV. Soil Microbial Count	
1. Bacterial (No. X 10^7 cfu g^{-1} of soil)	21.65
2. Fungi (No. X 10^5 cfu g^{-1} of soil)	25.83
3. Actinomycetes (No. X 10^3 cfu g^{-1} of soil)	18.78

2.1 Statistical analysis and interpretation of data

The analyses and interpretation of the data was done using the Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1967) [12]. The level of significance used in 'F' and 't' test was 5 per cent probability and wherever 'F' test was found significant, the 't' test was performed to estimate critical differences among various treatments.

3. Results and Discussion

The data on chemical properties (soil pH, electrical conductivity (dS m^{-1}), organic carbon (%), physical and biological properties of soil as influenced by tillage and residue retention and their interaction after harvest of chickpea are presented in Table 2 to 4.

3.1 Effect on chemical properties

The data on chemical properties soil pH, electrical conductivity (dS m^{-1}), organic carbon (%) of soil as influenced by tillage and residue retention and their interaction after harvest of chickpea are presented in Table 2.

Tillage and residue retention and their interaction of pH and EC in soil were not differed significantly after harvest of chickpea. General, the pH and EC of the soil ranges from 7.54 to 7.80 and 0.30 to 0.47 respectively.

In case of organic carbon in the soil showed significant differences among treatments as influenced by different tillage practices after harvest of chickpea crop. Among the main plot tillage treatments, zero tillage recorded significantly higher Organic carbon in the soil (0.3 %) over conventional tillage (0.57 %) and in sub plot residue treatments, with residue retention recorded significantly higher Organic carbon in the soil (0.75 %**)** over all other treatments. However, significantly lower Organic carbon in the soil was recorded in without residue retention (0.63 %) and interaction of tillage and residue treatments on Organic carbon in the soil differed significantly. Significantly higher Organic carbon in the soil (0.91 %**)** was observed in zero tillage with residue retention as compared to all other treatments. Conventional tillage without residue retention recorded significantly lower Organic carbon in the soil (0.50 %). This is may be due to less mineralization of stored OC and addition of rice residue under ZT increases the SOC content more than CT without residue the 11 % SOC increased under ZT with residue as compared to CT without residue. Increased SOC at 0-5 cm depth under reduced tillage and no-tillage than CT was possibly attributed to minimum soil disturbances and crop residue retention which helps in increasing SOC in the surface layers. The present results corroborated with the findings of Hati *et al*. (2014) [5] and Mc Carty *et al*. (1998) [10].

Table 2: Chemical properties of soil after harvest of the chickpea crop under conservation agriculture practices.

Treatments	pH (1 : 2.5)	EC (dSm^{-1})	OC (%)
Main Plot			
M_1:Conventional Tillage	7.54	0.30	0.57
M_2: Reduced Tillage	7.56	0.37	0.67
M_3:Zero Tillage	7.80	0.47	0.83
S.Em±	0.07	0.04	0.05
CD 5 %	0.23	0.13	0.18
Sub Plot			
S_1:With Residue	7.70	0.42	0.75
S_2:Without Residue	7.57	0.34	0.63
S.Em±	0.04	0.01	0.03
CD 5 %	0.13	0.05	0.08
Main x Sub Plot			
M_1S_1	7.54	0.31	0.65
M_1S_2	7.54	0.29	0.50
M_2S_1	7.57	0.41	0.70
M_2S_2	7.56	0.33	0.65
M_3S_1	7.99	0.55	0.91
M_3S_2	7.61	0.39	0.75
S.Em±	0.07	0.02	0.04
CD 5 %	0.23	0.08	0.14

3.2 Effect on physical properties of soil

Impact of tillage and residue retention and their interaction on physical properties such Porosity, maximum water holding capacity, mean weight diameter and aggregate stability of soil showed significant difference at harvest of chickpea are presented in Table 3.

3.2.1 Bulk density

Impact of tillage and residue retention and their interaction on bulk density of soil showed significant difference at harvest of chickpea presented in Table 3.

Among main plot tillage treatments, Zero tillage recorded significantly lowest Bulk density (1.36 Mg m^{-3}) over conventional tillage (1.44 Mg m^{-3}). Among sub plot residue treatments, without residue retention recorded significantly lowest bulk density (1.38 Mg m^{-3}) over all other treatments. With residue retention recorded significantly highest bulk density (1.41 Mg m^{-3}). Interaction of tillage and residue retention on Bulk density of soil at harvest differed significantly. Significantly lowest bulk density (1.34 Mg m^{-3}) was observed in zero tillage without residue retention as compared to all other treatments. Conventional tillage practices with residue retention recorded significantly highest bulk density (1.46 Mg m^{-3}). This might be due to the deposition of OM in ZT practice. Soil bulk density is the significant indicator of change of soil physical health and water retention capacity under different tillage depth. Similar result was reported by Sarwar *et al*. (2008) In New South Wales (NSW), Australia, the soil Bulk density was reduced by 6.7% in no tillage (at 50cm depth) compared to conventional tillage after 14 years. He *et al*. (2009) [6] reported that the mean bulk density (in 0–30 cm soil layer depth) under NT and CT treatments was 1.40 and 1.41Mgm^{-3}, respectively, and the difference was negligible in the long term which is in agreement with the findings of our study.

3.2.2 Porosity
Tillage and residue retention and their interaction on porosity were differed significantly in chickpea presented in Table 3.
Among the main plot tillage treatments, zero tillage recorded significantly highest porosity (51.15 %) over conventional tillage (46.28 %). Among sub plot residue treatments, with residue retention recorded significantly highest porosity (49.20 %) over all other treatments. However, significantly lowest porosity was recorded in without residue retention (47.71 %). Interaction of tillage and residue retention treatments on porosity differed significantly. Significantly highest porosity (52.50 %) was observed in zero tillage with residue retention as compared to all other treatments. Conventional tillage without residue retention recorded significantly lowest porosity (45.72 %). The increase of soil porosity in ZT might be due to the addition of OM and crop residues which was caused by zero and minimum disturbance of soil. Similar results were also reported by He *et al.* (2009) [6]. Many studies have indicated that tillage systems significantly influenced the soil pore size distribution and also reported that total porosity in the 0–15 cm layer was similar under different treatments.

3.2.3 Maximum water holding capacity (MWHC)
Tillage and residue retention and their interaction on Maximum water holding capacity were differed significantly in chickpea presented in Table 3.
Among the main plot tillage treatments, zero tillage recorded significantly highest Maximum water holding capacity (3.10 %) over conventional tillage (31.88 %). Where as in sub plot residue treatments, with residue retention recorded significantly highest Maximum water holding capacity (36.09 %) over all other treatments. However, significantly lowest Maximum water holding capacity was recorded in without residue retention (34.40 %). Interaction of tillage and residue treatments on Maximum water holding capacity differed significantly. Significantly highest Maximum water holding capacity (39.01 %) was observed in zero tillage with residue retention as compared to all other treatments. Conventional tillage without residue retention recorded significantly lowest Maximum water holding capacity (31.25 %).
The difference in maximum water holding capacity of soil between conventional and conservational agriculture systems that too at 0-5 cm soil depth where the soil under former system recorded the lowest MWHC as compared to that of later and this could be attributed to the more of organic matter in the soil under conservational agriculture systems than in the soil under conventional agriculture system. However either tillage or crop residue did not influence MWHC of soil significantly as per the statistical tool used to analyze the data on MWHC of soil. Increasing trend of MWHC of soil as that of clay down the solum suggested that genetic factor clay rather than management factors tillage and crop residue contributed much to MWHC of soil. Similar kind of observations was reported by Khurshid *et al*. (2006) [9].

3.2.4 Mean Weight Diameter (MWD)
Tillage and residue retention and their interaction on Mean weight diameter were differed significantly in chickpea presented in Table 3.
Among the main plot tillage treatments, zero tillage recorded significantly highest mean weight diameter (1.07 mm) over conventional tillage (0.81 mm). in case of sub plot residue treatments, with residue retention recorded significantly highest mean weight diameter (0.98 mm) over all other treatments. However, significantly lowest mean weight diameter was recorded in without residue retention (0.90 mm). Interaction of tillage and residue treatments on mean weight diameter differed significantly. Significantly highest Mean weight diameter (1.11 mm) was observed in zero tillage with residue retention as compared to all other treatments. Conventional tillage without residue retention recorded significantly lowest Mean weight diameter (0.75 mm).
In this study, soil aggregation was determined as mean weight diameter (MWD) at different depths. MWD decreased with increased soil depth with few variations across different tillage system. MWD was significantly lower ($P < 0.05$) under CT compared to RT and NT across different soil depths. The lowest MWD was observed in CT (0.80 mm) at 0-5cm depth. Same trend was found in sub-surface layers. By and large 0-5 and 5-15cm soil depth recorded relatively higher MWD under both NT and RT. This was possibly due to minimum soil disturbances with residue retention under this treatments favoured soil aggregation after three crop cycles. Lower MWD recorded under CT was due to repeated soil disturbances through tillage operations coupled with less residue addition results in lower soil aggregation. At Larger MWD in BBF is attributed to higher organic content in this treatment. It is well established fact that soil organic carbon is a basic factor affecting aggregation. It has been reported that aggregates ranging from 2 to 0.25 mm in size is protected by organic carbon binding agents otherwise, under heavy and intensive cultivation; the aggregates would be disrupted (Elliott, 1986; Bear *et al.*, 1994). The increased aggregate stability under the BBF system was significantly affected by the combination of no tillage, mulch covering, and raised beds, not by any of them separately. This result agreed with that of He *et al*., (2012) [7] and Naresh *et al*., (2012) [11].

3.2.5 Aggregate Stability (%)
Tillage and residue retention and their interaction on aggregate stability were differed significantly in chickpea presented in Table 3.
Among the main plot tillage treatments, zero tillage recorded significantly highest aggregate stability (74.27 %) over conventional tillage (62.56 %). With respect to sub plot residue treatments, with residue retention recorded significantly highest aggregate stability (69.35 %) over all

other treatments. However, significantly lowest aggregate stability was recorded in without residue retention (66.99 %). Interaction of tillage and residue treatments on aggregate stability differed significantly. Significantly highest aggregate stability (75.38 %**)** was observed in zero tillage with residue retention as compared to all other treatments. Conventional tillage without residue retention recorded significantly lowest aggregate stability (61.31 %).

Zero tollage with residue retention on soil aggregate stability mainly ascribed due to minimum soil disturbances and crop residue retention under these treatments. Similarly, many other researchers found higher percent water stable aggregates under RT and NT (Devine *et al*. 2014) [3], Kahlon *et al*. (2013) [8].

Table 3: Physical properties of soil under of conservation agriculture practices after harvest of chickpea.

Treatments	Bulk density (Mg m-3)	Porosity (%)	MWHC (%)	MWD (mm)	Aggregate stability (%)
Main Plot					
M_1:Conventional Tillage	1.44	46.28	31.88	0.81	62.56
M_2: Reduced Tillage	1.39	47.93	35.76	0.94	67.68
M_3:Zero Tillage	1.36	51.15	38.10	1.07	74.27
S.Em±	0.01	0.56	0.26	0.02	0.12
CD 5 %	0.03	1.94	0.90	0.06	0.41
Sub Plot					
S_1:With Residue	1.38	49.20	36.09	0.98	69.35
S_2:Without Residue	1.41	47.71	34.40	0.90	66.99
S.Em±	0.01	0.36	0.23	0.01	0.10
CD 5 %	0.02	1.15	0.74	0.04	0.31
Main x Sub Plot					
M_1S_1	1.46	46.84	32.52	0.88	63.81
M_1S_2	1.43	45.72	31.25	0.75	61.31
M_2S_1	1.40	48.25	36.73	0.97	68.86
M_2S_2	1.38	47.60	34.78	0.91	66.50
M_3S_1	1.36	52.50	39.01	1.11	75.38
M_3S_2	1.34	49.81	37.18	1.03	73.16
S.Em±	0.01	0.62	0.40	0.02	0.17
CD 5 %	0.03	1.99	1.28	0.07	0.54

3.3 Effect on biological properties of soil

The data pertaining to soil microbes like bacteria, fungi, actinomycetes after harvest of chickpea as influenced by tillage and residue retention and their interaction on soil microbial population were differed significantly at harvest in chickpea are presented Table 4.

Among the main plot tillage treatments, zero tillage recorded significantly higher number of soil bacterial (27.75 cfu × 10^{-6} g^{-1} soil), fungi (39.38 cfu x 10^{-4} g^{-1} soil) and actinomycetes (19.25 cfu x 10^{-3} g^{-1} soil) population over conventional tillage (22.25 cfu × 10^{-6} g^{-1} soil, 31.13 cfu x 10^{-4} g^{-1} soil and 13.62 CFU x 10^{-3} g^{-1} soil, respectively). In case of sub plot residue treatments, with residue retention recorded significantly higher number of soil bacterial (25.29 cfu × 10^{-6} g^{-1} soil), fungi (35.92 cfu x10^{-4} g^{-1} soil) and actinomycetes (16.58 cfu x 10^{-3} g^{-1} soil) over all other treatments. Without residue retention recorded significantly lower number of soil bacterial (23.39 cfu × 10^{-6} g^{-1} soil), fungi (32.67 cfu x 10^{-4} g^{-1} soil) and actinomycetes (14.58 cfu x 10^{-3} g^{-1} soil). Interaction of tillage and residue treatments on bacteria fungi and actinomycetes at harvest differed significantly. Significantly higher number of soil bacterial (29.88 cfu × 10^{-6} g^{-1} soil), fungi (43.75 cfu x 10^{-4} g^{-1} soil) and actinomycetes (22.25 cfu x 10^{-3} g^{-1} soil) were observed in zero tillage with residue retention compared to all other treatments. Conventional tillage without residue retention recorded significantly lower number of soil bacterial (21.75 cfu × 10^{-6} g^{-1} soil), fungi (31.01 cfu x 10^{-4} g^{-1} soil) and actinomycetes (14.00 cfu x 10^{-3} g^{-1} soil).

Soil biological properties *viz* cteria, fungi and actinomycetes biomass count at harvest of chickpea was significantly higher in zero tillage + with residue retention over rest of the treatments when compared to their initial values before sowing. However, significantly lower microbial population was observed in conventional tillage + without residue retention due to tillage practices with residue retention, Zero tillage with residue retention maintain the productivity by reducing erosion, maintain a favorable soil temperature, improve water-retention capacity, improve water use efficiency, increase nutrient use efficiency similar findings reported by Studies of Spedding *et al*. (2004) [14] revealed that residue management had significantly influenced soil microbial biomass than the tillage systems and influence of tillage was mainly confined to surface layers (Alvear *et al*., 2005) [1] and a higher microbial biomass was observed in soil under zero tillage as compared to the soil under conventional tillage.

Table 4: Soil microbial counts of soil after harvest of the chickpea crop under conservation agriculture practices.

Treatments	Bacteria (No. X 10^7 cfu g^{-1} of soil)	Fungi (No. X 10^5 cfu g^{-1} of soil)	Actinomycetes (No. X 10^3 cfu g^{-1} of soil)
Main Plot			
M_1:Conventional Tillage	22.25	31.13	13.62
M_2: Reduced Tillage	23.02	32.37	13.88
M_3:Zero Tillage	27.75	39.38	19.25
S. Em±	0.31	2.73	0.63
CD 5 %	1.06	9.45	2.17
Sub Plot			
S_1:With Residue	25.29	35.92	16.58
S_2:Without Residue	23.39	32.67	14.58
S.Em±	0.28	1.32	0.34
CD 5 %	0.90	4.22	1.08
Main x Sub Plot			
M_1S_1	22.75	31.25	13.25
M_1S_2	21.75	31.01	14.00
M_2S_1	23.25	32.75	14.25
M_2S_2	22.78	32.00	13.50
M_3S_1	29.88	43.75	22.25
M_3S_2	25.63	35.00	16.25
S.Em±	0.49	2.28	0.58
CD 5 %	1.56	7.31	1.87

4. Conclusion
Zero tillage with residue retention could be the best tillage practices for improved soil physical properties such as maximum water holding capacity, porosity, mean weight diameter and consequence increased abundance of microorganisms like bacteria, fungi and actinomycetes in the zero tillage surface soil.

5. References

1. Alvear M, Rosas A, Rouanet JL, Borie F. Effect of three soil tillage systems on some biological activities in an Ultisol from southern Chile. Soil Tillage Res. 2005; 82:195-202.
2. Bear MH, Hendrix PF, Coleman DC. Water-stable aggregates and organic matter fractions in conventional- and no-till soils. Soil Sci. Soc. Am. J. 1994; 58:777-786.
3. Devine S, Markewitz D, Hendrix P, Coleman D. Soil aggregates and associated organic matter under conventional tillage, no-tillage, and forest succession after three decades. Plos one. 2014; 9(1):1-12.
4. Elliott ET. Aggregate structure and carbon, nitrogen and phosphorous in native and cultivated soils. Soil Science Society of America Journal. 1986; 50:627-633.
5. Hati KM, Chaudhary RS, Somasundaram J, Saha R, Mohanty M, Singh RK. Conservation agriculture and pulses: Impact on soil health. In: Resource Conservation Technology in Pulses: (Eds Ghosh *et al*., 2014), Published by Scientific Publisher (India), 2014, pp. 405-418.
6. He J, Li H, Rasaily RG, Wang Q, Cai G, Su Y, Qiao X, Liu L. Soil properties and crop yields after 11 years of no tillage farming in cropping system in North China Plain. Soil Till. Res. 2009; 113:48-54.
7. He J, McHugh AD, Li HW, Wang QJ, Li WY, Rasaily RG, H Li. Permanent raised beds improved soil structure and yield of spring wheat in arid north-western China. Soil Use Manage. 2012; 28:536-543.
8. Kahlon MS, Lal R, Ann Varughese M. Twenty-two years of tillage and mulching impacts on soil physical characteristics and carbon sequestration in Central Ohio. Soil Till. Res. 2013; 126:151-158.
9. Khurshid K, Iqbal M, Arif MS, Nawaz A. Effect of tillage and mulch on soil physical properties and growth of maize. Intl. J Agri. Biol. 2006; 8:593-596.
10. MC Carty GW, Lyssenko NN, Starr JL. Short-term changes in soil carbon and nitrogen pools during tillage management transition. Soil Sci. Soc. Am. J. 1998; 62:1564-1571.
11. Naresh RK, Singh B, Singh SP, Singh PK, Kumar A, Kumar A. furrow irrigated raised bed (FIRB) planting technique for diversification of rice-wheat system for western igp region. Int. J Life Sc. Bt and Pharm. Res. 2012; 1(3):2250-3137.
12. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers. ICAR Publication, New Delhi, 1967, 167-174.
13. Sarwar G, Schmeisky H, Hussain N, Muhammad S, Ibrahim M, Safdar E. 2008 Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. Pakistan Journal of Botany. 1967; 40(1):275-282.
14. Spedding TA, Hamel C, Mehuys GR, Madramootoo CA. Soil microbial dynamics in maize growing soil under different tillage and residue management systems. Soil Biol. Biochem. 2004; 36:499-512.