in problem of biological classification. Journal of Royal Statistical Society, B10, 159-203.

Rao, C. R. 1973. Linear statistical inference and its applications. Willey, New York.

Rencher, A. C. 1993. The contribution of individual variables to Hotelling's T^2, Wilks' , and R^2. Biometrics, 479-489.

Roux, N. J. Le, Steel, S. J. and Louw, N. 1997. Variable selection and error rate estimation in discriminant analysis. Journal of Statistical Computation and Simulation, 59, 195-219.

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Effect of Conventional Tillage and Zero Tillage on Different Soil and Yield Parameters

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Abstract

Conservation and conventional tillage directly affects soil environment for crop production. Conservation tillage provides a layer of crop residue which increases soil fertility, soil erosion, leaching of fertilizer, pesticides and herbicides into the ground water. Studies conducted in different climate zones showed that no-tillage resulted in acidification of surface layer when continued for several years compared to conventional tillage. Some study shows Conservation tillage enhance water infiltration rate and reduce moisture evaporation from soil, while some other study stated slower water infiltration rate in no tillage soil then on tilled. surface tillage and no tillage instead of conventional tillage are to control soil erosion, enhance crop performance, and use energy more efficiently. Decomposition of crop residues kept on the soil surface possibly release allele-chemicals which further strengthen the inhibitory effects on weed seed germination and early growth and development of weed plant. As with impact of tillage on root distribution, no-tillage causes greater and deeper water accumulation in the soil profile and greater root growth. Higher labor, animal or equipment requirement is a major drawback of conventional tillage. Conservational tillage allows elimination of several operations, depending on the conservation tillage systems used. Observation of numerous studies reveals that zero-tillage is superior to conventional tillage resulting in higher yields. Similarly several studies reveals that crops grown under zero tillage have yields as similar as or better than those grown under conventional tillage.

Key words :

In moving the pattern of agriculture trend from traditional agriculture to modern agriculture, the use of energy has increased particularly fossil fuel resources. Tillage aims to create a soil environment favorable to plant growth. Different types of tillage systems have different tillage depths and capacity to change soil physical and chemical properties that affect the crop yield and quality (Strudley *et al.* 2008). Time and frequency of tillage also has significant effect on crop production (Stenberg *et al.* 1997). Important soil physical properties such as bulk density, penetration resistance, water infiltration, hydraulic conductivity and soil compaction are affected by tillage (Hamza and Anderson, 2005). Soil manipulation can change fertility status markedly and the changes may be manifested in good or poor performance of crops (Aiyellari *et al.* 2002). Zero tillage increases soil fertility, decreases soil erosion, leaching of fertilizer, pesticides and herbicides into the ground water. Conventional tillage and zero tillage defiantly affect soil aggregation and soil bulk density. Zero tillage improves activity of earth worm and other soil micro flora. Some studies showed that soil microbial activity was higher with conventional tillage due to better aeration. Numerous studies conducted in different climate zones showed that no-tillage resulted in acidification of surface layer when continued for several years compared to conventional tillage. Tillage of the soil stimulates microbial decomposition of soil organic matter, which results in emissions of CO_2 to the atmosphere (Cristina *et al.* 2010). Therefore, minimizing the amount of tillage promotes sequestration of carbon in the soil. In the last decades advancements in weed control methods and farm machinery now allow many crops to be grown with minimum tillage. According to Bhatt and kukul 2015 zero tillage enhance water infiltration rate and reduce moisture evaporation from soil, while some other study stated slower water infiltration rate in no tillage soil then on tilled. Soil organic carbon increases in no tillage due to higher residue on soil surface, while other work reported that higher organic matter in conventional tillage at upper soil layer (Sharma *et al.* 2016). In many ecological zones and on different soil types, crop response to tillage and indeed the economic viability of tillage systems are still subjects of investigation (Adamu and Abdulrazaq 2004). Several studies have shown that conventional tillage increased the yield of crops while some workers revealed that crops grown under zero tillage have yielded as similar as or better than those grown under conventional tillage, and other scientist revealed no yield difference between any tillage systems.

1. Tillage operations in various forms have been practiced from the very inception of growing plants. Primitive man used tools to disturb the soils for placing the seeds. Tillage is needed to make proper seed-bed, which varies with the crop to follow and largely depends upon soil types, nature of preceding crop and residue management systems. Tillage alters the physicochemical properties of soil by mixing the upper fertile profile with the lower profile. Seedling emergence is critical for better establishment of crop. Hence, it is important to ensure an adequate seed and soil contact to facilitate water movement into seed, which intern depends upon physical characters of seed bed, thus affect germination and plant stand (Bouaziz, 1987). Tillage helps in controlling weeds by burying weed seeds and emerged seedlings leaving a rough surface to hinder weed seed germination, expose underground parts of perennial weeds leading to their desiccation (Subbulakshmi, 2007). The resource-conservation and sustainability in agricultural technologies play a major role in modern agriculture. Recent trend of tillage demonstrates steps toward limiting mechanical manipulation of the soil. The goal in emphasizing surface tillage and no tillage instead of conventional tillage are to control soil erosion, enhance crop performance, and use energy more efficiently (Sprague, 1986). Recently, a new outlook to soil preservation by applying zero tillage becomes illustrious. Unsuitable management practices cause degradation in soil health (depletion of organic matter and other nutrients) as well as decline in crop productivity (Ramos et el., 2011). Any kind of conservation tillage (zero, strip, mulch, chisel, ridge and plow tillage, the latter with special plows that retain at least 30% plant residuals or plant mulch on the surface) provides safe land use from environmental, social and economic points of view (Moteva *et al.*, 2016). The zero tillage practices highly reduce water and wind erosion, enhance and preserve soil fertility, conserve nutrients and soil moisture, improve production and labor efficiency, reduce the specific energy

consumption and the production costs (Vrazhnov, 2013).

2. The objective of the paper is to compare the influence of conventional tillage and no-tillage technology on soil physical properties and other environmental effect. Scattered information about the advantages and disadvantages of conventional and zero tillage is there in the agriculture literature. A review of those studies will be advantageous to bring such information in a single envelop.

3. Tillage and environment

3.1. Energy use Conservation tillage in crop production is a greatest opportunities to conserve energy. The net energy and monetary return of a cropping system can be quantified for sound planning of sustainable systems (Chaudhary *et al*., 2006). An estimated 17 liters ha 1 of diesel-fuel equivalents (DFE = 41 MJ per liter) of energy is required for moldboard plowing to 20 cm depth. In contrast, chisel -plowing to 20 cm requires 1.18 and disking requires 0.64 liters ha 1 DFE (Frye, 1984). In no-tillage, tillage is eliminated and thus reduced energy consumption. Some, but not all, of the energy conservation is offset by slightly greater need for herbicides in no-tillage. Ozturnk *et al*., (2006) found that zero tillage recorded lower energy consumption compared to ploughed soils. Subbulakshmi, (2007) in her study reported that energy consumption was higher with conventional tillage while, lowest total energy was used by zero tillage. Even though lower energy consumption was recorded by zero tillage, higher energy output, net energy, energy use efficiency and energy productivity were higher with continuous conventional tillage due to increased crop productivity.

3.2 Soil physical properties

3.2.1 Soil compaction and bulk density: Soil compaction is related to soil physical properties such as soil textural parameters (e.g., sand, silt. and clay content), moisture content, bulk density, and cropping system, along with tillage practices (Taylor and Gardner, 1963). Bulk density is defined as the oven dry mass of soil per unit volume. Good soil structures are described by increased in soil macro aggregates and porosity. The bulk density is increase with increase in soil compaction, as compacting forces squeeze the volume of soil via eliminating pore spaces. Most of the field operations in the modern agriculture from sowing to harvesting are done mechanically by using heavy wheeled machines which can compact the soil at every passage (Williamson and Neilsen, 2000). The soil compaction by a machine, in general, depends on the soil strength and loading of machine (Alakukku *et al*., 2003). Soil compaction varies depending on the depth. Different technological operations of soil tillage demonstrate different effects on soil compaction of middle and deep layers. Soil compaction of middle layer only can be altered using conventional tillage methods such as ploughing, disking, and loosening by shallow cultivators. On the other hand, same machines cannot be used to reduce soil compaction of deeper layers. To the contrary, deep ploughing or disking might even lead to more compact soil of deeper layers (Sarauskis *et al*., 2011).

Blevins and Frye, (1993) at Kentucky revealed that, no significant effect on bulk density after 20 years of corn production compared no-tillage and moldboard-plow tillage. The surface of soil in moldboard-plow system had higher bulk density than the surface 0-5 cm of the no-tillage soil. Hill and Cruse (1985) reported no significant effect of tillage methods (no-tillage, conventional tillage, and minimum tillage) on bulk density of a loess-derived Iowa soil. Reduced yield of rice using zero tillage was observed due to higher strength and bulk density of surface soil layer (Sharma *et al*., 1988). Pratibha *et al*., (1994) reported that ploughing once with tractor drawn mould board plough plus rotavator twice resulted in lower bulk density and higher moisture availability. Similarly, Cavalaris and Gemtos, (2002) mould board ploughing created great stresses during tillage that caused shear planes and resulted in soil loosening. Bulk density in both the depths (0-8 cm, 8-16 cm) was highest in zero tillage treatment and lowest in conventional tillage due to natural soil consolidation and minimum disturbance of soil by tillage operation in zero tillage (John Anurag and Singh, 2007).

Conventional tillage can change significantly the soil physical properties within a growing season. For example, one experiment in France with conventional tillage shows bulk density increasing 15% to 20% from its initial value in a growing season of maize. The study also showed that the hydraulic conductivity decreased three to six times, according to the soil layer, and was negatively correlated with the bulk density (Alletto, *et al*., 2015). In the case of no tillage, changes in soil properties are observed only after several years. In a study conducted by Dam, *et al*., (2005) sandy loam soil with a monoculture of maize in Canada, over a period of 11 years, bulk density in a no tillage system increased only 10% at a depth of 0 to 10 cm compared to conventional tillage.

3.2.2. Soil water conservation During periods of water stress the capacity of a soil to supply water to plants is evaluated by the soil infiltration rate, soil water holding capacity, rate of evaporation, effective rooting depth, position of the landscape, and depth to the water table. Of these, tillage can significantly affect infiltration and evaporation in all soils and affects available water holding capacity and effective rooting depth in some soils. Arshad et al., (1999) coined higher water retention and infiltration rates under zero tilled plots which might be due to the redistribution of pore size classes into more small pores (Table 1). ZT wheat mulched plots dried at a slower pace than that of the CT un-mulched plots of wheat (Bhatt, 2015; Drury *et al*., 1999).

3.2.3 Water infiltration rate : Tillage and compaction significantly influence soil-hydraulic properties, infiltration, soil-water retention and soil-water flow (Klute, 1982; Onstad and Voorhees, 1987). Tillage can have both favorable and unfavorable effects on different physical properties of treated topsoil. Water infiltration into the soil profile and runoff losses in arable lands are related to the condition of the top layer. The tillage treatment (included no-till) of the top layer plays a key role in changes of the hydro-physical properties, mainly saturated hydraulic conductivity of the treated layer. Higher amounts of residue on the soil surface increases water infiltration (Lang and Mallett, 1984). Using conservation tillage practice reduces runoff (1.2 and 2.2%) and increase infiltration than ploughed soil (8.3 and 21.5%) at 1 and 15% slope respectively because of surface residues (Rockwood and Lal (1974). Lindstrom *et al*., (1984) stated that, no till treatment is results in higher bulk density, greater penetrometer resistance, and lower volume of macrospores and reduced infiltration rate. Gangwar et al., 2010 observed minimum infiltration rates in the zero tilled plots (0.75 cm

Table 1. Infiltration rate as affected by different tillage and crop residue management system (Soil type Silt Loam) (Source: Arshad *et al*., 1999)

Cumulative time (min)	Infiltration rate (cm h^{-1})	
	Convent-ional tillage	Zero tillage
10	25	25
20	12.5	12.5
25	6.5	9.7
33	4.5	6.8
78	4.6	6.5
120	4.5	6.3
150	4.4	6.2
185	4.2	6.2

h^{-1}) followed by plots where residue burned (1.44 cm h^{-1}) and highest in plots where residues incorporated (1.50 cm h^{-1}). They also observed detachment of soil particles from raindrop impact and subsequent soil crusting at a slower rate on no-tillage surface than on the tilled reducing the Infiltration rate.

3.3.4 Evaporation : As comparative to conventional tillage plant residue left on the soil surface reduces the rate of water evaporation in conservation tillage. Mulch provides protection against short-term but not long-term droughts. Bond and Willis (1969) stated that mulching provides protection against drought 7 to 14 days. Smika (1976) compared the effects of conventional, minimum and no-tillage treatments on soil water loss during a 34 day period following 165 mm of rainfall. At 34 days, soil with the conventional tillage treatment had dried to less than 0.1 cm cm-1 to 12 cm depth and the minimum tillage soil had dried to that water content to 9 cm depth. In contrast, soil with the no-tillage treatment dried to the 0.1 cm cm-1 water content only to 5 cm depth. Jasa (2007) back-calculated the 'water savings' of reduced- and no-till compared to a clean-tilled moldboard plow system, based on three extra bushels of soybean per extra inch of available water. His analysis was based on dry land data, from the Rogers Memorial Farm near Lincoln, Nebraska, in low rainfall years (2000 and 2006). He calculated that, in 2000, more than 200 mm (8 inches) of additional water was available for crop use by the no-till system, compared to a moldboard plow system, and more than 100 mm (4 inches) of additional water was available for crop use compared to a double-disk tillage system.

3.3.5 Soil Organic Carbon : The loss of carbon from agricultural soils has been, in part, attributed to tillage, a common practice providing a number of benefits to farmers. The promotion of less intensive tillage practices and no tillage aims to mitigate negative impacts on soil quality and to preserve soil organic carbon (Haddaway *et al.*, 2017). The comparison is made by Frye *et al.*, (1985) on a soil that is initially low in soil organic matter; the organic matter content will usually increase with conservation tillage, but remain fairly constant, or perhaps decrease further, with conventional tillage. Doran (1980) found that the organic carbon contents of surface soil (0-7.5 cm) with no-till averaged 1.25 and 1.20 (25 and 20%) times higher no-till than for conventionally tilled soil.

4. Tillage and crop environment

4.1 Distribution of Plant Root : Take up of nutrients and water depends upon distribution of plant root. Root systems serves as a bridge between the impacts of agricultural practices on soil and changes in shoot function and harvested yield (Klepper, 1990).Tillage affects root development and function, which by far the most important component in crop growth (Godwin, 1990). As with impact of tillage on root distribution, no-tillage causes greater and deeper water accumulation in the soil profile and greater root growth (Lampurlanés *et al.*, 2001). Merrill *et al.*, (1996) observes that spring wheat roots penetrate to greater soil depths under no tillage than under spring disking, with larger root length density due to the cooler soil and superior soil water conservation in the near-surface zone. However, no-tillage practice can gradually increase mechanical impediment of the surface soil, limiting the distribution of roots in the upper soil profile and root downward progression (Mosaddeghi *et al.*, 2009). Siridas *et al.*, (2001) recorded thicker barley roots under conventional tillage than under no tillage. Lampurlanes and Cantero- Martinez, 2003 stated that root length density profiles sometimes showed greater values for no tillage than for the other tillage systems, revealing a good soil condition for root growth under no tillage. Therefore, an increase in soil strength is observed under no tillage in the first year after its introduction and doesn't greatly affect root growth in well structured soils. Similarly Qin *et al.*, 2004.revealed that no tillage resulted in a slightly lower root length density and a slightly larger mean root diameter compared with conventional tillage.

4.2 weed control : Differential tillage systems placed the weed seeds at varying soil depths, where they may or may not able to receive the light, moisture and nutrients in ample amounts to germinate (Singh *et al.*, 2015). According to Clements *et al.*, (1996), lower total weeds at early crop growth stage with either country plough tillage or cultivator tillage against minimum tillage. Kandasamy and Krishna kumar (1997) observed that the effect of summer ploughing in reducing sedges was more pronounced. They also reported that tractor and power tiller puddling controlled most of the weeds except broad-leaved weeds in rice. Adequate tillage checks and delays the emergence of weeds and provides a more favorable environment for early crop establishment. In addition to this, decomposition of crop residues kept on the soil surface possibly release allele-chemicals which further strengthen the inhibitory effects on weed seed germination and early growth and development of weed plant. The studies on long-term trials on zero till have shown that Palmaris minor stand decreased over the three-year period because of the combined effect of the herbicides and zero tillage (Rice-Wheat Consortium and CIMMYT 2003). High input use without any significant yield gains and without compensating in the form of increased price of wheat have drained farmers of cash and squeezed them into financial difficulties. Zero tillage, therefore, can help farmers to pay for new herbicides. Any tillage system that leaves substantial mulch at the surface provides shading that may suppress weeds because the environment is unfavorable for germination of some weeds. Research has shown that rye killed in spring inhibits the growth of weeds (Smeda and Weller, 1988). No-till planting reduced emergence of hairy nightshade by 77 to 99% and Powell amaranth emergence by 50 to 87% compared with conventional tilled planting. Buhler *et al.* 1994) recorded higher density of perennial grass weeds in reduced tillage systems as the rooting depth of the soil was not disturbed. According to Peachey *et al.*, (2004) weed density increased as soil disturbance increased.

5. Tillage and Crop Economic

Higher labor, animal or equipment requirement is a major drawback of conventional tillage. Conservational tillage allows elimination of several operations, depending on the conservation tillage systems used. Maximum reduction in operations occurs with no-tillage system, but this system generally involves the use of herbicides to control weeds (Wiese et al., 1979). In India, widespread adoption of zero tillage method of cultivation was started in Haryana state. Resource conserving technologies such as zero tillage, surface seeding and raised bed in both rice and wheat have been found beneficial in terms of reducing cultivation cost and energy consumption and improving farmers income (Gupta and Seth, 2007). Savings in input cost, fuel consumption and irrigation water use have been reported due to zero tillage in wheat (Malik et al., 2002, 2003, Bhushan et al., 2007).

6. Tillage and crop Yield

Impact of tillage on crop yield is related to its effects on root growth (Boone & Veen, 1994), water and nutrient use efficiencies (Davis, 1994) and ultimately the agronomic yield (Lal, 1993). In contrast, a number of reviews have shown that no-till practices can reduce crop productivity due to the potential for soil water-logging and/or cooler soil temperatures which can inhibit crop establishment, compaction which can affect root growth, or altered soil fertility requirements which may lead to nutrient deficiencies (Alvarez and Steinbach, 2009, Ogle *et al*., 2012, Van den Putte *et al*., 2010). Mahli *et al.*, 1988 also stated that zero tillage resulted in lower yields than conventional tillage in barley. However, this was contrast to the findings of Brandt (1989) who observed that zero-tillage was superior to conventional tillage resulting in higher yields. Similarly several studies reveled that crops grown under zero tillage have yielded as similar as or better than those grown under conventional tillage (Mahli and Nyborg, 1990; McAndrew *et al*., 1994).

Conclusion

The technology to effectively cultivate crops utilizing a variety of conservation tillage strategies is accessible in the modern world to farmers. Crop residue management strategies and tillage techniques have been turned from a concept into a system that efficiently minimizes erosion, decreases soil degradation, is cost-effective, and is ecologically acceptable thanks to an alliance of farmers, scientists, and agribusiness. The constraints and suitability of adopting conservation tillage techniques are determined by soil characteristics and their biological surroundings.

References

Aiyellari, E. A. and Ndaeyo, Nyaudoh and Agboola, A. A. 2002. Effects of Tillage Practices on Growth and Yield of Cassava and some Soil Properties in Ibadan, Southwestern Nigeria. Tropicultura. 71.

Alakkuku, L., Weisskopf, P., Chamen, W. C. T., Tijink, F. G. J., Van der Linden, J. P. and Pires, S. 2003. Prevention strategies for field traffic-induced subsoil compaction: a review. Part1. Machine/soil interactions. Soil Tillage and Research. 73:145-160.

Alletto, L., Pot, V., Giuliano, S., Costes, M., Perdrieux, F. and Justes, E. 2015. Temporal variation in soil physical properties improves the water dynamics modeling in a conventionally-tilled soil. Geoderma , 243, 18-28.

Alvarez, R. and Steinbach. H. S. 200). A review of the effects of tillage systems on some soil physical properties, water content, nitrate availability and crop yield in the Argentine Pampas. Soil Tillage Resarch. 104: 1-15.

Arshad, M. A., Franzluebbers, A. J. and Azooz, R. H. 199). Components of surface soil structure under conventional and no-tillage in northwestern Canada. Soil Tillage Resarch. 53(1): 41-47.

Bhatt, R. and Kukal, S. S. 2015. Tillage residual effects on soil moisture dynamics after wheat during intervening period in rice-wheat sequence in South-Asia. Green Farming. 6(2): 744-749.

Blevins, R. L and. Frye, W. W. 1993. Conservation tillage: An ecological approach to soil management. Adv. Agron. 51:33-78.

Bond, J.J and Willis, W. O. 1969. Soil water evaporation: surfa ce residue rate and placement effects. Soil Sci. Soc. Amer. Proc. 33: 445-448.

Boone, F. R. and Veen, B. W. 1994. Mechanisms of Crop Responses to Soil Compaction. Soil compaction in crop production. Developments in Agricultural Engineering. 11: 237-264.

Bouaziz, A. 1987. Implantation of a tended wheat stand under dry conditions. Physical Analysis and Modeling. Doctoral thesis. Agricultural and Veterinary Institute Hassan II. Hort. Sci. 21: 1105-1112.

Cavalaris, C. K. and Gemtos, T. A. 2002. Evaluation of four conservation tillage methods in Sugar Beet crop. J. Sci. Res. Develop. 4: 1-23.

Chaudhary, V. P., Gangwar, B., Pandey, D. K, 2006. Auditing of energy use and output of different cropping systems in India. Agricultural Engineering International: The CIGR Journal of Scientific Research and Development VIII (June) (Manuscript EE 05 001).

Cristina Munoz, Leandro Paulino , Carlos Monrea , Erick Zagal. 2010. Greenhouse gas (CO_2 and N_2O) emissions from soils: a review. agr. res. 7:3.

Clements, David and L Benott, Diane and Murphy, Stephen and Swanton, Clarence. 1996. Tillage effects on Weed Seed Return and Seedbank Composition. Weed Science. 44. 314-322.

Dam, R. F., Mehdi, B.B., Burgess, M.S. E., Madramootoo, C. A., Mehuys, G. R. and Callum, I. R. 2005. Soil bulk density and crop yield under eleven consecutive years of corn with different tillage and residue practices in a sandy loam soil in central Canada. Soil Tillage Res. 84, 41-53.

Davis J. G. 1994. Managing Plant Nutrients for Optimum Water use Efficiency and Water Conservation. Advances in Agronomy.53: 85-120.

Doran, J. W. 1980. Soil microbial and biochemical changes associated with reduced tillage. Soil Sci. Soc. Am. J. 44: 765-771.

Drury, C. F., Tan, C. S., Welacky, T. W., Oloya, T. O., Hamill, A. S. and Weaver. S. E. 1999. Red clover and tillage influence soil temperature, moisture, and corn emergence. Agron. J. 91: 101-108.

Frye, W. W. 1984. Energy requirement in no tillage. No tillage agriculture: Principles and practices. Van Nostrand Reinhold. New York. 127-151.

Frye, W. W., Burnett, O. L. and Buntley, G. J. 1985. Restoration of crop productivity on eroded or degraded soils. In Soil Erosion and Crop Productivity, eds. R.F. Follet and B.A. Stewart. Madison, WI: American Society of Agronomy Journal. 335- 356.

Gangwar, K. S and H. R. Singh. 2010. Effect of rice (*Oryza sativa*) crop establishment techniques on succeeding crops. Ind. J. Agric. Sci. 80: 24-28.

Godwin, R. J. 1990. Agricultural Engineering in Development: Tillage for Crop Production in Areas of Low Rainfall. FAO, Rome. 124.

Gupta, R. K. and Seth, A. 2007. A review of resource conserving technologies for sustainable management of the rice wheat systems of the Indo-Gangetic plains. Crop Protection 26: 436-447.

Haddaway, Neal, R., Hedlund, Katarina and Jackson, Louise E. and Ktterer, Thomas and Lugato, Emanuele and Thomsen, Ingrid K. and Jorgensen, Helene B.and Isberg, Per-Erik. 2017. "How does tillage intensity affect soil organic carbon? A systematic review. Environmental Evidence. 6: 1-30.

Hamza, M. A. and Anderson, W. K. 2005. Soil compaction in cropping systems: A review of the nature, causes and possible solutions. Soil & Tillage Research, 82: 121-145.

Hill, R. L and Cruse, R. M. 1985. Tillage effects on bulk density and soil strength of two Mollisols. Soil Sci. Soc. Am. J. 49: 1270-1273.

Jasa, P. (2007). Water savings with residue management and no-till. Cropwatch, April 27, 2007. http://cropwatch.unl.edu/archives/2007/crop9/water_savings.html.

John, Anurag P. and Singh, R. K. 2007. Effect of different tillage practices and planting techniques in rice-wheat cropping system on crop productivity and soil fertility under mollisols of Pantnagar. Allahabad Farmer 15(2): 47-52.

Kandasamy, O. S., and Krishnakumar, L. 1997. Effect of tillage systems and weed management practices in two transplanted lowland rice crops grown in sequence. Acta Agronomica Hungarica 45 : 63-67.

Klepper, B. 1990. Root growth and water uptake. In: Stewart, B. A., Nielsen, D. R. (Eds.), Irrigation of Agricultural Crops. 281-322.

Klute, A. 1982. Tillage effects on the hydraulic properties of soils: A review. ASA Spec. Publ. 44: 29-42.

Lal, R. 1993. Tillage effects on soil degradation, soil resilience, soil quality, and sustainability. Soil and Tillage Research. 27(1-4): 1-8.

Lampurlanes, J., Angás, P., Cantero-Martínez, C. 2001. Root growth: soil water content and yield of barley under different tillage systems on two soils in semiarid conditions. Field Crop Res. 69, 27-40.

Lampurlanes, J. and Cantero-Martínez, C. 2003. Soil Bulk Density and Penetration Resistance under Different Tillage and Crop Management Systems and Their Relationship with Barley Root Growth. Agron. J. 95: 526-536.

Lang, P. M. and Mallett, J. B. 1984. Effect of the amount of surface maize residue on infiltration and soil loss from a clay loam soil. South Afr. J. Plant Soil. 1:97-98.

Lindstrom, M. J., Voorhees, W. B. and Onstad, C. A. 1984. Tillage system and residue cover effects on infiltration in northwestern corn belt soils. J. Soil Water Conser. 39: 64- 68.

Malhi, Sukhdev and Nyborg, M. 1990. Effect of tillage and straw on yield and N uptake of barley grown under different N fertility regimes. Soil and Tillage Research. 17. 115-124.

Malik, R. K., Yadav, A., Singh, S., Malik, R. S., Balyan, R. S., Banga, R. S, Sardana, P. K., Jaipal, S., Hobbs, P. R., Gill, G., Singh, S., Gupta, R. K., Bellinder, R. 2002. Herbicide resistant management and evolution of zero tillage-a success story. Research Bulletin, CCS. Haryana Agricultura University, Hisar, India. 43p.

Malik, R. K., Yadav, A., Singh, S., Sardana, P. K., Gill, G., Hobbs, P. R., Bellinder, R. 2003. Herbicide resistance management and introduction of zero tillage in wheat in India. Proc. Weed Sci. Soc. Am. 43:55.

McAndrew, D. W. and Fuller, L. G. and Wetter, L. G. 1994. Grain and straw yields of barley under four tillage systems in northeastern Alberta. Canadian Journal of Plant Science. 74. 713-722.

Merrill, S. D., Black, A. L., Bauer, A. 1996. Conservation tillage affects root growth of dry land spring wheat under drought. Soil Sci. Soc. Am. J. 60: 575-583.

Mosaddeghi, M. R., Mahboubi, A. A., Safadoust, A. 2009. Short-term effects of tillage and manure on some soil physical properties and wheat root growth in a sandy loam soil in western Iran. Soil Till. Res 104: 173-179.

Moteva, Milena and Kostadinov, Georgi and Spalevic, Velibor and Georgieva, Veska and Tanaskovik, Vjekoslav and Koleva, Natalia. 2016. Sweet Corn - Conventional Tillage vs. No-tillage in Humid Conditions. Agriculture and forestry. Vol 63(1): 17-25.

Ogle, S. M., Swan, A., and Paustian, K. 2012. No-till management impacts on crop roductivity, carbon input and soil carbon sequestration Agric. Ecosystem Environ. 149: 37-49.

Onstad, C. A. and Voorhees, W. B. 1987. Hydrologic soil parameters affected by tillage. Nitrates and Pesticides. Lewis Pubs. 95-112.

Ozturk, H. H., Ekinci, K., Barut, Z. B. 2006. Energy analysis of the tillage systems in second crop corn production. J. Sustainable Agric. 28(3): 25-37.

Peachey, R. E., William, R. D. and Smith, C. M. 2004. Effect of no-till or conventional planting and cover crops residues on weed emergence in vegetable row crop. Weed Tech. 18: 1023-1030.

Pratibha, G. 1994. Sustainability in Oilseeds. Ind. Soc. Oil Seeds Res. 33: 297-301.

Qin, R., P. Stamp and Richner, W. 2004. Impact of tillage on root systems of winter wheat. Agron. J., 96: 1523-1530.

Ramos, M. E., Robles, A. B., Sánchez-Navarro, A. and Gonzalez-Rebollar, J. L. 2011. Soil responses to different management practices in rainfed orchards in semiarid environments. Soil and Tillage Research. 112(1): 85-91.

Rockwood and Rattan Lal. 1974. No-tillage effects on soil properties and maize (*Zea mays* L.) production in Western Nigeria. Plant and Soil 40: 321-331.

Sharma, Peeyush and Abrol, Vikas and R. Sharma, K. and Sharma, Neetu and Phogat, V. K. and Vikas, Vishaw. 2016. Impact of Conservation Tillage on Soil Organic Carbon and Physical Properties -a Review. International Journal of Bio-resource and Stress Management. 7: 151-161.

Sarauskis, E., Romaneckas, K., Vaiciukevicius, E., Jasinskas A., Sakalauskas A., Buragiene S., Katkevicius E., Karayel, D. 2011. Effect of environmentally friendly tillage machinery on soil properties. Proceedings of 10 th International scientific conference, Engineering for Rural Development., Jelgava, Latvia, pp. 70-75.

Sidiras, N and Bilalis, D. and Vavoulidou, E. 2001. Effects of Tillage and Fertilization on Some Selected Physical Properties of Soil (0-30 cm Depth) and on the Root Growth Dynamic of Winter Barley. Journal of Agronomy and Crop Science. 187: 167-176.

Singh, M., Bhullar, M. S. and Chauhan, B. S. 2015. Seed bank dynamics and emergence pattern of weeds as affected by tillage systems in dry directseeded rice. Crop Protect. 67: 168-177.

Smeda, R. J. and Weller, S. C. 1988. Factors influencing the effectiveness of rye for weed management in transplanted tomatoes, Proc-North Cent. Weed Control conf. 43: 12.

Smika, D. E.1976. Mechanical tiliage for conservation fallow in the semi-arid central Great Plains. GPAC 77:78-92.

Sprague, M. A. 195). The substitution of chemicals for tillage in pasture renovation. Agron. J. 44: 405-409.

Strudley, M. W. and Green, T. R. 2008. Tillage effect on soil hydraulic properties in space and time: State of the science Soil and Tillage research. 99(1): 4-48.

Taylor H. M. and Gardner H. R. 1963. Penetration of cotton seedling taproots as influenced by bulk density, moisture content and strength of soil. Soil Science 96 (3): 153-156.

Van den Putte, A., Govers, G., Diels, J., Langhans, C., Clymans, W., Vanuytrecht, E., Merckx, R., Raes, D. 2012. Soil functioning and conservation tillage in the Belgian loam belt. Soil Till. Res. 122: 1-11.

Vrazhnov, A.V. (2013). Efficiency of minimizing of tillage. Journal "Zauralie fields 9:109

Wiese, A. F., Unger, P. W., Allen, R. R. and Musick, J. T. 1979. Herbicides make limited tillage work. In " What's New in Water Conservation?. Proc. Crop Prod. and Utiliz. Symp 1-6.

Williamson, J., Neilsen, W. 2000. The influence of forest site on rate and extent of soil compaction and profile disturbance of skid trails during ground-based harvesting. Candian Journal of Forest Research. 30: 1196-1205.