Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(5): 3161-3165
Received: 15-07-2018
Accepted: 19-08-2018

Nilotpal Hazarika
Department of Agronomy, Assam Agricultural University, Jorhat, Assam, India

Mohan Kumar Sarmah
Department of Agronomy, Assam Agricultural University, Jorhat, Assam, India

Anjali Basumatary
Department of Soil Science, Assam Agricultural University, Jorhat, Assam, India

Correspondence
Nilotpal Hazarika
Department of Agronomy, Assam Agricultural University, Jorhat, Assam, India

Tillage and integrated nutrient management effect the soil properties and yield of rice: A review

Nilotpal Hazarika, Mohan Kumar Sarmah and Anjali Basumatary

Abstract
Excessive or inappropriate tillage practices cause negative effect on soil properties and yield. Conventional tillage practices affect long term soil properties due to erosion and loss of organic matter in soil. Minimum and zero tillage systems generate higher yield, increase water content, reduce erosion and other forms of land degradation. Continuous use of chemical fertilizer alone creates various problems in the environment. Combined application of manure and chemical fertilizer to soil increase the available N, P, K status of soil and improve the organic carbon content of soil as well as increase crop yield.

Keywords: Conventional tillage, minimum tillage, zero tillage, vermicompost, enriched compost

Introduction
Tillage is the important factor affecting soil properties and crop yield. Proper tillage and stubble management practices improved the physico-chemical and biological properties of soil. Soil physical factor such as organic matter content, aggregation, porosity, bulk density, moisture content etc are influenced by tillage. Normal tillage results in desirable physical changes in soil environment which ultimately reflect the higher yield of crops. Continuous use of chemical fertilizer alone create various problems to environment. Some of the works done relating to the "Tillage and Integrated Nutrient Management effect the soil properties and yield of rice" have been reviewed under following heads:

Tillage
1. Effect of tillage on soil properties
2. Effect of tillage on yield

Integrated nutrient management
1. Effect of INM over chemical fertilizer
2. Residual effect of INM over succeeding crop

Effect of tillage on soil properties
According to Lal (1997a) [32], no-till system improve soil physical properties than tillage-based systems. Significantly better soil quality parameters *viz.*, Soil organic carbon (SOC) concentration, bulk density and moisture content were found under conservation tillage than conventional tillage (CT) (Bhattacharyya *et al*. 2006) [9]. Lal *et al.*(2007) [33] reported that no-till technologies reduce soil and crop residue disturbance, moderating soil evaporation, minimizing erosion losses and more stable aggregates in the upper surface of soil have been associated with no-till soils than tilled soils. Jacobs *et al*. (2009) [20] observed that minimum tillage (MT) improve aggregate stability, increased the SOC concentrations and N within the aggregates in the upper 5-8cm soil depth after 37-40 years of tillage treatments compared to CT. Pagliai *et al*. (2004) [38] found that MT increase the storage pores (0.5-50mm) and the amount of the elongated transmission pores (50-500mm) which improve the soil pore system. Su *et al*. (2007) [55] found that the soil water storage quantity 25% higher in zero tillage (ZT) than CT, WUE also significantly higher in ZT than CT and RT during a six year of study. Busari and Salako (2012) [13] reported that at the end of first year of study, higher unsaturated water flow parameters and infiltration rate under CT and MT than ZT but ZT had higher infiltration parameters than CT at the end of the second year. They also observed significantly higher pH at the end of the first year under ZT but the pH became significantly lower than CT soil at the end of the second year after tillage. The SOC and effective cation exchange capacity (ECEC) were significantly higher under ZT than CT at the end of two years of study.

Kemper *et al*. (1987) [24] found that less intense tillage kept the crop residue at the soil surface, increased the activity of surface-feeding earthworms and leaving the root channels undisturbed, which ultimately leads to the presence of numerous surface-connected macro-pores and inter-pedal voids resulting in higher infiltration. More favourable soil chemical properties of the surface layer are found with no-till than tilled soil (Lal, 1997b) [31]. No effect on soil pH under tillage technique Ramussen (1999) [43] but Rahman *et al*. (2008) [41] reported that no-till system has lower soil pH than CT. Ali *et al*. (2006) [3] reported that conventional till plots recorded the lowest values of soil OM, N, P, K, Ca and Mg and it could be due to ploughing inverse the top soil and shifts less fertile subsoil to the surface in addition to possible leaching. Kushwaha *et al*. (2001) [30] reported that the MT and residue- retained treatment recorded the highest SOC and total N than CT and residue-removed treatment. Maurya (1986) [36] observed that more organic carbon in no tillage plots than the tilled plots, respective of the residue treatment. As compared with other treatments, no tillage plus residue plots had high organic carbon content throughout the soil profile. Tilled plot without residue had least SOC. Significantly higher bulk density as well as penetration tillage in the 0-5 and 5-10cm soil profile was found under ZT direct seeded rice and ZT wheat than other CT systems (puddling in rice and repeated dry tillage in wheat) but these were higher under CT in the 10-15 and 15-20cm soil layer as compared to zero tillage/no puddling treatments (Jat *et al*., 2009) [21]. According to EI-Gohary (1978) [17], bulk density decreased with increasing the ploughing depth and the ploughing process increase in values of total porosity than the corresponding depth of ZT.

Effect of tillage on yield

Crop yield is related to the affects of root growth (Boon and Veen, 1994) [10], water and nutrient use efficiencies (Davis, 1994) [16] which are effected by tillage. Gosh *et al*. (2010) [18] observed that lower yield obtained in CT practice than ZT or MT in *kharif* upland rice and winter rice. This could be attributed to more water loss from tilled soil in comparision to ZT or MT. ZT also improves soil condition and its fertility status. Statistically similar grain yield obtained in direct seeded CT plots and direct seeded ZT plots of rice and wheat after 4 years of cropping (Bhattacharyya *et al*., 2008) [8]. Kumar (2008) [28] found that broadcast sprouted seed after puddling give higher yield (51.8q/ha) than broadcast sprouted seed without puddling, drum seeding after puddling, drum seeding without puddling and ZT but statistically same with CT (51.8q/ha). Rice grain yield obtained in reduced and no tillage system comparable to rice grown in CT system. The production costs of rice using reduced and no tillage systems were lower than the CT system. Therefore, reduced or no tillage systems produced higher net returns than the CT (Sharma and De Datta, 1986) [51]. Sarmah *et al*. (1988) [52] reported that, MT produced the similar gran yield as through puddling in clay soil. In direct seeded rice (DSR), rice yield was statistically at par in case of ZT when compared with the CT system (Bhattacharyya *et al*., 2006) [9]. Singh *et al*. (2008) [54] reported that direct seeding ZT gave at par yield as compared with transplanted (TP) rice. ZT produce rice grain yield (6.36 and 6.74t/ha) was similar to the puddle transplant (6.36 and 6.72t/ha) in 2002 and 2003, respectively (Reddy *et al*., 2005) [45]. The direct seeded ZT plots of rice and wheat had similar grain yield as the direct seeded CT plots after 4 years of cropping (Bhattacharyya, 2008) [8]. Sharma *et al*. (1995) [49] observed that the higher total productivity of 9.3t/ha was recorded under direct seeded, puddle condition followed by transplanting (9.1t/ha) and direct seeded dry condition (8.99t/ha). Due to labour saving under direct seeded, puddle condition higher net returns of Rs. 14741/ha was obtained compared with Rs 498/ha under direct seeded, dry condition and Rs 12981/ha under TP . Shad and De-Datta (1986) [48] showed two experiments on land preparation practices, consisting of ZT, MT and CT treatments, revealed that CT was the best practice in terms of grain yield, and tiller number followed by MT and ZT, respectively. Sharma *et al*. (1988) [52] found that, the root volume increased by increasing intensity of tillage. Increase in root volume means an increase in nutrient uptake by the root, which may explain the higher grain yield in tilled than in untilled treatments. Zein El-Din (2000) [60] studied the effect of different plowing and planting methods on rice crop yield (Chisel ploughing twice and moldboard ploughing followed by harrowing). He found that increasing tillage practices did not increase both 1000-grain weight and total yield for manual transplanting and broadcasting systems significantly. Lillard *et al*. (1964) [35] found that the average yield from the no tillage plots were the highest on the early planting and lowest on the late planting in comparison to conventional tillage. Basiliob (1967) [6] studied the effect of three methods of land preparations (ploughing), (ploughing + rotovator) and (ploughing+ harrowing) on grain yield of rice. He found that (ploughing+ harrowing) treatments gave the maximum yield than the other methods.

Effect of INM over chemical fertilizer

Kumarjit Singh *et al*. (2005) [29] reported that increased organic carbon content in post harvest soils of rice with the application of vermicompost plus inorganic fertilizers. Increase in organic carbon content due to use of chemical fertilizers over control can also be attributed to higher contribution of biomass to the soil in the form of stubbles and residues (Bajpai *et al*. 2006) [5]. Virdia and Mehta (2009) [58] reported that available phosphorus content increased with the application of vermicompost plus chemical fertilizers as compared to chemical fertilizer alone and this might be due to mineralization of added P. The integrated use of vermicomposts from different sources and chemical fertilizers with 75% and 50% of recommended dose of nitrogen provide higher grain and straw yield of rice. This might be due to higher availability and uptake of macro and micro nutrients, occurrence of different beneficial microorganisms, presence of growth promoting substances, hormones, enzymes, antibiotics etc., in vermicompost resulting in better growth and dry matter production (Prasad *et al*. 2010) [40]. Brar *et al*. (1995) [11] observed that application of manure with chemical fertilizer to soil increased the available N, P, K status of soil and improved the organic carbon content of soil in rice-wheat rotation. Prasad *et al*. (1995) [39] reported that the integrated use of manure with chemical fertilizer resulted in build-up of available nutrients in soil much more effectively than that of chemical fertilizer alone. Significant increases in paddy grain yield and yield attributes with the application of available farm manures (compost, sesbania green manure and farm yard manure) with mineral fertilizer (Sarwar *et al*., 2008) [46], (Buri *et al*., 2012) [12]. Sharma (2013) [53] indicated that when 50% N through farm yard manure and 50% NPK was applied in rice-wheat cropping system the growth, development, yield attributes of rice was found to be the best. Ali *et al*. (2009) [4] reported that application of 70% of recommended dose of chemical fertilizers and 3 tones poultry manure ha^{-1} significantly increased the grain and straw yield of rice (5.52t ha^{-1} and 6.73t ha^{-1}, respectively) than 70% NPKS alone and the control. Ranjitha *et al*. (2013) [42] indicated that application of 50% recommended dose of nitrogen through urea + 50% recommended dose of nitrogen through vermicompost recorded the significantly maximum grain and straw yield of rice. Larijani and Hoseini (2012) [34] found that combined use of organic and chemical fertilizer increased the tiller number (28%), more panicle/m^2 (60%), number of filled grains/m^2 (20.6%), spikelet per panicle (19.6%) and more grain yield (30.6%) compared with chemical fertilizer alone. Application of 100% recommended dose of nitrogen from urea significantly influenced the yield of rice in 1st year of experiment but significantly highest grain and straw yield of rice produced with the application of 50% recommended dose of nitrogen from vermicompost and the rest through chemical fertilizer (urea) during the 2nd year of experiment in rice-wheat cropping system (Koushal *et al*., 2011) [26]. Kumar *et al*. (2014) [27] reported that application of 125% RDF + 5t ha^{-1} vermicompost was increased the number of panicles (20.5%), panicle length (23.12%), panicle weight (13.02%), 1000 grain weight (12.90%), grain yield (31.15%) and straw yield (37.12%) over the control and the individual nutrient sources. Virdia and Mehta (2009) [58] found that the application of organic fertilizer along with recommended dose of fertilizer (RDF) gave numerically higher uptake value of N, P, K in grain, straw and total uptake than only RDF treatment. Sen and Bandyopadhya (2001) [47] reported that significantly higher yield of rice (both grain and straw) produced with the application of chemical fertilizers supplemented through organic manure than chemical fertilizer alone. Higher N concentration in rice grain (1.7%) and straw (1.08%) was obtained in case of city compost combined with urea. Vasanthi and Kumarswamy (1996) [57] reported that application of vermicompost plus recommended levels of N, P and K fertilizer increased grain yield of rice. Ravi and Srivastava (1997) [44] observed that increased plant height, grain yield and yield components of rice with supplying one third or one quarter of N as vermicompost as compared with N fertilizer alone. Integrated application of vermicompost, fertilizer N and biofertilizers *viz*., Azospirillum and phosphobacteria increased rice yield by 15.9% over application with fertilizer N alone (Jeyabal and Kuppuswamy, 2001) [22]. Das *et al*. (2002) [15] found that application of 50% vermicompost plus 50% chemical fertilizers gaves the best results in terms of straw and yield of rice. Ahmed *et al*. (2001) [1] reported that application of 20ton/ha green manure plus 150-100-100kg/ha N, P, K recorded maximum tillers per plant, paddy and straw yield of rice. Sudha and Chandini (2003) [56] reported that application of vermicompost at 5t/ha along with the N,P,K dose of 105: 52.5: 52.5kg/ha supplied through inorganic sources had positive influence on growth and yield attributes of rice and resulted in a better grain yield of 4.54t/ha and straw yield of 5.15t/ha. Khan *et al*. (2004) [25] reported that application of organic manure and fertilizer resulted higher rice yield due to improvement in soil properties, as organic manure is being rich in nutrients, especially nitrogen. Das *et al*. (2010) [14] at Meghalaya observed higher values of yield and yield attributes with composts prepared with microbial and nutrient fortified compost (enriched with microbial culture, rock phosphate and neem cake) compared to that with microbial enriched compost (microbial culture alone). Gogoi *et al*. (2010) [19] found significantly higher effective tillers/m^2, panicle length, filled grain/panicle, test weight and grain yield of rice with the substitution of 50% N with farmyard manure over control and RDF (60: 20: 40kg N,P,K per ha). Nath *et al*. (2011) [37] reported that INM treatment which received 25% NP coupled with enriched compost (2t/ha) gave significantly higher rice yield (3.68t/ha) compared to recommended dose of fertilizer (40:20:20kg NPK ha^{-1}). Ahmed *et al*. (2007) [2] observed that enriched compost in the presence of 50% N fertilizer cause significant increases in N, P, K contents (76.2, 54.6 and 63% respectively) over control and also showed superiority (upto 5.7%) over full dose of chemical fertilizer alone. Zahir *et al*. (2007) [59] found significantly improved plant height, number of tillers per hill, panicle length, number of grains per panicle, 1000 grain weight, total biomass, straw weight and paddy yield by 14, 43, 30, 23, 18, 40, 45 and 74 percent, respectively with integrated application of enriched compost and 50 percent N fertilizer compared with untreated control.

Residual effect of INM over succeeding crop

The increased yield of wheat crops through residual effect of FYM or green manuring plus 100% recommended dose of N,P,K over 100% recommended dose of N,P,K. Addition of FYM or green manure resulted in build up of soil N, P, K, Zn, organic carbon and reduced the soil pH (Sharma *et al*., 2001) [50]. Kalita (1999) [23] conducted an experiment on linseed sown as relay in rice at Jorhat. He found that fertilizer level of 80-40-40 N, P_2O_5, K_2O per ha showed superiority in result of yield, growth and nutrient uptake of rice and its residual effect showed significantly the highest growth and yield of relay crop linseed. Bezbaruha *et al*. (2009) [7] conducted an experiment on the direct effect of organic and inorganic sources of nutrients on the production potential of upland rice (*Oryza sativa* L.) and to assess their residual effect on succeeding winter crops *viz*., linseed (*Linum usitatissimum* L.), niger (*Guizotia abyssinica* L.) and barley (*Hordeum vulgare* L.). 25% N through VC + 75% NPK through chemical fertilizer gave significantly higher rice grain yield and biomass yield as compared with vermicompost (VC) and FYM alone treatments. This might be due to the indirect effects of organic manures to the soil, such as moisture retention and addition of macro and micronutrients and continuous supply of macro and micronutrients in a balance form for a longer period through vermicompost. Application of either VC or FYM alone gave lower rice grain yield. This might be due to N immobilization and/or slow release of major and minor nutrients. The winter crops grown under 100% N through VC produced the maximum grain yield of linseed (0.76 and 0.86Mg ha^{-1}), niger (0.35 and 0.41Mg ha^{-1}) and barley(1.24 and 1.3Mg ha^{-1}) in 2003-04 and 2004-05, respectively. Increase in the grain yield of following winter crops was due to residual effect of vermicompost or farmyard manure, which might be due to the slow release of major and minor nutrients.

Conclusion

Tillage and integrated nutrient management are the important factors affecting the soil properties and yield. Conservation tillage practices improve the soil properties and maintain crop yield. Integrated use of manure with chemical fertilizer resulted in build up of available nutrient in soil much more effectively than chemical fertilizer alone.

References

1. Ahmed R, Ranjha AM, Medhi SM, Hussain MJ, Sarfraz M, Hassan G. Integrated use of organic manures and fertilizers in rice-wheat cropping system. Pakistan J Biol. Sci. 2001; 4(3):184-186.

2. Ahmed R, Shahzad SM, Khalid A, Muhammad A, Muhammad HM. Growth and yield response of wheat (*Triticum aestivum* L) and maize (*Zea mays* L) to nitrogen and L-tryptophan enriched compost. Pakistan J. Bot. 2007; 39(2):541-549.
3. Ali A, Ayuba SA, Ojeniyi SO. Effect of tillage and fertilizer on soil chemical properties, leaf nutrient content and yield of soyabean in the Guinea savanna zone of Nigeria. Nigerian J Soil Sci. 2006; 16:126-130
4. Ali ME, Islam MR, Jahiruddin M. Effect of Integrated Use of Organic Manures with Chemical Fertilizers in the Rice-Rice Cropping System and Its Impact on Soil Health. Bangladesh J Agril. Res. 2009; 34(1):81-90.
5. Bajpai RK, Chitale, Shrikant, Upadhyay SK, Urkurkar JS. Long term studies on soil physico-chemical properties and productivity of rice-wheat system as influenced by INM in Inceptisol of Chhattisgarh. J Indian Soc. Soil Sci. 2006; 54(1):24-29.
6. Basiliob M. Tillage techniques and planting methods of lowland rice. M.Sc. Thesis, U.P. Collage of Agric. Philippines, 1967.
7. Bezbaruha R, Sharma RC, Banik P. Direct and residual effect of organic and inorganic sources of nutrients on rice based cropping systems in the subhumid tropics of India. J Sustainable Agric. 2009; 33:674-689.
8. Bhattacharyya R, Kundu S, Pandey SC, Singh KP, Gupta HS. Tillage and irrigation effects on crop yields and soil properties under the rice-wheat system in the Indian Himalayas. Agric. water management. 2008; 95:993-1002.
9. Bhattacharyya R, Singh RD, Chandra S, Kundu S, Gupta HS. Effect of tillage and irrigation on yield and soil properties under rice (*Oryza sativa*)- wheat (*Triticum aestivum*) system on a sandy clay loam soil of Uttaranchal. Indian J Agric Sci. 2006; 76:405-409.
10. Boone FR, Veen DE. Mechanisms of crop responses to soil compaction B.D. Soane, C. Van Ouwerkerk (Eds.), Soil compaction in crop production, Elsevier, New York, 1994, 237-264.
11. Brar BS, Dhillon NS, Chand M. Effect of FYM application on grain yield, uptake and availability of nutrients in rice-wheat rotation. Indian J agric. Sci. 1995; 65:350-53.
12. Buri MM, Issaka RN, Wakatsuki T, Kawano N. Improving the Productivity of Lowland Soils for Rice Cultivation in Ghana: The role of the ‘Sawah’ system. J Soil Sci. and Environ. Mgt. 2012; 3(3):56-62.
13. Busari MA, Salako FK. Effect of tillage and poultry manure application on soil infiltration rate and maize root growth in a sandy Alfisol Agro-science. J Tropic. Agric., Food, Environ. and Ext. 2012; 11:24-31
14. Das A, Baiswar P, Patel DP, Munda GC, Ghosh PK, Chandra S. Productivity, nutrient harvest index, nutrient balance sheet and economics of lowland rice (*Oryza sativa*) as influenced by composts made from locally available plant biomass. Indian J Agric. Sci. 2010; 80(8):686-690.
15. Das PK, Jena MK, Sahoo KC. Effect of integrated application of Vermicompost and and chemical fertilizer on growth and yield of paddy in red soi of South Eastern Ghat zone of Orissa. Environ. Ecol. 2002; 20(1):13-15.
16. Davis JG. Managing plant nutrients for optimum water use efficiency and water conservation. Advances in Agronomy. 1994; 53:85-120.
17. El- Gohary EAA. Study of some soil physical properties effect of ploughing depth on some soil physical properties, cotton growth and yield in ~lay soil. M.Sc. Thesis, Fac. Of Agric., Tanta University, U.A.R, 1978.
18. Ghosh PK, Das A, Saha R, Kharkrang E, Tripathy AK, Munda GC, Ngachan SV. Conservation agriculture towards achieving food security in north east India. Curr. sci. 2010; 99(7):915-921.
19. Gogoi B, Barua NG, Baruah TC. Influence of integrated nutrient mangement on crop yield in rainfed rice-niger cropping sequence. *Oryza*. 2010; 47(3):221-226.
20. Jacobs A, Rauber R, Ludwig B. Impact of reduced tillage on carbon and nitrogen storage of two Haplic Luvisols after 40 years. Soil and Tillage Res. 2009; 102:158-164.
21. Jat ML, Gathala MK, Ladha JK, Saharawat YS, Jat AS, Kumar V, Sharma SK, Kumar V, Gupta R. Evolution of precision land levelling and double zero till systems in the rice-wheat rotation: water use, productivity, profitability and soil physical properties. Soil Till. Res. 2009; 105:112-121
22. Jeyabal A, Kuppuswamy G. Recycling of organic wastes for the production of Vermicompost and its response in rice-legume cropping system and soil fertility. European J Agron. 2001; 15(3):153-170
23. Kalita J. Effect of fertility and sowing density in rice linseed relay cropping. M.Sc (Agri) thesis submitted to Assam Agricultural University, Jorhat, 1999.
24. Kemper WD, Trout TJ, Segeren A, Bullock M. Worms and water. J Soil and Water Conserv. 1987; 42:401-404
25. Khan AR, Chandra C, Nanda P, Singh SS, Ghori AK, Singh SR. Integrated nutrient management for sustainable rice production. Arch. Agron. Soil Sci. 2004; 50:161-165.
26. Koushal S, Sharma AK, Singh A. Yield performance, Economics and Soil Fertility through Direct and Residual Effects of Organic and Inorganic Sources of Nitrogen as Substitute to Chemical Fertilizer in Rice-Wheat Cropping System. Research Journal of Agricultural Science. 2011; 43(3):189-193.
27. Kumar A, Meena RN, Yadav L, Gilotia YK. Effect of Organic and Inorganic Sources of Nutrient on Yield, Yield Attributes and Nutrient Uptake of Rice. Rice, Cv. Prh-10. Int. Quart. J Life Sci. 2014; 9(2):595-597.
28. Kumar D. Influence of different planting techniques and levels of nitrogen on rice (*Oryza sativa*) M.Sc. Thesis, Punjab Agricultural University, Ludhiana, Punjab, India, 2008.
29. Kumarjit Singh RK, Herojit Singh Athokpam, Zoliana Changteand, Gopimohon Singh N. Integrated Management of Azolla, Vermicompost and Urea onyield and nutrient uptake by rice and soil fertility. J Indian Soc. Soil Sci. 2005; 53(1):107-11
30. Kushwuha CP, Tripathi SK, Singh KP. Soil organic matter and water stable aggregates under different tillage and residue conditions in a tropical dry land agro ecosystem. Applied soil Ecology. 2001; 16(3):229-241.
31. La1 R. Long-term tillage and maize monoculture effects on a tropical Alfisol in western Nigeria. II. Soil chemical properties. Soil and Tillage Res. 1997b; 42:161-174
32. Lal, R. Long-term tillage and maize monoculture effects on a tropical Alfisol in western Nigeria. I. Crop yield and soil physical properties. Soil and Tillage Res. 1997a; 42:145-160
33. Lal R, Reicosky DC, Hanson JD. Evolution of the plow over 10000 years and the rationale for no till farming. Soil and Tillage Res. 2007; 93:1-12.

34. Larijani BA, Hoseini SJ. Comparison of Integrated Chemical and Organic Fertilizer Management on Rice Growth and Yield under System of Rice Intensification (SRI). Int. J Agron. Plant Prod. 2012; 3(S):726-731.
35. Lillard JH, Jones HN. Planting and seed environment problems with corn in killed on seedbeds. Transactions of the ASAE. 1964; 7(3):204-208.
36. Maurya PR. Effect of tillage and residue management on maize and wheat yield and on physical properties of an irrigated sandy-loam soil in Northern Nigeria. Soil and Tillage Res. 1986; 8:161-170
37. Nath DJ, Ozah B, Baruah R, Baruah RC, Borah DK. Effect of integrated nutrient management on soil enzymes, microbial biomass carbon and bacterial population under rice (*Oryza sativa*)- wheat (*Triticum aestivum*) sequence. Indian J Agric. Sci. 2011; 81(12):1143-1148.
38. Pagliai M, Vignozzi N, Pellegrini S. Soil structure and the effect of management practices. Soil and Tillage Res. 2004; 79:131-143
39. Prasad B, Prasad J, Prasad R. Effect of nutrient management for sustainable rice and wheat production in calcareous soil amended with green manure, Organic Manure and Zn. Fert News. 1995; 40:39-45
40. Prasad J, Kurmakar S, Kumar R, Mishra B. Influence of Integrated Nutrient Management on yield and soil properties in maize-wheat cropping system inan Alfisol of Jharkhand. J Indian Soc. Soil Sci. 2010; 58(2):200-204.
41. Rahman MH, Okubo A, Sugiyama S, Mayland HF. Physical, chemical and microbiological properties of an Andisol as related to land use and tillage practice. Soil Tillage Res. 2008; 101:10-19
42. Ranjitha Sri P, Kumar RM, Jayasree G. Evaluation of Rice (*Oryza sativa* L.) Varieties and Hybrids in Relation to Different Nutrient Management Practices for Yield, Nutrient Uptake and Economics in SRI. Ann. Biol. Res. 2013; 4(10):25-28.
43. Rasmussen KJ. Impact of ploughless soil tillage on yield and soil quality: A Scandinavian review. Soil and Tillage Res. 1999; 53:3-14.
44. Ravi R, Srivastava OP. Vermicompost: A potential supplement to nitrogenous fertilizer in rice nutrition. Inter. Rice Res. Newesl. 1997; 23(3):30-31.
45. Reddy CV, Malik RK, Yadav A. Evaluation of double zero tillage in rice-wheat cropping system. In: Proc Accelaration of Resource Conservation Technologies in rice-wheat systems of the Indo-Gangetic Plains. CCS HAU. 2005, 1-2.
46. Sarwar G, Hussain N, Schmeisky H, Suhammad S, Ibrahim M, Ahmad S. Efficiency of Various Organic Residues for Enhancing Rice-Wheat Production under Normal Soil Conditions. Pak. J Bot. 2008; 40(5):2107-2113.
47. Sen HS, Bandyopadhyauy BK. Management and development of coastal saline area. In: Development and management of the problem soils for sustainable agricultural production. JNKVV, Jabalpur. 2001.
48. Shad AR, De Datta SK. Reduced tillage techniques for wetland rice as affected by herbicides. Soil and Tillage Res. 1986; 6:291-303.
49. Sharma SK, Tomar RK, Gangwar KS. Effect of crop-establishment and tillage practices on the yield and economics of irrigated rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system. Indian J Agric. Sci. 1995; 65:636-638.
50. Sharma MP, Bali SV, Gupta DK. Soil fertility of rice-wheat cropping system in an Inceptisol as influenced by integrated nutrient management. J Indian Soc. Soil Sci. 2001; 71(2):82-86.
51. Sharma PK, De Datta SK. Physical properties and processes of puddled rice soils. Adv. Soil Sci. 1986; 5:139-178.
52. Sharma PK, De Datta SK, Redulla CA. Tillage effects on soil physical properties and wetland rice yield. Agron. J. 1988; 80:34-39
53. Sharma R. Effect of Long Term Integrated Nutrient Management System on Soil and Crop Productivity in Rice-Wheat Crop Sequence. PhD Dissertation. 2013, 155.
54. Singh G. Singh OP, Kumar V, Kumar T. Effect of methods of establishment and tillage practices on the productivity of rice (*Oryza sativa*)-wheat (*Triticum astivum*) cropping system. Indian J Agric. Sci. 2008; 78:163-166.
55. Su Z, Zhang J, Wu W, Cai D, Lv J, Jiang G, *et al*. Effects of conservation tillage practices on winter wheat water-use efficiency and crop yield on the Loess Plateau, China Agric. Water Mgt. 2007; 87:307-314
56. Sudha B, Chandini S. Vermicompost-A potential organic manure for rice. Intern. Agric. 2003; 41(1-2):18.
57. Vasanthi D, Kumaraswamy K. Efficiency of Vermicompost on the yield of rice and on soil fertility. Abst. National Seminar on organic farming and sustainable agriculture, 1996, 40.
58. Virdia HM, Mehta HD. Integrated Nutrient Management in Transplanted Rice (*Oryza sativa* L.). J Rice Res. 2009; 2(2):99-104.
59. Zahir AZ, Muhammad N, Muhammad Z, Khalid A, Muhammad A. Enrichment of composted organic wastes for improving rice production. J Chem. Soc. Pakistan. 2007; 29(5):514-519.
60. Zein El- Din AM. Mechanical harvesting losses and milling quality of rice as affected by different plowing and planting systems. Misr. J Agric. Eng. 2000; 17(1):79-100.