

Review Article

A Comprehensive Review of the Impacts of Regular, Long-Term Application of Chemical Fertilizers and Farmyard Manure on Soil Fertility

Abstract

Long-term fertilizer and manure experiments serve as invaluable resources for investigating various aspects of agriculture and soil management. These experiments provide a wealth of information on yield trends, nutrient dynamics, and soil nutrient balances. They also help in predicting a soil's carrying capacity, assessing soil quality, and evaluating the sustainability of agricultural systems. Long-term fertilizer experiments play a crucial role in separating the complex interactions among soils, plants, climate, and management practices and shedding light on their impacts on crop productivity. Long-term fertilizer experiments were initiated in the early 1970s, and they have been periodically evaluated since then. The continuous, long-term use of chemical fertilizers and manures is highly influencing the chemical nature and fertility status of the soil.

Keywords: Long-term fertilizer, organic manure, chemical fertilizer, soil fertility.

1.0 Introduction

Sustaining soil health is crucial for meeting three fundamental human necessities, i.e., food, fibre, and shelter. Beyond these essential requirements, soil serves a multitude of vital functions. It acts as a universal filter, purifying water and air while also serving as a reservoir for water and nutrients essential for plant growth. Soil is a habitat for beneficial soil organisms, provides physical support to plants, moderates the climate, and helps to maintain ecological balance by regulating atmospheric gases[37].

Soil plays a key role in providing the nutrients necessary for the sustained growth of crops, including vital elements like nitrogen, phosphorus, potassium, and trace elements. Soil fertility, which reflects a combination of plant growth and its ability to interact with nutrient and environmental conditions, is fundamental for achieving consistent, high, and sustainable crop yields [26]. Fertilisation is a well-established method for enhancing soil fertility and boosting crop production [16]. The continual application of fertiliser nutrients has contributed to steady increases in crop yields, ensuring a consistent food supply. However, it's essential to note that improper fertilisation practices can lead to deteriorating soil quality, reduced crop yield and quality, and various environmental issues, such as greenhouse gas emissions and agricultural non-point source pollution [46]. Consequently, employing scientific and well-

balanced fertilisation techniques is crucial for preserving soil fertility and ensuring stable crop yields. For instance, recent research has established that judicious fertilisation not only enhances soil fertility and farm productivity but also reduces fertiliser requirements, enhances fertiliser efficiency, and mitigates environmental risks [41]. The long-term fertiliser experiments conducted in India over many years have proven invaluable for assessing and quantifying the impact of continuous cropping and fertiliser application on soil quality. These experiments play a vital role in assessing the sustainability of agricultural systems. Long-term trials serve as a healthy basis for evaluating sustainable agricultural management practices by capturing past data and potentially acting as an early care system for future challenges.

2.1 Effect of chemical fertilizer and organic manure on soil pH and electrical conductivity:

Soil physico-chemical parameters, notably soil pH and electrical conductivity (EC), exert profound influences on the solubility of nutrients within the soil matrix. These parameters are the outcome of multi-layered processes, often driven by the activities of soil biota. Their primary significance lies in their key roles in modifying the osmotic equilibrium of plants, directly influencing the uptake of water and essential nutrients. The chemical fertility of soil emerges as an intermediary between overall soil health and the sustainability of agricultural crops. It serves as a reliable metric for assessing the availability of vital nutrients for plants. The chemical attributes of soil mirror its capacity to provide an amenable chemical and nutritional environment for plant growth [39].

An experiment on Vertisols at Jabalpur found that the addition of FYM along with inorganic nutrients slightly reduced the soil pH. The change was marginal and non-significant, which was attributed to the higher buffering capacity of vertisols. The high buffering capacity of the soil on the one hand and the presence of an appreciable amount of free calcium carbonate on the other hand neutralise the H⁺ forms in the mineralization of nitrogenous fertiliser [6]. In addition to fertiliser-induced changes, the introduction of organic matter was observed to release organic acids that could also affect soil pH, indicating the impact of organic matter on soil pH levels through the release of organic acids. Similar findings were observed by the authors [12,36 &2].

The application of integrated nutrients did not result in a significant impact on the electrical conductivity (EC) of the soil. Typically, inorganic fertilisers contain residual salts, and their prolonged use over an extended period is expected to influence the EC of the soil. However, in this study, it was observed that the values of EC remained relatively stable and did not exhibit remarkable changes. The applied inputs had a low residual effect on the soil,

meaning that the nutrients applied did not accumulate in the soil over time to a significant degree. The integrated nutrient application had a limited impact on soil electrical conductivity due to the low residual effect of the applied inputs and the soil's high buffering capacity [23, 2].

2.2 Effect of chemical fertilizer and organic manure on soil organic carbon:

Soil organic carbon is a critical soil property that plays an essential role in determining soil productivity. Its significance in preserving soil fertility and supporting crop productivity has been acknowledged for centuries. Soil organic carbon serves as a crucial and general indicator of the level of biological activity in soil. Maintaining adequate levels of soil organic carbon is especially vital in intensive cropping systems. Organic carbon serves as an indicator of the availability of essential plant nutrients in the soil. However, it's worth noting that continuous reliance on inorganic fertilisers has been observed to decrease the organic carbon content of the soil [47]. This reduction in soil organic carbon underscores the importance of adopting sustainable agricultural practices to mitigate the decline in soil health caused by excessive use of inorganic fertilizers. An increase in organic matter content was attributed to the direct incorporation of organic matter, better root growth, and more plant residue addition [10] in the evaluation of long-term fertility trials. highest organic C status due to the application of a higher rate of FYM with a half dose of N and P fertiliser. Organic C content increased significantly in cultivated soil over the control plot under the long-term soybean-wheat cropping systems [3]. A decline in organic carbon is a result of the continuous application of N fertiliser alone, while the balanced use of chemical fertiliser along with organic manure improves organic carbon [33,34].

Additionally, it has been reported that the incorporation of organic material into the soil not only enhances crop production but can also help mitigate the rate of soil acidification in agricultural ecosystems. This finding underscores the multifaceted benefits of incorporating organic matter into agricultural systems, as it can positively impact both crop yields and soil health by counteracting soil acidification [15].

2.3 Effect of chemical fertilizer and organic manure on available nitrogen:

One of the most essential nutrients for the growth of plants is nitrogen. Changes in the quantity of organic matter in the soil have significant effects on the dynamics of nitrogen in the soil. The available nitrogen (N) content of the soil was found to rise slightly when 100% NPK and farmyard manure (FYM) treatments were used in a study that was conducted over 47 years of continuous cropping. According to [2], this suggests that organic matter

inputs in the form of inorganic and FYM may significantly raise the amount of nitrogen found in the soil. However, the N content in the soil exhibited even further enhancement when an integrated approach of applying both manure and fertiliser was adopted. This suggests that the combination of organic and inorganic inputs had a synergistic effect on increasing soil nitrogen content. The presence of organic matter within the root zone was likely a contributing factor to this favourable condition, as it can enhance nutrient availability and support plant growth. The integrated use of manure and fertiliser appears to promote a more conducive environment for nutrient retention and utilisation in the soil, resulting in higher nitrogen content [17].

This integrated approach was found to enhance the efficiency of nitrogen utilisation compared to using an imbalanced fertiliser application. This effect could be attributed to the presence of a higher root biomass in the rhizosphere zone of the soil, particularly in the upper soil layers, and this root biomass decreased with increasing soil depth. Similar observations were made regarding the importance of integrated nutrient management and the influence of root biomass on nutrients [12, 7].

The Long-Term Manurial Experiments' results showed that the amount of phosphorus (P) or potassium (K) supplied had no effect on the availability of N. However, when P and K were used without FYM, the amount of accessible N was reduced [24]. Furthermore, each increase in the rate of FYM treatment was associated with a rise in the amount of soil N that was available [19]. When 100 percent NPK + FYM treatment was used, the soil's available N content also increased, which was attributed to the Inceptisol soil type's higher organic carbon content [27]. In plots receiving only FYM, continued cropping without fertilisation caused a decrease in the available N status. However, the availability of nitrogen has been significantly enhanced by applying nitrogen fertilisers on a regular basis. This rise was attributed to the use of organic manure, which improved the conversion of organically bound nitrogen into inorganic forms by increasing the activity of soil microorganisms [21].

2.4 Effect of chemical fertilizer and organic manure on available phosphorus:

After a building in the available P status of the soil past the initial value recorded in 1972, two particular fertiliser treatments-the 100% NPK + FYM treatments and the 150% NPK therapy-saw an apparent increase in soil phosphorus (P) levels. The P status of the soil was higher than the 1972 era value of reference. According to many Long-Term Fertiliser Experiments (LTFEs) carried out across the nation, the use of nitrogen (N) alone in fertilisers may cause a rapid depletion of phosphorus (P) in the soil. The buildup of available phosphorus in soil resulting from the application of NPK fertilisers, either alone or in

combination with organic materials, may be attributed to several factors. One contributing factor is the release of organic acids during the decomposition process. These organic acids, as reported by studies such as those conducted by [1,14, 35&44], play a crucial role in solubilizing native phosphorus in the soil, making it more readily available for plant uptake.

Additionally, the organic matter present in conjunction with fertilisers forms a protective cover for sesquioxides in the soil. This covering has the effect of rendering sesquioxides less active, thereby reducing the soil's capacity to fix phosphate. Ultimately, this reduction in phosphate fixing capacity contributes to the release of a greater quantity of phosphorus into the soil.

2.5 Effect of chemical fertilizer and organic manure on available potassium:

The soil's potassium (K) availability was significantly boosted throughout an extended soybean experiment cultivated on black soil. The application of farmyard manure (FYM), along with organic nitrogenous and phosphatic fertilisers, was blamed for this increase. By combining organic materials with fertilisers, the soil's potassium status was noticeably improved, making more of this crucial nutrient available for plant uptake, [1,32]. The findings are in agreement with research by [36], which identified trends in soil potassium (K) availability carried on by inconsistent applications of fertiliser, such as nitrogen in addition to phosphorus (NP) or nitrogen alone (N). The appropriate fertiliser dose was consistently combined with organic matter to produce the highest amount of easily available potassium. [40,7] found that maintaining soil fertility over the long term depended significantly on the integrated use of farmyard waste and chemical fertilisers. In addition to direct potassium supplementation, a reduction in potassium fixation and the release of potassium from the soil as a result of interactions between organic matter and clay can both be attributed to the increase in potassium the availability that results from the addition of organic manures [44,14&35] similar found an increase in the amount of potassium that was readily accessible when organic and inorganic fertilisers were combination.

2.6 Effect of chemical fertilizer and organic manure on available sulphur:

The treatment involving farmyard manure (FYM) with balanced, optimum doses of fertilisers was found to have the highest sulphur (S) level in the soil. The S content was increased by additional nutrient supplementation that was carried out using the optimum fertiliser and FYM doses [11]. The surface soil's S level increased in all other treatments, and the amount of this rise correlated with the amount of fertiliser used. According to [5], treatments with 150% NPK and 100% NPK + FYM showed the greatest increases in S

content. According to [9], the addition of FYM creates optimal conditions for higher nutrient utilisation efficiency and is associated with the greatest S content.

However, when only nitrogen (N) was applied without other nutrients, the available S content in the surface soil was notably low. The available S amount in the surface soil was, however, significantly reduced when only nitrogen (N) and no additional fertilisers were added. With higher levels of fertiliser application, available S content increased and peaked at 37.79 kg ha⁻¹ when 100% NPK + FYM was used [40]. It's important to note that there wasn't much of a difference in the amount of S between post-harvest soil samples and pre-sowing soil. Similar patterns of sulphur availability were also observed in the study [45].

2.7 Effect of chemical fertilizer and organic manure on micronutrient:

In the study, DTPA-Cu levels improved in the balanced and imbalanced fertiliser treatments compared to the control group. The treatments combining NPK and FYM (with zinc) demonstrated the highest DTPA-Cu levels [38,4]. In addition, balanced fertiliser treatments with FYM alone or combined with (NPK + FYM and NPK + FYM + Zn) showed considerably higher DTPA-Fe (iron) content than other treatments across a 10-year rice-wheat cropping sequence. With the addition of a single superphosphate, this increase in DTPA-Fe further increased [45,15]. The study additionally found that the application of FYM caused cationic micronutrients in the soil to practice a buildup. The chelation approach may be responsible for this rise in availability [29]. It's interesting to know that soils with greater pH values have been found with increased copper (Cu) solubility. The amount of Cu complexation in the soil solution is related to the pH of the soil. Although the total copper solubility in the soil increases in high pH circumstances, the free Cu²⁺ solubility remains low [20,42], the addition of farmyard manure (FYM) improved the soil's availability of manganese (Mn). The increase may be due to the release of Mn²⁺ ions by organic matter's organic ligands. Furthermore, the presence of organic matter rapidly up the conversion of Mn⁴⁺ to Mn²⁺, resulting in increased amounts of available Mn [30]. In a different study on Chromusterts soil, it was noted that the application of larger doses of NPK fertilisers resulted in an increase in the available Mn status.

3.0 Conclusion

The above literature review highlights the critical importance of long-term fertilizer experiments (LTFE) in various dimensions, including environmental sustainability and soil health. As the country faces the challenge of feeding a growing population, the spotlight is squarely on the sustainable maintenance of soil fertility, especially in the context of intensive

crop cultivation. The goal is to achieve higher grain production per unit area, per unit time, and per unit input, all while preserving the integrity of the soil environment and soil health. To meet this goal, continuous monitoring of changes in nutrient dynamics is essential. LTFE serves as a valuable resource, providing both soil and plant materials for further scientific research. These experiments offer a foundation for investigating the intricate processes that govern soil fertility, plant productivity, and the quality of water, soil, and air. LTFE plays a pivotal role in advancing our understanding and practices related to sustainable agriculture and environmental stewardship.

Reference

1. Babhulkar PS, Wandile RM, Badole WP, Balpande SS. Residual effect of long-term application of FYM and fertilizers on soil properties (Vertisol) and yield of soybean. *Journal of the Indian Society of Soil Science*. 2000; 48(1):89-92.
2. Bangre J. Ph.D. (Ag.). Retrieving crop parameter and discriminating nutrient management practices through hyperspectral remote sensing approaches in wheat. Thesis, JNKVV, Jabalpur. 2020.
3. Bangre J, Dwvedi AK, Mohanty M, Subhash, Dwvedi BS, Dwvedi SK. Effect of long-term fertilizer application on performance of wheat crop and soil properties in a vertisol. *Indian Journal of Pure & Applied Bioscience*. 2020; 8(1): 217-227.
4. Bhojar SM, Deshmukh VN, Deshmukh PW. Micronutrient status of Chromusterts under long-term effects of fertilisers and FYM under sorghum-wheat sequence. *Ann Plant Physiol*. 1998; 12(2): 126-129.
5. Dwivedi AK, Singh M, Kauraw DL, Wanjari RH, Chauhan SS. Research bulletin on impact of fertilizer and manure use for three decades on crop productivity and sustainability and soil quality under Soybean-Wheat system on a Vertisol in Central India. IISS (ICAR), Bhopal 2007; 224-235.
6. Dwivedi AK, Dwivedi BS. Impact of long-term fertilizer management for sustainable soil health and crop productivity: Issues and challenges. *JNKVV Res Journal*. 2015; 49(3): 387-399.
7. Dwivedi BS, Dwivedi AK, Sharma A, Nagwanshi A. Effect of continuous fertilizer and manure application on productivity of soybean-wheat cropping sequence. International Conference on Sustainability of smallholder agriculture in developing countries under changing climate scenario held of Kanpur. 2018; 74-156.
8. Dwivedi BS, Dwivedi AK, Sharma A. Effect of continuous fertilizer and manure application on productivity of soybean-wheat cropping sequence (pp156). International Conference on sustainability of small holder agrarian in developing countries changing climate Scenario, CSAUAT, Raipur held on 14-17 feb. 2018.
9. Eresha Gowda RC, Mallikarjuna L, Patil S, Srinivas DK, Babu AG. Effect of long-term manure and fertilizer application on major available nutrient status and sulphur fractions under finger millet maize cropping system in Karnataka. *International Journal of Farm Sciences*. 2016; 6(2): 13-18.
10. Gathala MK, Kanthaliya PC, Verma A, Chahar MS. Effect of integrated nutrient management on soil properties and humus fractions in the long-term fertilizer experiments. *Journal of the Indian Society of Soil Science*. 2007; 55(3):360-363.
11. Gokila B, Baskar K, Saravanapandian P. Nutritional Significance of Sulphur on Growth, Yield and Quality of Blackgram in Major Contrasting Soil Series of Tamil Nadu, India. *International Journal of Current Microbiology and Applied Sciences*. 2017; 6(11): 3139-3149.

12. Gupta A, Dwivedi AK, Nagwanshi A, Dwivedi BS. Effect of long-term application of chemical fertilizers and organic manure application on crop quality parameters in Soybean crop. *International Journal of Current Microbiology and Applied Science*. 2018; 7: 1403-1407.
13. Gupta AP, Antil RS, Norvell RP. Effect of FYM on organic carbon, available N, P content of soil during different periods of wheat growth. *J Indian Soc Soil Sci*. 1988; 36: 269-273.
14. Gupta V, Sharma RS, Vishwakarma SK. Long-term effect of integrated nutrient management on yield sustainability and soil fertility of rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy*. 2006;51(3): 160-164.
15. Huang S, Zhang WJ, Yu XC, Huang QR. Effects of long-term fertilization on corn productivity and its sustainability in an Ultisol of southern China. *Agric. Ecosyst. Environ*. 2010;138: 44-50.
16. Jahan M, Javadi M, Hesami E, Amiri MB. Nutritional Management Improved Sesame Performance and Soil Properties: a Function-Based Study on Sesame as Affected by Deficit Irrigation, Water Superabsorbent, and Salicylic Acid. *Journal of Soil Science and Plant Nutrition*. 2021;21(4): 2702-2717.
17. Kushwaha S, Savarkar SD, Thakur RK, Khamparia, NK, Singh M. Impact of long-term nutrient management on soil N dynamics under soybean-wheat cropping sequence on a Vertisol. *Indian Society of Soil Science*. 2017; 65(3):274-282.
18. Mairan NR, Patil SG, Kachhave KG. Physico-chemical properties under sorghum-sunflower cropping sequence in Vertisols. *J Soils Crops*. 2005; 15(2): 352-355.
19. Mandal BC, Saha MN, Adhikari M. Yield of rice and nutrient status of soil due to continuous cropping and manuring in a jute-rice-wheat sequence on Indo-Gangetic alluvial soil. *J Indian Soc Soil Sci*. 1991; 39: 689-692.
20. McBride, M.B. (1994). *Environmental Chemistry of Soil*, Oxford University Press, New York
21. Parmar DK, Sharma V. Studies on long-term application of fertilisers and manures on yield of maize-wheat rotation and soil properties under rain fed conditions in Western-Himalayas. *J Indian Soc Soil Sci*. 2002; 50: 311-312.
22. Patel G. Microbiological and enzymatic studies in a Vertisol as influenced by long term application of fertilizer and FYM on soybean. M.Sc. (Ag.) Thesis, JNKVV, Jabalpur. 2014.
23. Patidar S. Effect of long-term application of fertilizer and FYM on biochemical attributes, yield, and quality of soybean. M.Sc. (Ag.) Thesis, JNKVV, Jabalpur. 2014.
24. Rao J, Dakhore RC. Nutrient changes in a Vertisol under sorghum-wheat rotations for five years. *J Soils Crops*. 1994; 4:108- 112.
25. Rawal N, Chalise D, Tripathi J, Khadka D, Thapa K. Wheat yield trend and soil fertility status in long term rice-rice-wheat cropping system. *Journal of Nepal Agricultural Research Council*. 2015; 1:21-28.
26. Rawat W, Wang Z. Deep convolutional neural networks for image classification: A comprehensive review. *Neural computation*. 2017; 29(9):2352-2449.
27. Santhy P, Muthuvel P, Murugappan V, Selvi D. Long Term Effects of Continuous Cropping and Fertilization on Crop Yields and Soil Fertility Status. *J Indian Soc Soil Sci*. 1998;46(3): 391-395.
28. Santhy PP, Muthuvel D, Selvi D. Status and Impact of Organic Matter Fractions on Yield, Uptake and Available Nutrients in a Long -Term Fertilizer Experiment. *J Indian Soc Soil Sci*. 2001; 49(2): 281-285.
29. Sarkar AK, Singh RP. Importance of long-term fertiliser use for sustainable agriculture in Jharkhand. *Fert News*. 2002; 47(11): 107-111.
30. Selvi R, Augustine, Selvaseelan D. Effect of mushroom spent rice straw compost on soil physical properties of alluvial and laterite soils. *Madras Agric J*. 1997;84(1):15-19.
31. Setia RK, Sharma KN, Rathod, R.K. (2004). Sulphur regime of an arable soil (Typic Ustrochrept) under long term differential fertilization at various growth stages of wheat. *Journal of Indian Society of Soil Science*, 52(2): 150-155.
32. Sheeba S, Chellamuthu S. Long term influence of organic and inorganic fertilization on the micronutrient status of Inceptisols. *Journal of the Indian Society of Soil Science*. 1991;47(4): 803-804.

33. Singh GB, Swarup A. Lessons from long-term fertility experiments. *Fertiliser News*. 2000; 45(2), 13-24.
34. Singh GB, Swarup P. Lessons from long-term fertility experiments. *Fertilizer News*. New Delhi. 2000; 45: 13-18 and 21-24.
35. Singh K, Bansal SK, Moinuddin. Effect of continuous cropping for twenty years on some properties of the intensively cultivated alluvial soil and nutrient indexing of rice. *Journal of the Indian Society of Soil Science*. 2007; 55: 265-269.
36. Singh M, Wanjari RH, Kumar U, Chaudhari SK. AICRP on Long-term Fertilizer Experiments: Salient Achievements and Future Directions. *Indian Journal of Fertilisers*. 2019; 15 (4): 356-372.
37. Singh M, Wanjari RH, Kumar U. Long-Term Fertilizer Experiments in India: Achievements and Issues for Future Research. *Soil Science: Fundamentals to Recent Advances*. 2021; 781-800.
38. Singh NP, Sachan RS, Pandey PC, Bisht PS. Effect of decade long fertilizer and manure application on soil fertility and productivity of Rice-Wheat system in a Mollisol. *J Indian Soc Soil Sci*. 1999; 47(1): 72-80.
39. Sinha SK, Singh VN, Singh P. Effect of continuous use of fertilisers on physical and physico-chemical properties of an alluvial soil. *J Res (BAU)*. 1997; 9(1):31-34.
40. Suman J, Dwivedi BS, Dwivedi AK, Pandey SK. Distribution of sulphur pools as influenced by long-term application of fertilizers and manure in a vertisol. *Green Farming*. 2017a; 8(5): 1105-1110.
41. Stockdale EA, Shefered MA, Fortune S, Cuttle SP. Soil fertility in organic farming systems. *Soil Use and Management*, 118: 301-30 soils. *Current Science*. 2002; 25: 259-260.
42. Takamitsu W. A numerical study on efficient jury size. *Humanities & Social Sciences Communications*. 2020; 7(1).
43. Takeda A, Tsukada H, Nanzyo M, Takaku Y, Uemura T, Hisamatsu S. Effect of Long-Term Fertilizer Application on the Concentration and Solubility of Major and Trace Elements in a Cultivated Andisol. *Soil Sci Plant Nutr*. 2005; 51(2): 251-260.
44. Tolanur SI, Badanur VP. Effect of integrated use of organic manure, green manure and fertiliser nitrogen on sustaining productivity of rabi sorghum- chickpea system and fertility of a Vertisol. *J Indian Soc Soil Sci*. 2003; 51: 41-44.
45. Urkurkar JS, Tewari S, Bajpai RK. Influence of long-term use of organic and inorganic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Inceptisols. *Indian Journal of Agricultural Science*. 2010; 80(3): 208-212.
46. Venugopal G, Sharma SHK, Qureshi AA, Vidya GE, Bhave MHV. Release Pattern of Available Sulphur and Sulphur Fractions Influenced by Elemental Sulphur and Poultry Manure in Different Soils of Northern Telangana. *International Journal of Pure Applied Bioscience*. 2017; 5(4): 1606-1610.
47. Wu W, Ma B. Integrated nutrient management (INM) for sustaining crop productivity and reducing environmental impact: A review. *Science of the Total Environment*. 2015; 512: 415-427.
48. Yaduvanshi NPS. Effect of five years of rice-wheat cropping and NPK fertilizer use with and without organic and green manures on soil properties and crop yields in a reclaimed sodic soil. *Journal of the Indian Society of Soil Science*. 2001; 49(4): 714-719.
49. Zhong WT, Wang W, Huang Q, Shen W. The effects of mineral fertilizer and organic manure on soil microbial community and diversity. *Plant and soil*. 2010; 326: 511-522.