FYM superimposed with inorganic fertilizer: enhanced wheat yield, and soil quality in degraded red Alfisol

Abstract

The soil multi-nutrient deficiency is not only a problem for soil quality, but also for crop productivity. In problematic soils, in particular acid soils, where low nutrient availability isa concern for general soil use, organic fertilizers are important. The importance of FYM is not limited to their role as accessibility, cost-effectiveness, soil nutrient reservoirs, moisture and ameliorating soil properties that determine soil fertility and productivity status. A pot experiment was conducted on wheat crop at Banaras Hindu University, India, to investigate the short term effects of FYM superimposed with/without inorganic fertilizers on crop productivity, quality, and soil chemical properties in a red Alfisol. The study includes following nine treatments: unfertilized control (CK), recommended NPK (RF), 1.5 RF, FYM1 (5 t ha^{-1}), FYM2 (10 t ha^{-1}), RF+FYM1, 1.5RF+FYM1, soil test-based fertilizer (STF), STF + FYM1. The results revealed that maximum number of tiller pot^{-1} (17.0), plant height (78.0 cm), grain yield (27.4 g pot^{-1}), straw yield (9.98 g pot^{-1}), biological yield (67.5 g pot^{-1}), harvest index (40.6%), were recorded in 1.5RF+FYM1applied pots. The correlation study revealed a significant positive correlation of soil organic carbon with biological yield, and soil available N, P and K. The integration of FYM along with 1.5 times RF significantly enhanced wheat productivity, quality, and soil nutrient availability, indicating the potential of this integrated approach for restoring soil fertility in degraded soils tosustainable crop production in red Alfisol.

Key word: *Integrated nutrient management, crop productivity, soil fertility, degraded land, super optimal dose*

Introduction

Red soils (Alfisol in the US soil taxonomy system), are particularly prevalent in India and cover approximately 70 million hectares or 28% of the total geographical area (Singh et al., 2018).With the high temperature and rainfall, these regions are important for agriculture. However, because of high weathering, poorly developed soil structure and some unsuitable management practices, produce significant multi-nutritional deficiency including both primary (Nitrogen, phosphorous and potassium),and secondary nutrients(calcium, magnesium and sulfur) (Zhang et al., 2009). Therefore, effective reclamation strategies are required for these soils such as incorporation of organic matter, irrigation management and the use of appropriate soil amendments to improve soil structure and fertility. As such, inorganic fertilizers play an important role in crop production and the growth of the agricultural economy (Wang et al., 1996, Zuli et al., 2008). Theunsatisfied effect of the sole application of chemical fertilizer on soil fertility and crop productivity under degraded land,need for better planning for resource and nutrient management besides intensification of cropping. The use of chemical fertilizers increases in an unbalanced manner and has produced problems of multi-nutrient deficiency, mainly micronutrients, reducing soil fertility and unsustainable crop productivity (Moharanaet al., 2017). The application of inorganic fertilizers with organic manures seems to be a good solution for these problems (Abbas et al., 2012).

Wheat (*Triticum aestivum L.*) is the most important cereal crop grown worldwide and a staple of about 2.5 billion of the world population (Ramadas et al., 2019). The nutrient-rich cereal is grown in various environmental conditions; globally wheat established around 217 million hectares holding the position of highest acreage among all other crops with annual production up to 731 million tonnes (USDA, 2018). It requiresa high amount of nitrogen (N) fertilizers to enable grain protein production which is necessary for backing and processing quality (Zörbet al., 2018). The recommended dose of fertilizers was not able to maintain soil fertility, productivity and quality of grain under degraded soil conditions, thus we used integrated nutrient management with various rates of NPK doses. Hence the use of fertilizers either alone or in combination with organic fertilizers is important for sustaining soil fertility and crop productivity (Shambhavi et al., 2017) because organic manures supply a good amount of plant nutrients (Subehiaet al., 2013).

The organic sources might include green manure, organic manure, crop residues, rural wastes, vermicompost and biofertilizers (Kant et al., 2018). Among many kinds of organic sources, farmyard manure (FYM) is a commonly used organic fertilizer in developing countries because it is easily available and cheap in rate (Kei and Palanichamy,2013). The use of well-decomposed farmyard manure (FYM) in soil management practices is a good practice for increasing crop yield, improving SOM, enhancing microbial activity, provide eco-friendly soil environmental management (Blair et al., 2006; Kundu et al., 2007; Rathod et al., 2013) and increasing plant available macro and micronutrients in soil(Sandhu, Walia, Gill and Dheri, 2020). Moreover, organic fertilizers act as slow-release fertilizers and provide nutrients over a long period (Shaji, Chandran, Mathew. 2021).However, to date, little attention has focused on how the FYM with various NPK rates influences the management of soil fertility.

The utilization of inorganic nutrient sources with organic is a feasible approach for higher crop productivity and maintaining soil health (Kumar et al., 2021; Kakraliyaet al., 2017).FYM is a good nutrient source that has the potential to positively affect soil physical, chemical and biological properties (Chandra et al., 2022; Wolieet al., 2016; Khayat et al., 2021) and thus, help in improve nutrient availability and crop yield (Islam et al., 2012).Integrated nutrient management(INM) are essential for better plant growth, water utilization, soil and land management which is more important for sustaining agriculture productivity (Shah et al., 2010; Singh et al., 2017).Schoebitzet al. (2017) revealed that INM increases applied nutrient use efficiency while reducing nutrient losses.A better soil physical environment helped in better uptake of water and nutrients due tonutrient sufficiency in FYM and inorganic fertilizer application together (Rasool, Kukal and Hira. 2008).Therefore, the purpose of this study was to compare the various doses of inorganic fertilizer management with or without FYM to improve low nutrient availability, soil properties, crop growth and productivity in degraded red alfisolusing a pot experiment.

Material and method

Experimental site and experimental methods

The pot experiment of wheat crop was conducted at the Rajiv Gandhi South Campus, Banaras Hindu University,Barkachha, Mirzapur (at 25.07^0 N latitude and 82.59^0 E longitudes and altitude of 427 meters above mean sea level) during the rabi season of 2019-2020. The experimental soil was collected from an agricultural research farm, Barkachha, Mirzapur. The soil was air-dried, gently powdered to pass through a 2 mm sieve and homogenized and placed in an earthen pot.The pots had a diameter of 15 inches and height 17 inches. We used twenty-seven pots with 10 kg of prepared soil. The treatment comprised a combination of FYM (0, 5, 10 t ha^{-1}) and inorganic fertilizers i.e. NPK (0%, RF, 1.5RF and soil test based) (Table 2). There were total nine treatments, replicated thrice in a completely randomized design viz., T_1: control, T_2: RF, T_3: 1.5 RF, T_4: FYM1 (5 t ha^{-1}), T_5: FYM2 (10 t ha^{-1}), T_6: RF+FYM1 (5tha^{-1}), T_7: 1.5RF+FYM1(5t ha^{-1}), T_8: Soil test based fertilizer, T_9: Soil test based fertilizer + FYM1 (5t ha^{-1}). According to the recommended doses of fertilizers (RF) for wheat, (120 N: 60 P_2 O_5: 60 K_2 O kg ha^{-1}), we calculated doses of N, P, and K for each of the experimental treatments (Table 2).

The dose of nitrogen(N) and full dose of phosphorous(P) and potassium (K) were applied as basal dose at the time of sowing. The remaining dose of N was top dressed in two equal splits at 30 and 60 days after sowing of wheat. The source of N, P and Kwere urea, di ammonium phosphate (DAP) and murate of potash (MOP), respectively.After application of NPK fertilizers and FYM, the soil in each pot was thoroughly remixed and equilibrated for 1 week before sowing. The seeds of wheat (var.Malviya234) were sown in mid-november during the year as a test crop. Ten seeds of wheat were sown in the mixture filled pots. Seven days after seedling emergence the seedlings were thinned to 5 per pot. The moisture contain in all pots was maintained and irrigated with tap water. During the experiment, the maximum mean air temperature was 34.7 ^{o} C and the minimum 16 ^{o} C. The crop was harvested at physiological maturity, washed with dilute HCl, soap solution and deionized water. Soil samples were also collected for chemical analysis. Soil samples were packed in plastic bags and labelled accordingly.The soil properties like pH and electrical conductivity (EC), organic carbon (OC), available nitrogen, phosphorous and potassium were analyzed. General properties of soil and FYM prior to the experiment are provided in Table 1.

Statistical analysis

Statistical analysis was used to establish the significance between the treatment means and draw valid results. Analysis of variance (ANOVA) method was adopted as the statistical analysis tool for the raw data recorded during the whole experiment. The difference of the treatment means wasevaluated using the least significant difference (LSD) at 5% level of probability as per Gomez and Gomez (1984) following the complete Randomized Design (CRD). Statistical analysis of data was carried out with the help of SPSS statistical package (version 23.0, SPSS Inc.) for windows.

Result and discussion

Effect of FYM with inorganic fertilizer on growth indices of wheat

The plant height of wheat had an increasing trend from 30 days after sowing to harvest of the crop, and significant changes among the treatments were also noticed (Table3). Plant height ranged from 7.0 to 18.2 cm at 30 DAS, 19.3 to 35.6 cm at 60 DAS, 49.6 to 65.8 cm at 90 DAS, and 59.6 to 78.0 cm at harvest of wheat. The highest plant height of wheat was recorded in treatment T_7 (1.5 NPK + FYM1) followed by T_3 (1.5 NPK) and minimum was in treatment T_1 irrespective of growth stage of crop. Secondly, the combined application of inorganic fertilizers with FYM favoured the growth of plant and recorded higher plant height than only inorganic fertilizers applied plants.The plants grown in treatment T_7 and T_3 had159% and 143% at higher plant height at 30DAS,respectively. However, the intensity of increment of plant height was decreased 31% and 28% at harvest over control, respectively. It might be due to the N uptake at the initial stage of growth being more.Plant height increased availability of nutrients in soil due to higher fertilizer application may have increased meristematic activity (multiplication and elongation of cells) leading to enhanced plant height (Bahuguna et al.,2023).

The range of tiller number was 9.0 to 17.0 (Table3).It was revealed that application of 1.5 NPK+FYM1 (T_7) recorded significantly the highestnumbers of tillerplant^{-1}over the rest of treatments followed by 1.5RF(T_3) and minimum number tiller was observed in T_1 (9.0). Treatment $T_6$was found at par with respect to $T_{8.}$The plant growth had 88.8% and 84.4% highernumbers of tillers in T_7 and T_3 over control, respectively. It may be due to FYM with NPK application help in improving physical properties of the soil, enhancing soil fertility and availability of many nutrients elements to plant uptake which increases plant growth.Apriyaniet al., (2021) observed thatincreasing supply of NPK and micronutrients from the FYM offers more balanced nutrition for plants. Inorganic fertilizers improve the quick availability of nutrients compared to the gradual release of nutrients from organic fertilizer sources (Abera et al., 2018).

Effect of FYM with inorganic fertilizer on growth yield attributes and yield of wheat

The crop under integrated fertilization recorded a significantly higher yield of wheat compared to inorganic fertilizers alone (Fig.1).The grain yield of wheat observed range from 10.5 to 27.4 g pot^{-1}. The maximum grain yield of wheat wasin 1.5NPK+FYM1(27.4g pot^{-1}) followed by 1.5 RF (25.6 g pot^{-1}). The lowest grain yield was recorded in control (T_1) (10.5 g pot^{-1}).It might be due to integrated fertilizer application increasing soil quality and availability of nutrients to sustain greater yield compared to inorganic fertilizer alone.The grain yield of wheat was also increased with the rate ofFYM application increased. It was recorded that 12.5 g pot^{-1} to 15.2 g pot^{-1} with application of 5t ha^{-1} (FYM1) to 10 t ha^{-1}(FYM2), respectively. Organic manure increases total soil porosity, soil water and nutrient holding capacity and concentration of essential plant nutrients (macro and micro) (Ahmad et al., 2021) in soil ultimately improving wheat grain yield. Sharma and Biswas. (2017) revealed that microbiological activity increases with the application of organic manures, providing better nutrient mobilization from applied nutrientmanures to higher root density that helps in adequate absorption of water and nutrients from the soil.

The straw yield of wheat ranged from 15.7 to 39.9 (g pot^{-1}) (Fig.1). The highest straw yield (39.9 g pot^{-1})was revealed in 1.5NPK+FYM1(T_7) followed by 1.5NPK (T_3) (37.5 g pot^{-1}). It was significantly higherover rest of the treatments. The straw yield was 6.35% higher in T_7 over T_3. Adding NPK with organic fertilizers supplied not only additional quantities of NPK directly, but also additional secondary and micronutrientsthat were limiting in the soil (Bhatt et al., 2016).According to Meena et al.(2018) increased uptake of N in leaf, stem and grain in NPK +FYM incorporated treatment might be associated with the mineralization of FYM throughout the growing season that ensured its availability to wheat crop and help to increase crop yield.

The biological yield (g pot^{-1}) of wheat significantly increased as the application of NPK with or without FYM increased. The highest biological yield was observed with the application of 1.5NPK+FYM1(T_7) (67.5 g pot^{-1}) followed by 1.5 RF (63.2 g pot^{-1}) (Table 3). The minimum yield was recorded in T_1 (26.2 g pot^{-1}). It was revealed that 31.2 to 37.8 g pot^{-1} in T_4 and T_5, respectively. It might be due to the FYM application increasing nutrient availability that helps in the improvement of yield. Increased availability of nutrients would have helped in the synthesis and translocation of carbohydrates from source to sink (grain) resulting in higher yield production (Aasif et al., 2018). Harvest index of wheat varied from 40.6 to 40.0% (Table4).The highest harvest index was recorded with the application of 1.5NPK+FYM1(T_7) among all treatments and minimum (40.0%) with control(T_1). The integrated application of fertilizer increases the harvest index more compared to the sole application. The same results were also observed by Ahmad et al., (2013), Kumar et al., (2024).

Effect of FYM with inorganic fertilizer soil properties and nutrients status

Soil pH generally decreased after the addition of manure and inorganic fertilizers. The highest soil pH was observed in CK (T_1) over the remaining treatments. same results were also found by Sharma et al. (2014). However, soil pH and EC both were non- significantly affected with the application of various treatments.As expected, integrated nutrient management significantly improve soil organic carbon values (Table 7). We observed maximum soil organic carbon value in 1.5RF+FYM1(T_7) treatment followed by 1.5 RF (T_3). The enhancement of organic carbon in T_7 was 11.11% with respect to CK (T_1). This might be due to the direct incorporation of organic matter, and better root-growth of plants (Ram et al., 2016).

There was a significant difference among treatments with respect tothe available N content of soil.The available N content of soils under various treatments ranged from 116 kg ha^{-1} to 171 kg ha^{-1}(Table 6). The maximum available N was recorded with the application of 1.5RF+FYM1 (T_7)(171kg ha^{-1}) followed by 1.5RF (T_3)(168 kg ha^{-1}) and minimum in CK(T_1) (116 kg ha^{-1}). It was 2.04% higher in T_7 as compared to 1.5NPK(T_3). It might be due to an additional supply of N through chemical fertilizers and mineralization of N from the decomposition of FYM. Sharma et al., (2014) also reported greater available N where FYM applied along with 100%NP than in 100%NPK alone. The beneficial soil conditions like organic carbon, porosity, water holding capacity and greater multiplication of soil microbes help in improvement of soil available nitrogen (Dhiman et al., 2019).The available phosphorous ranged from 7.5kg ha^{-1} to 12.1 kg ha^{-1}(Table 6). The maximum amount of available P was significantly higher in 1.5RF+FYM1(T_7)over the rest of the treatments followed by 1.5RF(T_3). Available P level inRF +FYM1(T_6) was found at part with respect to soil test based (T_8). The enhancement in available phosphorous with the application of NPK fertilizers in combination with organic manure might be due to organic acids secretion during decomposition which, improvesthe release of native phosphorous in soil (Dhiman et al., 2019).Sharma et al. (2023) foundthat FYM reduces P fixation by the inactivation of iron, aluminium, and hydroxyl-aluminium ions.Besides, the addition of FYM in soil increased available P in soil by mineralization or solubilization of native P reserves (Chauhanet al., 2020).

Study revealed that available potassium ranged from 160to 212kg ha^{-1}(Table 6).The higher content of available K in 1.5RF+FYM1(T_7) followed 1.5 RF and minimum in CK (T_1). TheK contentwas observed3.60%, 7.55%,16.33% and 32.56% higher in T_7 over 1.5RF (T_3), soil test based(T_8), RF (T_2) and control (T_1), respectively. It mightbe due to an additional supply of K through the decomposition of FYM.Sharma and Walia (2018) was found mineralization of organic fertilizers and solubilization from native sources during their decomposition increases available K content.

Correlation study

Results on simple correlation coefficient revealed that most of the soil and plant parameters significantly ($p<0.001$) correlated with each other as depicted (Table 7). Organic carbon was positively correlated with tiller number (r=0.85), total N uptake (r=0.83), available phosphorous (r=0.82), and available potassium (r=0.81) and these parameters were found non-significant at $p<0.05$ but significant at $p<0.01$. Available N (r=0.76) and total K uptake (r = 0.77) were found significantly correlated to soil organic carbon at $p<0.05$ indicating that the availability of N and total K uptake increased as organic carbon content increased in soil. A non-significant positive correlation was also observed between wheat biological yield and total uptake of N (r=0.98), P(r=0.90) and K (r=0.99) by the crop. On the other hand, pH showed a negative correlation between protein content, available N and available K, indicating decreased availability with increased pH.The protein content significantly correlated with biological yield (r=0.89, p<0.01). This indicated that FYM is an important source of maintaining soil fertility, nutrient availability and crop productivity. Katkar et al. (2011) observed the same positive correlation after applying organic fertilizer alone or with mineral fertilizers.

Conclusion

The result from the present study indicated that the addition of FYMwithsuperimposed inorganic fertilizers had a maximum restoration effect on soil properties and crop productivity, nutrient uptake, quality of grainsover inorganic fertilizers alone, organic fertilizers alone and control treatments. The highest wheat production and soil quality parameterswere observed in 1.5RF+FYM1treated pots.This justifies that the application of integrated nutrient management with a super optimal dose can improve the soil's nutritional status to get good plant growth, higher yields and better produce quality in degraded land. The addition of FYM is one of the best options for sustaining soil health and crop productivitywith an affordable cost by reclamation of alfisol, which can significantly improve soil structure and fertility.

References

Aasif, M., Chinnamani, I., Kumar, N. S., Hemalatha, M., & Suresh, S. 2018. Influence of integrated nutrient management practices on yield and nutrient uptake of rice under system of rice intensification. *International journal of advances in agricultural science and technology 5* :10-6.

Abbas, G., Khattak, J. Z. K., Mir, A., Ishaque, M., Hussain, M., Wahedi, H. M., ... & Ullah, A. 2012. Effect of organic manures with recommended dose of NPK on the performance of wheat (Triticum aestivum L.). *J. Anim. Plant. Sci.* 22: 683-687.

Abera, T., Tufa, T., Midega, T., Kumbi, H., & Tola, B. 2018. Effect of integrated inorganic and organic fertilizers on yield and yield components of Barley in Liben Jawi District. *International Journal of Agronomy* 2018: 1-7. doi:10.1155/2018/2973286.

Ahmad, S., Ghaffar, A., Rahman, M. H. U., Hussain, I., Iqbal, R., Haider, G., ... & Bashir, M. S. 2021. Effect of application of biochar, poultry and farmyard manures in combination with synthetic fertilizers on soil fertility and cotton productivity under arid environment. *Communications in Soil Science and Plant Analysis* 52: 2018-2031.doi: 10.1080/00103624.2021.1908324.

Ahmad, W., Shah, Z., Khan, F., Ali, S., & Malik, W. 2013. Maize yield and soil properties as influenced by integrated use of organic, inorganic and bio-fertilizers in a low fertility soil. *Soil & Environment* 32:121-129.

Apriyani, S., Wahyuni, S., Harsanti, E. S., Zu'Amah, H., Kartikawati, R., &Sutriadi, M. T. 2021. Effect of inorganic fertilizer and farmyard manure to available P, growth and rice yield in rainfed lowland Central Java. In *IOP Conference Series: Earth and Environmental Science* 648:1-012190. doi:10.1088/1755-1315/648/1/012190.

Bahuguna, A., Singh, D. K., Hodkashia, S., Padhan, S. R., & Verma, P. 2023. Effect of Different Fertility Levels on Growth and Production Potential of Rice Genotypes. *Int. J. Plant Soil Sci* 35: 539-548.doi: 10.9734/IJPSS/2023/v35i173243.

Bayu, W., Rethman, N. F. G., Hammes, P. S., & Alemu, G. 2006. Effects of farmyard manure and inorganic fertilizers on sorghum growth, yield, and nitrogen use in a semi-arid area of Ethiopia. *Journal of plant nutrition* 29:391-407. doi: 10.1080/01904160500320962.

Bhatt, B., Chandra, R., Ram, S., & Pareek, N. 2016. Long-term effects of fertilization and manuring on productivity and soil biological properties under rice (Oryza sativa)–wheat (Triticum aestivum) sequence in Mollisols. *Archives of Agronomy and Soil Science* 62 :1109-1122. doi:10.1080/03650340.2015.1125471.

Blair, N., Faulkner, R. D., Till, A. R., & Poulton, P. R. 2006. Long-term management impacts on soil C, N and physical fertility: Part I: Broadbalk experiment. *Soil and Tillage Research* 91: 30-38.doi: 10.1016/j.still.2005.11.002.

Chandra, P., Gill, S. C., Prajapat, K., Barman, A., Chhokar, R. S., Tripathi, S. C., ... & Singh, G. P. 2022. Response of wheat cultivars to organic and inorganic nutrition: Effect on the yield and soil biological properties. *Sustainability* 14:15-9578. doi: 10.3390/su14159578.

Chauhan, N., Sankhyan, N. K., Sharma, R. P., Singh, J., & Gourav. 2020. Effect of long-term application of inorganic fertilizers, farm yard manure and lime on wheat (Triticum aestivum L.) productivity, quality and nutrient content in an acid alfisol. *Journal of Plant Nutrition* 43:2569-2578. doi: 10.1080/01904167.2020.1783298.

Dhiman, D., Sharma, R., Sankhyan, N. K., Sepehya, S., Sharma, S. K., & Kumar, R. 2019. Effect of regular application of fertilizers, manure and lime on soil health and productivity of wheat in an acid Alfisol. *Journal of Plant Nutrition* 42:2507-2521. doi: 10.1080/01904167.2019.1659317.

DV, P., Krishnamurthy, R., & Naveen, D. V. 2020. Long-term effect of integrated nutrient management on soil nutrient status, content and uptake by finger millet crop in a typic kandiustalf of eastern dry zone of Karnataka. *Communications in Soil Science and Plant Analysis* 51: 161-174.doi: 10.1080/00103624.2019.1695829.

FAOSTAT (2019): *Food and Agriculture Organization of the United Nations Statistics Division. Crops and Livestock Statictics*. Retrieved from http://faostat3.fao.org/download /Q/*/E.

Gill, J. S., & Walia, S. S. 2014. Influence of FYM, brown manuring and nitrogen levels on direct seeded and transplanted rice (Oryza sativa L.) A review. *Research Journal of Agriculture and Environmental Management* 3: 417-426.

Gomez, K. A., & Gomez, A. A. 1984. Statistical procedures for agricultural research. *John wiley& sons*.

Gosal, S. K., Gill, G. K., Sharma, S., & Walia, S. S. 2018. Soil nutrient status and yield of rice as affected by long-term integrated use of organic and inorganic fertilizers. *Journal of Plant Nutrition* 41:539-544. doi:10.1080/01904167.2017.1392570.

Islam, M. R., Sikder, S., Bahadur, M. M., & Hafiz, M. H. R. 2012. Effect of different fertilizer management on soil properties and yield of fine rice cultivar. *Journal of Environmental Science and Natural Resources* 5: 239-242.doi: 10.3329/jesnr.v5i1.11588.

Kakar, K., Nitta, Y., Asagi, N., Komatsuzaki, M., Shiotsu, F., Kokubo, T., & Xuan, T. D. 2019. Morphological analysis on comparison of organic and chemical fertilizers on grain quality of rice at different planting densities. *Plant Production Science* 22:510-518. doi: 10.1080/1343943X.2019.1657777.

Kakraliya, S. K., Jat, R. D., Kumar, S., Choudhary, K. K., Prakash, J., & Singh, L. K. 2017. Integrated nutrient management for improving, fertilizer use efficiency, soil biodiversity and productivity of wheat in irrigated rice wheat cropping system in Indo-Gangatic plains of India. doi:10.20546/ijcmas.2017.603.017.

Kannan, R. L., Dhivya, M., Abinaya, D., Krishna, R. L., & Krishnakumar, S. 2013. Effect of integrated nutrient management on soil fertility and productivity in maize. *Bulletin of Environment, Pharmacology and Life Sciences* 2: 61-67.

Kant, S., P. K. Sharma, V. Kumar, and A. Kumar. 2018. Chelating compounds influence the chemical properties of post-harvest chromium contaminated soil after maize and mustard. *International Journal of Chemical Studies*6:1672–80.

Katkar, R. N., Sonune, B. A., & Kadu, P. R. 2011. Long-term effect of fertilization on soil chemical and biological characteristics and productivity under sorghum (Sorghum bicolor)-wheat (Triticum aestivum) system in Vertisol. *Indian journal of agricultural sciences* 1: 81- 734.

Khayat, M. 2021. Evaluation Effect of Farmyard Manure (FYM) to Improve Cereal Crop Yield. *Journal of Crop Nutrition Science* 7: 59-67.

Kumar, B., Dhar, S., Paul, S., Paramesh, V., Dass, A., Upadhyay, P. K., ... &Abdelbacki, A. M. 2021. Microbial biomass carbon, activity of soil enzymes, nutrient availability, root growth, and total biomass production in wheat cultivars under variable irrigation and nutrient management. *Agronomy* 1:11: 669.doi: 10.3390/agronomy11040669.

Kumar, A., Bandyopadhyay, K. K., Prasad, S., Kumar, S. N., Singh, R., Kaur, R., & Shrivastava, M. (2024). Impacts on Various Management Practices on Crops Yield and Soil Biology in Maize-Wheat Cropping System. *Asian Journal of Soil Science and Plant Nutrition*, *10*(2), 445-454.

Kundu, S., Bhattacharyya, R., Prakash, V., Ghosh, B. N., & Gupta, H. S. 2007. Carbon sequestration and relationship between carbon addition and storage under rainfed soybean–wheat rotation in a sandy loam soil of the Indian Himalayas. *Soil and Tillage Research* 92: 87-95.doi: 10.1016/j.still.2006.01.009.

Masood, S., Naz, T., Javed, M. T., Ahmed, I., Ullah, H., & Iqbal, M. 2014. Effect of short-term supply of farmyard manure on maize growth and soil parameters in pot culture. *Archives of Agronomy and Soil science* 60:337-347.doi:10.1080/03650340.2013.792990.

Meena, K. B., Alam, M. S., Singh, H., Bhat, M. A., Singh, A. K., Mishra, A. K., & Thomas, T. 2018. Influence of farmyard manure and fertilizers on soil properties and yield and nutrient uptake of wheat. *International Journal of Chemical Studies* 6: 386-390.

Moharana, P. C., Sharma, B. M., & Biswas, D. R. 2017. Changes in the soil properties and availability of micronutrients after six-year application of organic and chemical fertilizers using STCR-based targeted yield equations under pearl millet-wheat cropping system. *Journal of Plant Nutrition* 40: 165-176.doi: 10.1080/01904167.2016.1201504.

Moharana, P. C., Sharma, B. M., Biswas, D. R., Dwivedi, B. S., & Singh, R. V. 2012. Long-term effect of nutrient management on soil fertility and soil organic carbon pools under a 6-year-old pearl millet–wheat cropping system in an Inceptisol of subtropical India. *Field Crops Research* 136: 32-41.doi:10.1016/j.fcr.2012.07.002.

Patel, A., Singh, S., Babu, A., Verma, S., & Singh, S. K. (2018). Effect of monthly rainfall distribution on physico-chemical properties and availability of nutrients in upland red soil of Mirzapur. *Journal of Pharmacognosy and Phytochemistry*, 7(1), 424-429.

Ram, S., Singh, V., &Sirari, P. 2016. Effects of 41 years of application of inorganic fertilizers and farm yard manure on crop yields, soil quality, and sustainable yield index under a rice-wheat cropping system on Mollisols of North India. *Communications in Soil Science and Plant Analysis* 47: 179-193.doi: 10.1080/00103624.2015.1109653.

Ramadas, S., Kumar, T. K., & Singh, G. P. 2019. Wheat production in India: Trends and prospects. In *Recent advances in grain crops research*. IntechOpen. doi:10.5772/intechopen.86341.

Rasool, R., Kukal, S. S., & Hira, G. S. 2008. Soil organic carbon and physical properties as affected by long-term application of FYM and inorganic fertilizers in maize–wheat system. *Soil and Tillage Research* 101:31-36. doi:10.1016/j.still.2008.05.015.

Rathod, D. D., Rathod, P. H., Patel, K. P., & Patel, K. C. 2013. Integrated use of organic and inorganic inputs in wheat-fodder maize cropping sequence to improve crop yields and soil properties. *Archives of Agronomy and Soil Science* 59: 1439-1455. doi:10.1080/03650340.2012.724171.

Sandhu, P. S., Walia, S. S., Gill, R. S., &Dheri, G. S. 2020. Thirty-one years study of integrated nutrient management on physico-chemical properties of soil under rice–wheat cropping system. *Communications in Soil Science and Plant Analysis* 51:1641-1657. doi:10.1080/00103624.2020.1791156.

Schoebitz, M., & Vidal, G. 2016. Microbial consortium and pig slurry to improve chemical properties of degraded soil and nutrient plant uptake. *Journal of soil science and plant nutrition* 16: 226-236. doi:10.4067/S0718-95162016005000018.

Shah, S. A., Shah, S. M., Mohammad, W., Shafi, M., Nawaz, H., Shehzadi, S., & Amir, M. 2010. Effect of integrated use of organic and inorganic nitrogen sources on wheat yield. *Sarhad J. Agric* 26: 559-563.

Shaji, H., Chandran, V., & Mathew, L. 2021. Organic fertilizers as a route to controlled release of nutrients. In *Controlled release fertilizers for sustainable agriculture* (pp. 231-245). Academic Press. doi:10.1016/B978-0-12-819555-0.00013-3.

Shambhavi, S., Kumar, R., Sharma, S. P., Verma, G., Sharma, R. P., & Sharma, S. K. 2017. Long-term effect of inorganic fertilizers and amendments on productivity and root dynamics under maize-wheat intensive cropping in an acid Alfisol. *Journal of Applied and Natural Science* 9: 2004-2012. doi:10.31018/jans.v9i4.1480.

Sharma, J., Goyal, V., Dahiya, R., Kumar, M., & Dey, P. 2023. Response of Long-Term Application of Fertilizers and Manure on P Pools in Inceptisols. *Communications in Soil Science and Plant Analysis* 54: 1042-1061.

Sharma, U., Paliyal, S. S., Sharma, S. P., & Sharma, G. D. 2014. Effects of continuous use of chemical fertilizers and manure on soil fertility and productivity of maize–wheat under rainfed conditions of the Western Himalayas. *Communications in soil science and plant analysis* 45: 2647-2659. doi:10.1080/00103624.2014.941854.

Singh, D. K., Pandey, P. C., Nanda, G., & Gupta, S. 2019. Long-term effects of inorganic fertilizer and farmyard manure application on productivity, sustainability and profitability of rice-wheat system in Mollisols. *Archives of Agronomy and Soil Science* 65: 139-151.doi: 10.1080/03650340.2018.1491032.

Singh, N., Pal, N., Mahajan, G., Singh, S., &Shevkani, K. 2011. Rice grain and starch properties: Effects of nitrogen fertilizer application. *Carbohydrate Polymers* 86:219-225. doi:10.1016/j.carbpol.2011.04.039.

Singh, R. J., Ghosh, B. N., Sharma, N. K., Patra, S., Dadhwal, K. S., Meena, V. S., ... & Mishra, P. K. 2017. Effect of seven years of nutrient supplementation through organic and inorganic sources on productivity, soil and water conservation, and soil fertility changes

of maize-wheat rotation in north-western Indian Himalayas. *Agriculture, Ecosystems & Environment* 249:177-186.doi:10.1016/j.agee.2017.08.024.
Subehia, S. K., Sepehya, S., Rana, S. S., Negi, S. C., & Sharma, S. K. 2013. Long-term effect of organic and inorganic fertilizers on rice (Oryza sativa L.)–wheat (Triticum aestivum L.) yield, and chemical properties of an acidic soil in the western Himalayas. *Experimental agriculture* 49: 382-394. doi:10.1017/S0014479713000173.
USDA-FAS. 2018. United States Department of Agriculture/Foreign Agricultural Service. Accessed July 1. https:// www.fas.usda.gov/commodities/cotton.
Wolie, A. W., & Admassu, M. A. 2016. Effects of integrated nutrient management on rice (Oryza sativa L) yield and yield attributes, nutrient uptake and some physico-chemical properties of soil: A review. *Journal of Biology, Agriculture and Healthcare* 6: 20-26.
Zörb, C., Ludewig, U., &Hawkesford, M. J. 2018. Perspective on wheat yield and quality with reduced nitrogen supply. *Trends in plant science* 23:1029-1037. doi:10.1016/j.tplants.2018.08.012.

Table1. Physio-chemical properties of soil and farm yard manure used in the experiment.

Properties	**Soil**	**FYM**
Soil texture	Sandy loam	-
pH	6.6	6.56
EC (dSm^{-1})	0.204	3.52
Organic Carbon (%)	0.36	9.82
Available nitrogen	238 (kg ha^{-1})	0.46%
Available phosphours	7.69 (kg ha^{-1})	0.23%
Available potassium	168 (kg ha^{-1})	0.44%

Table 2**:** Description Treatment detail.

Treatments	**Treatments detail**	
	Per ha	**Per pot**
T_1 -CK	-	-
T_2-RF	120 kg N+ 60kg P_2O_5 +60 kg K_2O ha^{-1}	0.53 g N + 0.26 g P_2O_5 + 0.26 g K_2O pot^{-1}
T_3- 1.5 RF	180 kg N + 90 kg P_2O_5 + 90 kg K_2O ha^{-1}	0.79 g N+ 0.39g P_2O_5 + 0.39g K_2O pot^{-1}
T_4- FYM1 (5t ha^{-1})	23 kg N+11.5 kg P_2O_5 + 22 kg K_2O ha^{-1}	0.102 g N + 0.051 g P_2O_5 + 0.098 g K_2O pot^{-1}
T_5- FYM2 (10 t ha^{-1})	46 kg N + 23 kg P_2O_5 + 44 kg K_2O ha^{-1}	0.204 g N + 0.102 g P_2O_5 + 0.196 g K_2O pot^{-1}
T_6-RF+FYM1	143 kg N + 71.5 kg P_2O_5 + 82 kg K_2O ha^{-1}	0.632 g N + 0.311 g P_2O_5 + 0.358 g K_2O pot^{-1}
T_7 -1.5 RF+FYM1	203 kg N + 101.5 kg P_2O_5 + 112 kg K_2O ha^{-1}	0.892 g N+ 0.441 g P_2O_5 + 0.488 g K_2O pot^{-1}
T_8-Soil test-based (STF)	150 kg N + 75 kg P_2O_5 + 40 kg K_2O ha^{-1}	0.66 g N + 0.33 g P_2O_5 + 0.17 g K_2O pot^{-1}
T_9 -STF + FYM1	173 kg N + 86.5 kg P_2O_5 + 62 kg K_2O ha^{-1}	0.762 g N+ 0.381 g P_2O_5 + 0.268 g K_2O pot^{-1}

CK- Control (unfertilized); RF- recommended dose of inorganic NPK by inorganic fertlizers; FYM-farm yard manure

Table 3. Effect of FYM and inorganic fertilizer on plant growth rate and tiller numbers.

Treatment	**Plant height**				**Tiller pot^{-1}**
	30DAS	**60DAS**	**90DAS**	**At harvest**	
T_1	7.02	19.3	49.6	59.6	9.0
T_2	14.2	30.1	58.1	68.5	12.6
T_3	17.0	34.0	65.3	76.0	16.6

T_4	14.1	22.3	56.0	66.9	9.3
T_5	14.2	28.1	56.5	67.8	10.0
T_6	15.0	31.0	60.1	70.0	13.6
T_7	18.2	35.6	65.8	78.0	17.0
T_8	16.0	32.1	64.2	73.9	13.6
T_9	16.4	33.5	65.0	75.0	14.3
LSD (P = 0.05)	1.0	1.8	2.8	2.0	1.0

CK- Control (unfertilized); RF- recommended dose of inorganic NPK by inorganic fertlizers; FYM-farm yard manure

{T_1: CK, T_2: RF, T_3: 1.5 RF, T_4: FYM1 (5t ha^{-1}), T_5: FYM2 (10t ha^{-1}), T_6: RF+FYM1, T_7 1.5RF+FYM1, T_8 : Soil test based fertilizer(STF), T_9 : STF+ FYM (5t ha^{-1}),LSD = Least significant difference}.

Table 4. Effect of FYM and inorganic fertilizer on yield and quality of wheat crop.

Treatment	**Grain yield (g pot^{-1})**	**Stover yield (g pot^{-1})**	**Biological yield (g pot^{-1})**	**Harvest index(%)**
T_1	10.5	15.7	26.2	40.0
T_2	21.4	31.8	53.3	40.2
T_3	25.6	37.5	63.2	40.5
T_4	12.5	18.7	31.2	40.0
T_5	15.2	22.6	37.8	40.1
T_6	22.4	33.1	55.5	40.3
T_7	27.4	39.9	67.5	40.6
T_8	23.5	34.6	58.1	40.3
T_9	24.9	36.5	61.5	40.5
LSD (P = 0.05)	1.6	2.7	3.5	NS

CK- Control (unfertilized); RF- recommended dose of inorganic NPK by inorganic fertlizers; FYM-farm yard manure

{T_1: CK, T_2: RF, T_3: 1.5 RF, T_4: FYM1 (5t ha^{-1}), T_5: FYM2 (10t ha^{-1}), T_6: RF+FYM1, T_7 1.5RF+FYM1, T_8 : Soil test based fertilizer(STF), T_9 : STF+ FYM (5t ha^{-1}),LSD = Least significant difference}.

Table 5. Effect of FYM and inorganic fertilizer on soil pH, EC, SOC and available nitrogen, phosphorous and potassium

Treatment	**Soil chemical properties**			**Nitrogen**	**Phosphorous**	**Potassium**
	pH	**EC (dSm^{-1})**	**SOC (g kg^{-1})**	**(kg ha^{-1})**		
T_1	5.91	0.10	3.60	116.5	7.5	160.5
T_2	5.90	0.10	3.60	142.1	9.5	182.9
T_3	5.85	0.11	3.90	168.0	11.2	205.4
T_4	5.78	0.07	3.60	133.8	8.0	171.7
T_5	5.73	0.06	3.60	137.9	8.2	175.4
T_6	5.82	0.06	3.60	158.8	10.3	195.0
T_7	5.81	0.10	4.0	171.4	12.1	212.8
T_8	5.87	0.10	3.70	161.0	10.6	197.8

T_9	5.85	0.08	3.80	163.0	10.8	198.8
LSD (P = 0.05)	NS	NS	0.17	12.1	1.5	17.2

{T_1: CK, T_2: RF, T_3: 1.5 RF, T_4: FYM1 (5t ha^{-1}), T_5: FYM2 (10t ha^{-1}), T_6: RF+FYM1, T_7 1.5RF+FYM1, T_8 : Soil test based fertilizer (STF), T_9 : STF+ FYM (5t ha^{-1}),LSD = Least significant difference, SEm± = Standard error of mean}.

Table 6. Correlation between soil and crop characteristics

	Tiller pot-1	Biological yield (g pot-1)	pH	EC	OC	N	P	K
Tiller pot-1	1							
Biological yield(g pot-1)	0.96***	1						
pH	0.13	0.12	1					
EC	0.44	0.34	0.71*	1				
OC	0.85**	0.74*	0.006	0.5	1			
N	0.94***	0.95***	-	0.1	0.76*	1		
P	0.98***	0.97***	0.101	0.3	0.82**	0.96***	1	
K	0.97***	0.97***	-0.01	0.2	0.81**	0.99***	0.99***	1

***Correlation is significant at 0.001 level
**Correlation is significant at 0.01 level
*Correlation is significant at 0.05 level