AF-724
[1-6]

Effects of Organic and Inorganic Fertilization: Response of Wheat Cultivation and Interaction with Soil Properties

R. Ghedabna[1], Bazri Kamel[4], H. Benmati[1], M. Benmati[2], M. Gana[3], I. Kerrouche[4]

10.18805/IJARe.AF-724

ABSTRACT

Background: This paper aimed to evaluate and determine the short-term effectiveness of different fertilizations methods: organic (bovine manure) and inorganic (NPK 15-15-15) on agricultural sites in eastern Algeria.

Methods: The study was conducted in three different plots of 100 Ares where we tested three main treatments: mineral fertilizer with a precedent of leguminous cultivation (Min CC), manure inputs with previous manure and without crop rotation (Fum CA), mineral fertilizer with previous bare soil cultivation (MinJ). With the same tillage, the obtained results revealed that the use of cattle manure as a fertilizer is to be recommended because it allows increasing the yield of wheat compared to the soil receiving inorganic fertilization (NPK).

Result: Organic fertilizers ensure and maintain soil fertility and agricultural production in the soil studied.

Key words: Cattle manure, Durum wheat, Mineral fertilizer, Organic amendments, Yield.

INTRODUCTION

The term fertilization is generally used to describe the sum of management practices to maintain or improve the productivity of soils and crops. This latter is also known to affect plant growth, productivity, crop quality and influences soil quality. Recently, chemical fertilizers have been progressively replacing traditional organic manure aiming to ameliorate crop yields. However, the risk of soil pollution and the degradation of its productivity due to the utilization of these chemicals is considerable (Hati *et al*. 2008; Naveed *et al*. 2013; Blanco-Canqui *et al*. 2014 ; Bi *et al*. 2015).

Thus, maintaining soil productivity is a challenging issue particularly in extensive agriculture adopted in developing countries (Rezig *et al*. 2012).

Therefore, these soils can be recovered by supplementing commercial fertilizers with organic wastes, such as household garbage compost and farmyard manure (Wong and Wong 1989; Raymond and Roy 1992; Chu and Bradshaw 1996; Agele2000), as soil fertilizers can improve the recycling of nutrients by supporting the cropping system (El-Shakweer *et al*. 1998). It also ameliorates soil fertility through the activation of its microbial biomass.

At the same time, using intermediate crops as green manure may be beneficial to the sustainability of the cropping system and soil fertility as it participates in the enrichment of organic matter in the soil by providing plant residues reducing erosion by soil cover and retaining nutrients by biological fixation (Sørensen, 1991; Merbach *et al*., 1997; Dinnes *et al*., 2002; Nziguheba and B¨unemann, 2005). Therefore, PGPR (Plant Growth Promoting Rhizobacteria) can be used for biological fertilization of the soil given its importance in enriching the soil by biological nitrogen fixation (Benmati *et al*. 2020).

Wheat (*Triticum aestivum* L.) is one of the most widely grown cereal crops, contributing to the global food supply and economic security (Vichitra *et al*. 2017). The contribution of fertilizers can contribute to the improvement of wheat yields; however, the rational use of fertilizers must be based on knowledge of the initial richness of the soil in fertilizing elements and their availability in periods of high use by crops and the desired performance objective. Nutrient management is an important issue in autumn rice and wheat a precise schedule should be followed to get optimum result (Debasish and Saikia, 2018). In addition, the role of soil is fundamental in primary production as it provides chlorophyll plants with the mineral ions they need, so the soil must be managed sustainably as it does not regenerate quickly.

The impoverishment of soils by the intensification of crops and the excessive use of fertilizers is today a major

[1]Laboratory of Biology and Environment, Chaab-erssas Campus, Biopôle University of the Mentouri brothers, Constantine 1, Ain Elbey road, Constantine Algeria.
[2]National School of Biotechnology, Constantine Algeria.
[3]Laboratory for the Development and Enhancement of Phytogenic Resources, University of the Mentouri Brothers, Constantine 1, Route Ain Elbey, Constantine Algeria.
[4]Laboratory of Biology and Environment, University of the Mentouri Brothers, Constantine 1, Route Ain elbey, Constantine Algeria.

Corresponding Author: R. Ghedabna, Laboratory of Biology and Environment, Chaab-erssas Campus, Biopôle University of the Mentouri brothers, Constantine 1, Ain Elbey road, Constantine Algeria. Email: ghedabna.rayane@umc.edu.dz

How to cite this article: Ghedabna, R., Kamel, B., Benmati, H., Benmati, M., Gana, M. and Kerrouche, I. (2022). Effects of Organic and Inorganic Fertilization: Response of Wheat Cultivation and Interaction With Soil Properties. Indian Journal of Agricultural Research. DOI: 10.18805/IJARe.AF-724.

Submitted: 31-01-2022 **Accepted:** 13-05-2022 **Online:** 14-06-2022

problem in ecology, because it can lead to the depletion and destruction of this resource. The use of manure and / or green manure seems to be the most attractive method, especially since it is respectful of the environment and the sustainability of the soil.

In Constantine, cereal producers complain about the concern for yield despite sufficient rainfall and the application of adequate cultivation methods.

According to the protocols of the national durum wheat network in Algeria, it appears that soils are starting to lose their viability due to the overuse of chemical fertilizers, which are sometimes unapproved. To cope with these constraints, great attention must be focused on the change in soil quality after heavy application of chemical fertilizers.

To this end, we have found useful to try in this work, to identify the behavior of the soil and the yield of the durum wheat plant towards chemical and / or organic fertilizers.

MATERIALS AND METHODS

This research was carried out in a real environment during the 2017-2018 cropping season in Algeria in the municipality of El khroub, Wilaya of Constantine Algeria in the open field (Fig 1) on three farms whose geographic coordinates are as follows: Plot(S1) : 36°11′56, 96″N et 6°41′4’E, Plot(S2): 36°12′06,00N 6°36′57,80″E and Plot(S3): 36°14′41, 24184 N 6°37′25,09968″E (Fig 1).

Two types of fertilizers used during the test; ternary mineral fertilizer NPK (15-15-15) and organic fertilizer; cattle manure (cultivation of wheat annually) and mineral fertilizer in plot (S02) and plot (S03) previous type of culture leguminous crops and flanking soil respectively (Table 1).

In each of the experimental plots, sixty soil samples are collected using an auger before (initial) treatment and after harvesting every 10 m diagonally at 0-25 cm depth over an area of one hectare.

The soil samples are dried and sieved at 2mm to determine the following parameters: the pH according to a ratio 1 / 2.5 (NF X 31-103,1998), the electrical conductivity CE according to a ratio of 1/5 (ISO11265, 1994), the total limestone using the Bernard calcimeter according to standard NFISO10693 (1995), the organic matter is carried out according to the method of Walkley and Black (Duchaufour, 1991), the nitrogen is determined by the Kjeldahl method according to ISO11261 (1995)and phosphorus by the Olsen method and yield estimation.

Data analysis

Analysis of variance (ANOVA) and separation of means (Newman-Keuls test) are used to determine differences between treatments, using IBM SPSS Statistics ver. 23.0. The changes in soil characteristics before and after treatments are calculated using the formula:

$$X\% = 100*(X2-X1)/X1$$

Where,

X1= Value of the parameter considered before processing.

X2= Value of the parameter considered after processing.

RESULTS AND DISCUSSION

In our experience, the pH as well as the EC of the soil receiving organic amendments have increased compared to other treatments, values range from 8.14 to 8.39 for the pH and from 189.22 µs /cm to 281.46 µs /cm for the EC (Table 2).

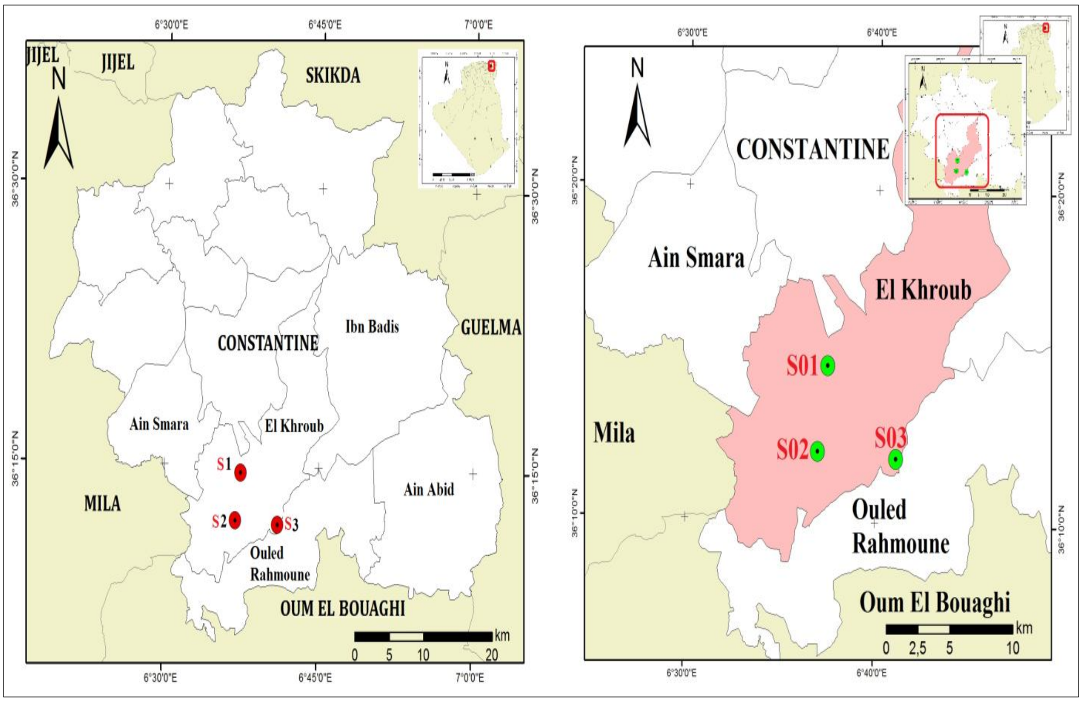

Fig 1: Location of study plots (made by the author with Arc GIS 10.2.2.).

We recorded a decrease in the pH and EC from 8.36 to 8.31 and from 525.31 µs /cm to 274.48 µs /cm respectively (Table 2). In their studies in rice-wheat system Dhaliwal *et al*. (2012) report similar results by studying the impact of the combined use of organic and inorganic fertilization on soil properties. Interestingly, Babu *et al*. (2007) report a slight decrease in soil pH and an increase in EC due to the application of organic fertilizers while Jagtap *et al* (2007) discussed the influence of integrated nutrient management on soil properties, that adding FYM with chemical fertilizers reduces soil pH and increases electrical conductivity.

Whereas for total limestone (CT), there is no change in soil treated with bovine manure and an increase in mineral fertilizer-treated soil of 23.26% and 95.49% for treated soil treated with mineral fertilizer and precede legume.

After treatment, we observed a marked increase in MO of the soil treated with bovine manure (4.45%) (Fig 2), as well as the one under mineral fertilizer with a legume rotation (3.67%). Analysis of the variance reveals a significant treatment effect ($p<0.05$).

Our results are consistent with those of Celik *et al*. (2010) who demonstrated the long-term effects of organic and mineral fertilizers on the chemical properties of semi-arid Mediterranean soils. They reported that the MO content is interestingly higher with manure application while mineral fertilizers has no effect on MO accumulation.

In our experiment Organic soil, C is higher in treatments receiving organic (cattle smoke) and organic fertilizers with crop rotation (intermediate legume) compared to soils receiving only inorganic fertilizers. Increase is 71.62%, 64.84%, 21.49% respectively this increase is highlighted by the analysis of variance which reveals a significant treatment effect ($p<0.05\%$).

The highest nitrogen and phosphorus content is recorded in soil receiving bovine manure (Table 1) Many studies (Sarma *et al*. (2015); Hemalatha and Chellamuthu (2013); Singh *et al*. (2006a) reported that manure application results in an increase of N and P amounts in soil.

The increase in N content available with the addition of organic fertilizers may be due to the release of nitrogen through the decomposition of organic fertilizers (Narwal and Antil 2005). But after harvest, there is a 10.17% decrease in the soil receiving bovine manure, while for soil treated with mineral fertilizer alone there is an increase of 3.51% and 31.37% for soil treated with mineral fertilizer with legume rotation preceding results According to the results obtained by Shahid *et al*. (2015).

The levels of N, P and K available in the soil are significantly affected by different fertilization treatments (Table 2). It has been demonstrated that long-term manure application and chemical fertilizers led to significant increase values of N available in the soil compared to other fertilization treatments. Dhaliwal Walia and (2008) found that the application of fertilizer and manure results in a significant improvement the accumulation of available N levels of underground soil. This is consistent with our work, which shows an increase in N only in soil that has received organic mineralization and that of an intermediate chemical culture (NPK) with a legume rotation. We can conclude that the application of organic fertilizers increases the nitrogen available in the soil.

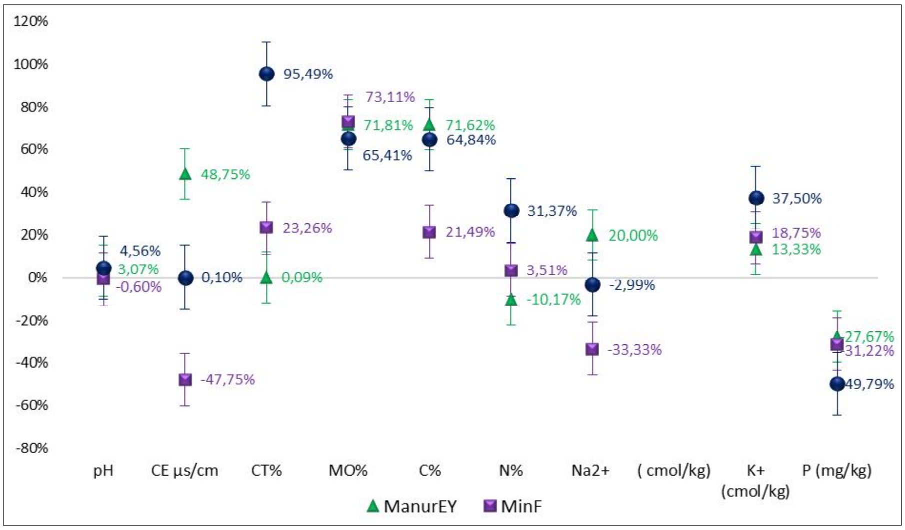

Fig 2: Percentage of changes in soil characteristics before and after treatments.

Table 1: Type of fertilizer used during the test.

	Plot 1 (FumCA)	Plot 2 (MinCC)	Plot 3 (MinJ)
Treatments	Organic fertilizer: cattle manure	Mineral fertilizer :$N_{15}P_{15}K_{15}$	Mineral fertilizer: fertilizer : $N_{15}P_{15}K_{15}$
Previous type of culture	Cultivation of wheat annually	Leguminous crops	Flanking soil

Table 2: Mean values of soil chemical parameters before the start of the experiment and after the different treatments.

	ManurEY		MinF		MinCC	
	Before the start of the experiment	After harvest	Before the start of the experiment	After harvest	Before the start of the experiment	After harvest
pH	8.14±0.44*	8.39±0.09*	8.36±0.20*	8.31±0.28*	7.90±0.23	8.26±0.65
CE µs/cm	189.22±0.40**	281.46±64.71**	525.31±36.55**	274.48±51.71**	182.12±29.68**	182.31±29.68**
CT	10.86±1.47	10.87±1.63	18.14±3.81**	22.36±3.60**	5.76±1.11**	11.26±2.33**
MO%	2.59±0.83**	4.45±0.69**	2.12±1.31**	3.67±0.92**	1.59±1.31**	2.63±0.57**
C%	1.48±0.47**	2.54±0.39**	1.21±0.74**	1.47±0.32**	0.91±0.75	1.50±0.32
N%	0.59±0.10	0.53±0.10	0.57±0.13**	0.59±0.16**	0.51±0.11	0.67±0.10
Na^{2+} (cmol/kg)	1.20±0.38*	1.44±0.40*	0.36±0.24*	0.24±0.10*	0.67±0.29**	0.65±0.34**
K (cmol/kg)	0.15±0.09	0.17±0.13	0.16±0.04**	0.19±0.51**	0.16±0.07**	0.22±0.22**
Passm (mg/kg)	17.02±1.93**	12.31±1.49**	15.92±0.77**	10.95±0.94**	13.96±0.77**	7.01±0.94**

Average values ± standard deviation *Significant at (p<0.05). **Correlation is significant at (p<0.01).

Furthermore, Singh and Singh (2013) also reported that the P available in the soil is improved through the combined use of fertilizer and manure compared to 100% NPK. Several groups have developed models for applying the main and micronutrients with all soil amendments for large areas, taking into account livestock manure, bio solids, phosphate and other fertilizers.

At the same time there was an increase in k concentration for the three treatments of 13.33%, 18.75% and 37.50% and a marked decrease for phosphorus of around 27.67%,3 1.22% and 49.79% respectively (Fig 2).

The high amounts of K in treatment can be due to bovine manure supplement with K applied to the soil each year, which could provide a certain amount of K and may insure the interaction of organic matter with clay. The decomposition of organic matter releases a substantial amount of CO_2 that forms carbonic acid after its dissolution in water and is responsible for the decomposition of certain primary minerals leading to the release of nutrients (Rajneesh *et al*. 2017).

A similar effect of the addition of manure is demonstrated by Hemalatha and Chellamuthu (2013); Mazumdar *et al*. (2014); Sathish *et al*. (2011). Singh *et al*. (2006b) observed that the level of SOC, total N and available P increases significantly due to the application of manure alone or in combination with chemical fertilizers. The study by Singh, *et al*. (2008) demonstrated that appliying FYM, VC, green manure and rice residue in the soil alone or in combination with bio fertilizers added to NPK, improved soil fertility and maintained high levels of productivity.

Accordingly, Kumar and Prasad's (2008) studies showed a significant increase of available N, P and K levels in soils due to the addition of green manure and green gram residues and their incorporation into the rice wheat growing system.

The best result of yield is obtained in the plot treated with bovine manure and the plot treated with chemical fertilizer with an intermediate crop that is in the order of 46 q/ha and 35 q/ha (Table 3) compared to the treatment with the mineral fertilizer alone; this could be due to an ameliorated availability of soil nutrients (Marschner 2011).

Table 3: The yield of each plot according to the different treatments.

	Treatements		
plot	ManurEY	MinF	MinCC
Yield quintals/ha	46	35	20

Our findings are in concordance with those of Shirani *et al*. (2002) and Iqbal *et al*. (2005) who reported that application in manure alone or in combination with different tillage practices improves plant growth and yields.

The results of different treatment's show that; cattle manure has promoted the availability of nutrients and especially organic matter Organic manure has achieved the best yield, when mineral fertilization has recorded the lowest yield. However, the use of manure and/or green manure seems to be the most attractive method, especially as it is environmentally friendly.

Conflict of interest: None.

REFERENCES

Agele, S.O. (2000). Effects of animal manure and NPK fertilizer on simulated erosion and maize yield. J. Environ Educ. Inform. 19: 131-138.

Abu, M., Vijaya, S., Reddy, C.M., Subramanyam, A. and Balaguravalah, D. (2007). Effect of integrated use of organic and inorganic fertilizers on soil properties and yield of sugarcane. Journal of Indian Society of Soil Science. 55: 161-6.

Behera, S.K., Singh, D., Dwivedi, B.S., Singh, S., Kumar, V. and Rana, V. (2008). Distribution of fraction of zinc and their contribution towards availability and plant uptake of zinc under long-term maize (*Zea mays* L.)-wheat (*Triticum astivum* L.) cropping on an Inceptisol. Soil Research. 46 (1): 83-9. doi: 10.1071/SR07073.

Benmati, M., Mouellef, A., Belbekri, N., Djekoun, A. (2020). Effects of durum wheat (*Triticum durum Desf.)* inoculation with PGPR (*Azospirillum brasilense, Bacillus sp and Frankia Ccl3*) and its tolerance to water deficit. Indian Journal of Agricultural Research. 54(4): 437-444.

Bi, L., Yao, S., Zhang, B. (2015). Impacts of long-term chemical and organic fertilization on soil puddlability in subtropical China. Soil Till Res. 152: 94-103.

Blanco-Canqui, H., Ferguson, R.B., Shapiro, C.A., Drijber, R.A., Walters, D.T. (2014). Does inorganic nitrogen fertilization improve soil aggregation? Insights from two long-term tillage experiments. J. Environ Qual. 43: 995-1003.

Celik, I., Gunal, H., Budak, M. and Akpinar, C. (2010). Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediterranean soil conditions. Geoderma. 160(2): 236-43.

Chaudhary, M. and Narwal, R.P. (2005). Effect of long term application of farmyard manure on soil micronutrients status. Archives of Agronomy and Soil Science. 51(3): 351-9.

Chu, C.M., Bradshaw, A.D. (1996). The value of pulverized refuse fines (PRF) as a substitute for topsoil in land reclamation. 1. Field studies. J Appl Ecol. 33: 851-857.

Debasish, B. and Mrinal, S. (2018). Agronomic biofortification in rice varieties through zinc fertilization under aerobic condition. Indian J. Agric. Res. 52(1): 89-92.

Dhaliwal, S.S., Walia, M.K. and Phutela, R.P. (2012). Effect of inorganic fertilizers and manures application on macro and micronutrients distribution under long term rice-wheat system. The Journal of Plant Science Research. 28(1): 149-61.

Dhaliwal, S.S. and Walia, S.S. (2008). Integrated nutrient management for sustaining maximum productivity of rice-wheat system under Punjab conditions. Journal of Research. PAU 45: 12-16.

Dinnes, D.L., Karlen, D.L., Jaynes, D.B., Kaspar, T.C., Hatfield, J.L., Colvin, T.S., Cambardella, D.A. (2002). Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soil. Agron. J. 94: 913-916.

Duchaufour, P. (1991). Pedologie: Sol, Vegetation, Environnement. pp. 289 pp.

El-Shakweer, M.H.A., El-Sayed, E.A., Ewees, M.S.A. (1998). Soil and plant analysis as a guide for interpretation of the improvement efficiency of organic conditioners added to different soil in Egypt. Comm Soil Sci Plant Anal. 29: 2067-2088.

Hati, K.M., Swarup, A., Mishra, B., Manna, M.C., Wanjari, R.H., Mandal, K.G., Misra, A.K. (2008). Impact of long-term application of fertilizer, manure and lime under intensive cropping on physical properties and organic carbon content of an Alfisol. Geoderma 148:173 179. doi: 10.1016 /j.geoderma.

Hemalatha, S. and Chellamuthu, S. (2013). Impacts of long-term fertilization on soil nutritional quality under finger millet-maize cropping sequence. Journal of Environmental Research and Development. 7: 1571-6.

Iqbal, M., Hassan, A.U., Ali, A., Rizwanullah, M. (2005). Residual effect of tillage and farm manure on some soil physical properties and growth of wheat (*Triticum aestivum* L.). Int J Agric Biol. 7: 54-57.

Jagtap, P.B., Patil, J.D., Nimbalkar, C.A. and Kadlag, A.D. (2007). Influence of integrated nutrient management on soil properties and release of nutrients in saline-sodic soil. Journal Indian Society of Soil Sciences. 55: 147-56.

Kumar, V. and Prasad, R.K. (2008). Integrated effect of mineral fertilizers and green manure on crop yield and nutrient availability under rice-wheat cropping system in calciorthents. Journal of Indian Society of Soil Sciences. 56: 209-14.

Marschner, P. (2011). Marschner's Mineral Nutrition of Higher Plants. 3rd ed. London: Academic Press. Mengel, K., Kirkby, E.A. (2001). Principles of Plant Nutrition. 5th ed. London: Kluwer Academic Publishers.

Mazumdar, S.P., Kundu, D.K., Ghosh, D., Saha, A.R., Majumdar, B. and Ghorai, A.K. (2014). Effect of long-term application of inorganic fertilizers and organic manure on yield, potassium uptake and distribution of potassium fractions in the new Gangetic alluvial soil under jute-rice-wheat cropping system. International Journal of Agriculture and Food Science Technology.5: 297-306.

Merbach, W., Wurbs, A., Jacob, H.J., Latus, C. (1997). Temporary biological conservation by winter oilseed turnip (*Brassica rapa* L.) and its influence on following crops and N-percolation. Isotops Environ. Health Stud. 33: 39-43.

Narwal, R.P. and Antil, R.S. (2005). Integrated Nutrient Management in Pearl Millet-Wheat Cropping System. In: Management of Organic Wastes for Crop Production, [(ed.) K. K. Kapoor, S.S. Dudeja and B.S. Kundu.] 205-13.

Naveed, M., Moldrup, P., Vogel, H.G., Lamandé, M., Wildenschild, D., Tuller, M., de Jonge, L.W. (2013). Impact of long-term fertilization practice on soil structure evolution. Geoderma. 217-218: 181-189.

Nziguheba, G., B¨unemann, E.K. (2005). Organic Phosphorus Dynamic in Tropical Agroecosystems. In: Organic Phosphorus in the Environment [(Ed.) Turner, B.L., Frossard, E., Baldwin, D.S]. Wallingford, Oxfordshire, UK: CABI Publishing: 243-268.

Rajneesh, R.P. Sharma, N.K. Sankhyan and Kumar, R. (2017). Long-term effect of fertilizers and amendments on depth-wise distribution of available NPK, micronutrient cations, productivity and NPK uptake by maize-wheat system in an acid alfisol of North Western Himalayas. Communications in Soil Science and Plant Analysis. 48: 2193-209.

Raymond, W.M., Roy, L.D. (1992). Organic Matter and Container Media soils: An Introduction to Soils and Plant Growth. 6th ed. Delhi: Prentice Hall. 181-224.

Rezig, A.M.R., Elhadi, E.A., Mubarak, A.R. (2012). Effect of incorporation of some wastes on a wheat-guar rotation system on soil physical and chemical properties. Int J Recycling Org Waste Agric. 1: 1-15.

Sarma, B., Bhattacharya, S.S., Gogoi, N., Paul, S. and Baroowa, B. (2015). Impact of N fertilization on C balance and soil quality in maize-dhaincha cropping sequence. Journal of Agricultural Sciences. Belgrade. 60: 135-48.

Sathish, A., Gowda, G.V., Chandrappa, H. and Kusagur, N. (2011). Long term effect of integrated use of organic and inorganic fertilizers on productivity, soil fertility and uptake of nutrients in rice and maize cropping system. International Journal of Science and Nature. 2: 84-8.

Shahid, M., Kumar, A.S., Bhattacharyya, P., Tripathi, R., Mohanty, S., Kumar, A., Lal, B., Gautam, P., Raja, R., *et al.* (2015). Micronutrients (Fe, Mn, Zn and Cu) balance under long-term application of fertilizer and manure in a tropical rice-rice system. Journal of Soils and Sediments. 16: 737-47.

Singh, F., Kumar, R. and Pal, S. (2008). Integrated nutrient management in rice-wheat cropping system for sustainable productivity. Journal of Indian Society of Soil Science. 56: 205-8.

Singh, G., Singh, O.P., Singh, R.G., Mehta, R.K., Kumar, V. and Singh. R.P. (2006a). Effect of integrated nutrient management on yield and nutrient uptake of rice (*Oryza sativa*)-wheat (*Triticum aestivum* L.) in lowland of eastern Uttar Pradesh. Indian Journal of Agronomy. 51: 85-8.

Singh, G., Singh, S. and Singh, S.S. (2013). Integrated nutrient management in rice and wheat crop in rice-wheat cropping system in lowlands. Annals of Plant and Soil Research. 15: 1-4.

Singh, Y., Singh, B., Pabbi, S., Dhar, D.W. and Singh, P.K. (2006b). Influence of integrated plant nutrient supply system on grain yield, quality and soil fertility in rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. Paper presented at the Proc. National Symp on Conservation Agriculture and Environment, BHU, Varanasi, October. 26-28, 157-8.

Shirani, H., Hajabbasi, M.A., Afyuni, M., Hemmat, A. (2002). Effect of farm manure and tillage systems on soil physical properties and corn yield in central Iran. Soil Till Res. 68: 101-108.

Sørensen, J.N. (1991). Effect of catch crops on the content of soil mineral nitrogen before and after winter leaching. Z. Pflanzenernahr. Bodenk. 155: 61-66.

Vichitra K.A., Singh, J., Kumar, L., Kumar, R., Kumar, P. and Chand, P. (2017). Indian J. Agric. Res. 51(2): 128-134.

Wong, M.H., Wong, J.W.C. (1989). Germination and seedling growth of vegetable crops in fly ash amended soil. Agric Ecosys Environ. 26: 232-235.

Walia, M.K., Walia, S.S. and Dhaliwal, S.S. (2010). Long-term effect of integrated nutrient management on properties of typic ustochrept after 23 cycles of an irrigated rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) system. Journal of Sustainable Agriculture. 34(7): 724-43. doi: 10.1080/10440046.2010.507519.