International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(6): 1318-1322
© 2019 IJCS
Received: 01-09-2019
Accepted: 03-10-2019

Deblina Ghosh
Research Scholar, Bidhan Chandra Krishi Viswavidyalya. Mohanpur, Nadia, West Bengal, India

Mitali Mandal
Assistant Professor, Department of Soil Science and Agricultural Chemistry Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India

Riju Dey
Research Scholar, Bidhan Chandra Krishi Viswavidyalya. Mohanpur, Nadia, West Bengal, India

Sushanta Kumar Pattanayak
Professor, Department of Soil Science and Agricultural Chemistry Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India

Corresponding Author:
Deblina Ghosh
Research Scholar, Bidhan Chandra Krishi Viswavidyalya. Mohanpur, Nadia, West Bengal, India

Effect of integrated nutrient management on fertility status of soil in acid inceptisols

Deblina Ghosh, Mitali Mandal, Riju Dey and Sushanta Kumar Pattanayak

Abstract
A field experiment was conducted during the *kharif* season of 2016 taking maize as a test crop to study the effect of integrated nutrient management practices on the physical and chemical properties of the soil, at College of Agriculture, O.U.A.T., Bhubaneswar. The integrated nutrient management practices include i) soil test dose(STD) @ 130-36-70-20 kg N-P_2O_5-K_20-SO_4 ha^{-1} as pure inorganic source ii)Combination of inorganic with organic in the form of either FYM @5 t ha^{-1} or vermicompost @2.5 t ha^{-1},iii) inclusion of microbial inoculant / biofertiliser (Azotobacter, Azospirillum and PSB(1:1:1) and soil amendment in the form lime @ 0.2 lime requirement(LR) compared with iv) Absolute control i.e. without any fertilisation. Maintenance of soil acidity at lower level (higher pH), higher available nutrients and higher organic carbon status with improved CEC and base saturation status in post harvest soil was influenced by INM practices. The application of organics with STD, BFs and lime improved the water holding capacity (35%), bulk density (1.41 Mg/m^3), organic carbon (5.5 g/kg), cation exchange capacity (7.3 $cmolp^+/kg$), available nitrogen (325 kg/ha), available potassium (180 kg/ha), available sulphur (22.5 kg/ha) and micronutrient status of the soil as compared to other treatments.

Keywords: INM, maize, physical and chemical properties of soil

Introduction
Maize (*Zea mays* L.) is the most important cereal crop in India and due to its high yield potential it is called “queen of cereals”. It is having special significance because it is a staple food in many areas, which provides nutritional security due to its high nutritional value and having great demand. On account of its quick growth habits, maize is a highly nutrient exhaustive crop. The demand of maize plant for nitrogen and phosphorus is more than any other essential elements for the development of all phases. It is absolutely necessary that essential nutrient elements should be supplied in appropriate proportion to maintain soil fertility and to get higher yield. According to Sarkar *et al*. (2000) [19] Hybrid maize is a heavy feeder and more responsive to nutrients and the required amount of nutrients may be supplied through organic maures and inorganic fertilizers to grow it and to maintain soil fertility on a sustained manner.

Chemical fertilizer cannot be avoided completely since they are the potential sources of high amount of nutrients in easily available forms. Most of the crops respond quickly to chemical fertilizers and give higher yield and maize is more responsive. But continuous application of chemical fertilizers alone is not desirable as it has been reported to deteriorate soil health. Application of imbalanced and excessive nutrients also led to declining nutrient-use efficiency making fertilizer consumption uneconomical and producing adverse effects on atmosphere (Aulakh and Adhya, 2005) [1] and groundwater quality (Aulakh *et al*. 2009) [2] causing health hazards and climate change.

Supplementing the nutrient requirement of crops through organic manures *e.g.* vermicompost, farm yard manure *etc.*, especially plays a key role in sustaining soil fertility and crop productivity, reducing use of fossil fuels and restoring overall soil quality. These sources are often cheaper and more efficient than inorganic compounds. Organic materials hold great promise as source of multiple nutrients because of their ability to improve soil characteristics, boosting yield, reducing production cost and improving soil health. The organic products besides supplying nutrients to the first crop, also provides substantial residual effect of unutilized nutrients on the succeeding crop. At the same time application of organic manures alone do not produce required yields due to their low nutrient status. Integration and incorporation of organic manure (FYM/urban compost) in the agricultural systems helps to improve the fertility status of the soil and which in turn helps to stabilize the production and productivity of the crops. Integration of organic and inorganic fertilizers may be beneficial for achieving a sustainable crop production. Integrated Nutrient Management(INM) is also important for marginal farmers who cannot afford to supply crop nutrients through costly chemical fertilizers.

Long-term experiments can be more useful for studying the changes in soil properties and processes over time and for obtaining information on sustainability of agricultural systems for developing future strategies to maintain soil health (Haynes and Naidu, 1998) [11]. The present study was thus initiated to find out the effect of different combination of organic sources and inorganic fertilizers on the long term basis in maize, to monitor the changes in fertility status of soil.

Material and Methods

The field experiment was conducted during 2015-16 at College of Agriculture, OUAT, Bhubaneswar. The field trial is in continuation since 2010 with maize crop, located at $25^{0}15'$ N latitude and $80^{0}2'$ E longitude and altitude of 25.9 m above mean sea level (MSL). The present crop maize (var. monsanto hybrid) was 17^{th} crop in the sequence (*kharif* 2016). The succeeding crops were green gram, maize, cabbage, and cowpea followed by crop maize (under discussion).The residues of individual crops were incorporated in situ. The initial status of the soil sample of the experimental field (0-15 cm depth) was with pH- 5.18, Organic carbon- 2.7 g/kg, available nitrogen- 207 kg ha^{-1}, available P_2O_5 - 37 kg ha^{-1}, available K_2O-84 kg ha^{-1} and $CaCl_2$ extractable sulphur-25kg ha^{-1}. The experiment was initiated with 10 different INM treatments, namely: (1) absolute control, (2) STD (100% NPK), (3) STD + FYM, (4) STD + VC, (5) STD + F + BFs, (6) STD + VC + BFs, (7) STD + F + L + BFs, (8) STD + VC + L + BFs, (9) BFs alone, (10) 50% STD + BFs. These treatments were replicated three times with RBD design. The test crop received N-P_2O_5-K_2O-SO_4 @ 130-36-70-20 kg ha^{-1} in the form of, Navaratna (20-20-0-13), urea and MOP respectively. The FYM and vermicompost were applied @ 5.0 and 2.5 t ha^{-1} respectively. The inorganic nutrients as fertilizers were applied in three splits and organics and bio fertilizers as basal.The *Azotobacter*, *Azospirillum* and PSB (1:1:1) @4 kg each ha^{-1}, inoculated to limed (5%) vermicompost, incubated for 7 days at 30% moisture and applied as basal. Lime was applied @ 0.2 LR as paper mill sludge as per the treatment specificity. Representative composite soil samples were collected after harvest from all the treatments. The samples were dried under shade, grinded with wooden hammer and sieved through 2mm sieve. The samples were preserved in polythene bags with proper labels for analysis. The texture of the soil samples were determined by Bouyoucos Hydrometer method and the water holding capacity of the soil was determined by Keen Raczkowski box method as described by Piper (1950) [18]. The bulk density of experimental soil was determined by core method. Soil pH and EC was determined as described by Jackson (1973). The Cation Exchange Capacity of the soil was determined by successive extraction of soil with neutral 1N ammonium acetate and the Organic carbon content of soil was determined by wet oxidation procedure of Walkley and Black as outlined by Page *et al.*, (1982) [17]. Available nitrogen, phosphorus, potassium and sulphur in soil was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 1956) [23], Bray's 1 method, neutral normal ammonium acetate solution and $BaCl_2$ method (Chesin and Yien, 1950) [6] respectively. Micronutrients were estimated by DTPA extraction method (Lindsay and Norvell, 1978) [15] as described by Page *et al.*, (1982) [17] The statistical analysis of the experimental data was carried out as per the methods suggested by Gomez and Gomez (1983) [10].

Result and discussions

Effect of INM practices on physical properties of soil

Influence of INM treatments on soil texture and water holding capacity are depicted in table 1.The results demonstrated that the particle size differentiation remains unchanged under the influence of different treatments. Soil textural class was loamy sand. The water holding capacity of the soil varied from 23% to 35%, being highest in STD + F + BFs + L treated plot and lowest in only biofertilizer treated plot. Improvement in structural condition of soil due to application of FYM with inorganic chemical fertilizer and microbial inoculants could be the possible reason as reported by Bhatnagar *et al.*, 1992 [5]. The water holding capacity is controlled by number of pores, their size distribution and specific surface areas of soils (Haynes and Naidu, 1998) [11]. Soils high in organic matter content had greater available water holding capacity tham the soils of similar texture with less organic materials.

The bulk density of the soil varied from 1.41 to 1.80 Mg m^{-3} in surface layer (0-15cm) and from 1.57 to 1.85 Mg m^{-3} in sub surface layer (15-30cm). Results indicated that the maximum reduction (18.96%) in BD was recorded in integration of inorganic + organic + F + BFs + L treatment as compared to initial values. The lowest BD values was recorded in INM treatments. This could be ascribed to the greater level of organic residues that are added to the soil, undergo microbial decomposition and in this process various organic products of decay like polysaccharides are released which acts as strong binding agent in the formation of large and stable aggregates which help to improve the physical properties of soil (Manickam,1993). There was a significant difference in BD in mineral fertilizer with absolute control, probably because of increased biomass production with consequent increase in organic matter content in soil by application of NPKS fertilizers (Bharadwaj and Omanwar, 1992) [4]. In general less BD in the surface soil was observed in present study (Table-1). This can be attributed to the greater SOC content in the surface soil and more compaction in sub surface soil resulting from continuous cultivation practice with intercultural operations and mass of soil above (Ghuman and Sur, 2001) [9].

Effect of INM practices on physico- chemical properties of soil

The initial soil sample collected from the experimental site in 2010, before the commencement of experiment was acidic (5.14). After the harvest of the 17^{th} crop i.e. maize, the pH of the soil varied from 4.22 to 5.49. As compared to initial status, soil reaction decreased among all the treatments except the treatments that received soil ameliorant. Regarding pH of the soil in INM treatments except lime application, there was no significant variation. There was a significant decrease in pH in mineral fertilizers alone or integration with organic manure or both organic manure and biofertilizer compared to absolute control (4.74). Gawai (2003) [8] reported reduction in soil pH due to microbial decomposition of organic manures. Decline in soil pH can have positive impacts on availability of nutrients such as P, Zn, Fe and Mn which will be discussed later. The data indicated that electrical conductivity of the soil increased as compared to initial value of 0.18 dSm^{-1} (Table 2). Seven years of incorporation of crop residues, organic additions helped in maintaining high organic carbon status by harvest of 17th crop in sequence. The SOC ranged from 4.1 to 5.5 g kg^{-1}. Significant increase in organic carbon (4 to 22 per cent) content due to INM treatments was observed. This was probably due to the rapid decomposition of organic material that has been added to the soil and intensive polymerisation process (humification) of organic matter as influenced by biofertilizer.

The integration of biofertilizers in the INM practices improved CEC in soils varying from 14 to 15.3 $cmol(p^+)kg^{-1}$ of soil, highest being recorded in INM treatments along with soil ameliorant addition treatments. Biofertilizers inclusion in the INM practices improved the Exchangeable K,Ca,Mg and Na in soil (Table 2). Among all the cations, Ca^{2+} remains the dominant one followed by Mg^{+2}, Na^+ and K^+. The base saturation of the soil varied from 41.4% in absolute control to 86.3% in STD + VC + BF + L.

Table 1: Influence of organics, inorganics, biofertilizers and INM practices on texture, water holding capacity and bulk density of soil.

Sl. No	Treatment	Texture				Water holding capacity (%)	Bulk density (Mg/m^3)	
		Sand (%)	Silt (%)	Clay (%)	Textural class		0-15cm	15-30cm
1	Absolute Control	84.4	4.8	10.8	LS	30	1.80	1.85
2	STD	84.0	6.0	10.0	LS	24	1.75	1.78
3	STD+F	81.4	6.6	12.0	LS	27	1.63	1.69
4	STD+VC	84.0	6.0	10.0	LS	26	1.67	1.68
5	STD+F+BF	81.2	6.8	12.0	LS	30	1.52	1.63
6	STD+VC+BF	81.5	6.5	12.0	LS	29	1.56	1.64
7	STD+F+BF+L	83.3	6.7	10.0	LS	35	1.41	1.58
8	STD+VC+BF+L	81.3	6.7	12.0	LS	33	1.42	1.57
9	BF	84.0	6.0	10.0	LS	23	1.73	1.77
10	50%STD+BF	81.5	6.5	12.0	LS	24	1.71	1.75
LSD (p=0.05)		-	-	-	-	3.93	0.02	0.02

*LS=Loamy Sand

Effect of INM on available nutrient status in soil

Available Nitrogen

Maximum available N (325 kg ha^{-1}) was attained in the treatment receiving organic manure in the form of vermicompost, inorganic manure, microbial inoculants and lime application. Appraisal of results of the present study (Table-3) demonstrated that all the treatments except control and BFs improved nitrogen status of soil after harvest of maize as compared to initial status of soil (207 kg ha^{-1}). Application of inorganics fertilizer failed to increase the nitrogen content in soil. Application of organic manure along with inorganic biofertilizer did not cause any significant increase in available N compared to STD alone. Inclusion of biofertilizer caused significant increase. The increase in available N content with the incorporation of organic sources may be attributed to N mineralisation (Sharma *et al*.,2008). Continuous removal by crops without external addition of fertilizers and FYM/VC over a period of time resulted decline in soil available nitrogen. The result of the present study is in line with those reported by Sharma *et al*.,(2008). In INM treatments inclusion of microbial consortia of *Azotobacter*, *Azospirillum* and PSB along with lime significantly increased the available nitrogen in soil. Because biofertilizers keep the soil environment rich in all kinds of of macro, micro nutrients via nitrogen fixation, phosphate and potassium solubilisation or mineralisation, release of plant growth regulating substances like IAA, NAA, GA, cytokinins, production of antibiotics and biodegradation of organic matter (Sinha *et al*., 2014) [22].

Available Phosphorus

Regarding the available P status in soil, it was observed that (Table- 3) available P content in surface soil improved significantly in all the treatments except control as compared to initial value (36 kg ha^{-1}). However, the available P status of the soil continued to increase with addition of organic manure and also with biofertilizers. Among the biofertilizers treatment PSB plays a very important role in phosphorus nutrition by exchanging its availability to plants through release from inorganic and organic soil phosphorus pools by solubilisation and mineralisation. Maximum P (126 kg ha^{-1}) build up was recorded in the treatment where only organic manure (VC) was added along with inorganic fertilizers. Higher availability may be due to solubilisation of P by organic acids released from the organic manures, reduction of P fixation in soil due to chelation of P fixing cations like Ca, Mg, Fe, Al, Zn, Mn and Cu and also due to enhanced microbial activity (Sathya,2010). There was no significant change in available P status in biofertilizer treated plot compared to control. However, control recorded lowest available P (23.3 kg ha^{-1}).

Available Potassium and sulphur

The available K status increased in all the treatments from its initial value of 84 kg ha^{-1}. Among the INM treatments exclusion of lime did not came with any significant difference. Only lime addition to the INM practices recorded higher available K ranging from 171 to 180 kg ha^{-1}. STD alone increased the appreciable amount of available K (171 kg ha^{-1}) which was closely followed by only biofertilizer application (161 kg ha^{-1}). The beneficial effect of organic manuring on K availability includes, minimizing the losses from leaching by retaining K ions on exchange sites, solubilisation of insoluble components through action of organic acids released during decomposition besides minimizing losses due to fixation (Dakshinamoorth y*et al*., 2000) [7]. Cultivation practices decreased the sulphur content in soil as compared to its initial status (26 kg ha^{-1}). Irrespective of its supplementation or residue incorporation the status followed the decreasing trend.

Table 2: Influence of organics, inorganics, biofertilizers and INM practices on soil pH, EC, organic carbon content and CEC of the soil

Sl. No	Treatment	pH	EC (dSm^{-1})	OC (g/Kg)	CEC (cmolp^{+}/ Kg soil)					
					CEC	Exc. Ca	Exc. Mg	Exc.Na	Exc. K	(%) BS
1	Absolute Control	4.74	0.26	4.1	3.6	1.5	0.12	0.003	41.1	3.6
2	STD	4.22	0.29	4.5	3.9	2.8	0.13	0.003	56.0	3.9
3	STD+F	4.37	0.28	4.7	4.4	3.4	0.15	0.003	66.3	4.4
4	STD+VC	4.47	0.32	4.8	4.7	3.8	0.15	0.004	84	4.7
5	STD+F+BF	4.22	0.37	5.1	5.7	4.7	0.16	0.004	75.5	5.7
6	STD+VC+BF	4.34	0.40	5.3	6.0	4.6	0.17	0.004	75.3	6.0
7	STD+F+BF+L	5.49	0.47	5.3	6.5	5.7	0.20	0.005	83.3	6.5
8	STD+VC+BF+L	5.49	0.44	5.5	7.3	5.7	0.20	0.005	86.3	7.3
9	BF	4.39	0.24	4.2	3.6	2.6	0.11	0.003	65.8	3.6
10	50%STD+BF	4.36	0.32	4.7	4.1	3.0	0.12	0.003	70.8	4.1
Initial year- 2010		5.14	0.18	2.7	1.55	0.48	0.48	0.01	0.0005	-
LSD (p=0.05)		0.31	0.097	0.65	7.23	3.6	1.5	0.12	0.003	41.1

*****STD = soil test dose, FYM = farm yard manure, VC = vermicompost, BF= biofertilizer and L = lime.

Table 3: Influence of organics, inorganics, biofertilizers and INM practices on available macro and micro nutrients status in soil

Sl. No	Treatment	N	P	K	S	Micronutrients (mg/kg)			
		(kgha^{-1})				Fe	Mn	Zn	Cu
1	Absolute Control	185	23.3	114	12.3	33.3	41.76	3.6	1.77
2	STD	206	90.5	171	13.3	91.7	26.00	8.0	1.63
3	STD+F	209	118.3	132	14.8	80.0	27.70	9.9	2.37
4	STD+VC	238	126.0	101	15.1	67.6	28.50	14.6	2.52
5	STD+F+BF	255	101.7	137	18.3	80.5	46.05	8.9	1.92
6	STD+VC+BF	290	98.0	144	16.8	69.3	42.91	16.2	1.81
7	STD+F+BF+L	300	96.6	180	22.5	44.0	31.13	10.9	1.46
8	STD+VC+BF+L	325	84.8	171	20.4	35.0	32.43	13.2	1.51
9	BF	190	57.0	161	15.0	48.6	28.40	4.4	2.03
10	50%STD+BF	210	76.4	153	14.0	52.6	35.9	13.0	2.09
11	Initial Status- 2010	207	36	84	26	-	-	-	-
LSD (p=0.05)		56.98	28.55	38.54	6.89	19.54	10.29	9.02	0.54

DTPA extractable micronutrients

The results showed that the available iron status varied from 33.3 mg kg^{-1} in absolute control to 91.7 mg kg^{-1} in STD alone. Lowest amounts of available iron (17.53 mg kg^{-1}) were observed in the absolute control which was due to the continued exhaustion of available iron. Similar results were also reported by Hemalatha *et al*. (2013) [12] and Jha *et al*. (2013) [14]. The effect of FYM was more prominent in increasing the availability as compared to VC among the treatments. The addition of biofertilizers with STD and organics did not increased the availability, whereas the addition of lime decreased the availability as compared to other sources.

The available manganese status varied from 26 mg kg^{-1} in STD to 46.05 mg kg^{-1} in STD + FYM + BFs. The addition of organics did not have pronounced effect on available manganese status as compared to absolute control.

Available zinc and copper status of the soil varied from 3.6 to 16.2 mg kg^{-1} and 1.46 to 2.09 mg kg^{-1} respectively. In both the cases the BFs alone and BFs with ½ STD showed more availability of micronutrients as compared to the integration of organics, inorganics, BFs and lime. Banerjee *et al*. (2011) [3] found that the available copper content gradually increased, which may be due to binding of copper with manganese oxides and organic matter present in the soil rendering it as non-exchangeable form and, therefore, not available to crop uptake.

The higher availability of micronutrients in soil on application of manures could be as cribbed to mineralization of these nutrients from added manures. Chelating action of FYM during decomposition of organic manures increases the availability of micronutrient cations and also protected these cations from fixations. Continuous cropping devoid of balanced fertilizers for long time may decrease the available zinc content in soil. Same result was reported by Verma *et al*. (2005) [24].

Conclusion

Adoption of INM practices including organics, inorganics, microbial inoculants and lime increased appreciable amounts of organic carbon and maintained the fertility status of the soil by increasing the availability of nutrients and by improving physical environment of the soil. The bulk density of the soil was found to be increasing depthwise and the inclusion of organics decreased the value of bulk density and increased the water holding capacity of soil. As the soil is acidic, it is mandatory to include lime as one of the key components of INM for better growth and crop yield.

Acknowledgements

This study was financially supported by the Indian Council of Agricultural Research sponsored All Indian Network Project on Soil Biodiversity and Biofertilisers.

References

1. Aulakh MS, Adhya TK. Impact of agricultural activities on emission of greenhouse gases-indian perspective. In International conference on soil, water and environmental Quality-Issues and strategies (Indian society of soil science: New Delhi), 2005, 319-335.
2. Aulakh MS, Khurana MPS, Singh D. Water pollution related to agricultural, industrial and urban cativities, and its effects on food chain. Case studies from Punjab. Journal of New Seeds. 2009; 10:112-137.

3. Banerjee, Arnab, Datta, Jayanta K, Mandal NK, Chanda T. Communications in Soil Science and Plant Analysis. 2011; 42:2473-2492.
4. Bharadwaj V, Omanwar PK. Impact of long-term fertilizing treatments on bulk density, water contents, and microbial population of soil, Journal of the Indian Society of Soil Science. 1992; 40:553-555.
5. Bhatnagar VK, Kundu S, Vedprakash K. Effect of long-term manuring and fertilization on soil physical properties under soybean (Glycine max)–wheat (*Triticum aestivum*) cropping sequence, Indian Journal of Agricultural Science. 1992; 62:212-214.
6. Chesnin L, Yien CH. Turbidimetric estimation of sulphur, Soil Science Society of America. 1950; 15:149-151.
7. Dakshinamoorthy M, Santhy P, Selvi D and Mathan KK. Sustenance of crop productivity and soil fertility on an Incepticol in a long term fertilizer experiment. Proceeding of International Conference on Managing Natural Resources for Sustainable Agricultural Production in the 21st Century, New Delhi, India, 2000; 3:1336-1337.
8. Gawai PP. Effect of integrated nutrient management system in sorghum-chickpea cropping sequence. Ph.D. thesis submitted to M.P.K.V, Rahuri (M.S.), 2003, 80-167.
9. Ghuman BS, Sur HS. Tillage and residue management effects on soil properties and yields of rainfed maize and wheat in a subhumid subtropical climate, Soil and Tillage Research. 2001; 58:1-10.
10. Gomez KA, Gomez AA. Statistical Procedure for Agriculture Research. New York: John Wiley & Sons, 1983.
11. Haynes R, Naidu R. Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: A review, Nutrient Cycling in Agroecosystem, 1998; 51:123-137.
12. Hemalatha S, Radhika K, Maragatham S, Katharine S, Praveena. Influence of Long Term Fertilization on Soil Fertility. Journal of Agriculture and Allied Sciences, 2013, 2319-9857.
13. Jakson ML. Soil Chemical Analysis, Prentice Hall of India. Pvt. Ltd, New Delhi, 1973.
14. Jha MN, Chaurasia SK, Bharti RC. Effect of Integrated Nutrient Management on Rice Yield, Soil Nutrient Profile, and Cyanobacterial Nitrogenase Activity under Rice–Wheat Cropping System. Communications in Soil Science and Plant Analysis, 2013; 44:1961-1975.
15. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper, Journal of American Society of Soil Science. 1978; 42:421-428.
16. Manickam TS. Organics in soil fertility and productivity management. In: Organics in soil water and crop production, Oryza. 1993; 30:54-59.
17. Page AL, Miller RH and Keeny DR. Methods of Soil analysis, Part-2. Chemical and Micro-biological properties, 2ndEdn. No (9) Part-2 in the series, Agronomy, American Society of Agronomy, Inc. Soil Science Society of America Inc., Medison Wisconsin, U.S.A., 1982.
18. Piper CS. Soil and plant analysis, A monograph from the Waite Agricultural Research Institute, South Australia, 1950.
19. Sarkar AK, Singh KP, Singh BP, Singh RP. Long term effect of fertilizers, manures and amendments on crop production and soil fertility. Technical bulletin of Soil Science and Agricultural Chemistry (BAU) No. 2/2000, 2000, 31-45.
20. Sathya S. Evaluation of enriched FYM and fly ash on soil fertility and yield of rice under system of rice intensification (SRI) in Periyar Vaigai Command (PVC) area -Tamil Nadu. Ph.D. Thesis, Agricultural College and Research Institute, Madurai, Tamil Nadu (India), 2010.
21. Sharma MP, Bali VS, Gupta DK. Crop yield and properties of Inceptisols as influenced by residue management under rice-wheat cropping sequence, Journal of Indian Society of Soil Scence. 2008; 48:506-509.
22. Sinha RK, Valani D, Chauhan K, Agarwal S. Embarking on a second green revolution for sustainable agriculture by vermiculture biotechnology using earthworms: reviving the dreams of Sir Charles Darwin. International Journal of Agricultire Health Safety. 2014; 1:50-64.
23. Subbiah BV, Asija GL. A rapid procedure for the determination of available nitrogen in soils, Current Science. 1956; 25:259-60.
24. Verma A, Nepalia V, Kanthaliya, PC. Effect of continuous cropping and fertilization on crop yields and nutrient status of a Typic Haplustept. Journal of the Indian Society of Soil Science. 2005; 53:365-368.