Bulgarian Journal of Agricultural Science, 19 (No 6) 2013, 1287-1291
Agricultural Academy

IMPACT OF RICE CROP ON SOIL QUALITY AND FERTILITY*[1]

M. A. TALPUR[1], J. I. CHANGYING[1,*2], S. A. JUNEJO[2] and A. A. TAGAR[1]
[1] *Nanjing Agricultural University, Department of Agricultural Mechanization, College of Engineering, Nanjing 210031, China*
[2] *Nanjing University, Department of Hydrology, School of Earth Science and Engineering, 210093, China*

Abstract

TALPUR, M. A., J. I. CHANGYING, S. A. JUNEJO and A. A. TAGAR, 2013. Impact of rice crop on soil quality and fertility. *Bulg. J. Agric. Sci.,* 19: 1287-1291

Soil fertility and quality play pivotal role in achieving the promising yield of the crops, which declines with intensive farming and it cannot last long unless managed properly. Maintenance of soil fertility is therefore very important for sustaining high paddy yields. This study was conducted to observe the impact of rice crop cultivation in paddy field. During these study physical, mechanical and chemical properties of soil at five different depths i.e. 0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm and 60-75 cm before cultivation and after harvesting were tested. Results show that continuous shallow plowing a layer is formed at 31-45cm depth, while, the availability of nitrogen (N) decreases as availability of phosphorus (P) increased and little decrease in the availability of micro nutrients were observed. It was also observed that soil fertility has an indirect relation with depth in case of nitrogen and phosphorus.

Key words: soil fertility, texture, nutrients, rice crop

Introduction

According to Food and Agriculture Organization (FAO), the global rice requirements in 2025 will be 800 million tons (MT) while the present production is 600 MT and an additional 200 MT is still needs to be produced by increasing productivity per hectare to meet the future requirements (Swaminathan, 2006). Suitable rice based cropping has to be evaluated, to assess the stability in production (Kumpawat, 2001).

The soils on which rice grows are as varied as the climatic regime to which the crop is exposed: texture ranges from sand to clay, pH from 3 to 10; organic matter contents from 1 to 50%; salt content from almost 0 to 1%, and nutrient availability from acute deficiencies to surplus (De Datta, 1981).

Intensive agriculture, involving exhaustive high yielding varieties of rice and other crops, has led to heavy withdrawal of nutrients from the soil; imbalanced and discriminate use of chemical fertilizers has resulted in deterioration of soil health (John et al., 2001). Increase in available nitrogen, phosphorus, potassium and sulphur content in cropping sequences involving vegetable, pea, green gram were reported by Gangwar and Ram (2005).

According to United Nations University Institute of Advanced Studies (UNU-IAS, 2008), degradation of natural resources reduces the productivity. Sanchez (2010) emphasized on the development of high yielding crop varieties with little attention given to the ecology on which the plant survives. He suggested that crop yields in Africa could be tripled through proper management of the soil environment. Ladaha (2003) also reported that long-term fertilization effects on crop yield and soil fertility changes.

The demand of the rice plant for other macronutrients mainly depends on the N supply (Dobermann et al., 1998). On the other hand, the average plant recovery of fertilizer N is only about 30% (Dobermann, 2000), although much knowledge has been gained about the nitrogen cycle in lowland rice environments. The increase in rice production to feed a growing world population will require a threefold increase in applied N at present levels of N fertilizer use efficiency (Cassman and Harwood, 1995). It is therefore important to increase fertilizer N recovery and internal N utilization efficiency (NUE) in rice production systems through cultivar improvement and better crop and soil management (Ying et al., 1998). The nitrogen effect is manifested quickly on plant growth and ultimately

*1 Supported by Engineering college, Nanjing Agricultural University, 210031 (China)
*2 Corresponding author: chyji@njau.edu.cn

on yields. Hence, the fertility status of a soil depends largely on the nitrogen status of the soil (Sinha and Prasad, 1980). Sta Cruz and Wada (1994) found substantial variation in nitrogen uptake between rice ecotypes (upland and lowland type cultivars), plant types, hybrids, and plants with different growth duration. Plant types based on leaf erectness, panicle number and growth duration was the most important. Nitrogen uptake during spikelet initiation, flowering, and maturity reportedly increased with growth duration. The variation in nitrogen uptake among genotypes with different growth duration is due to differences in the duration of the vegetative lag period (Sta Cruz and Wada, 1994).

In China most of the farmers have resorted to using higher (550-600 kgN ha^{-1} $year^{-1}$) than the recommended doses of N fertilizers to maintain previously attained yield levels (Wang, 2004), which has resulted in reduced N recovery rate and environment pollution.

Protection of soil quality under intensive land use and fast economic development is a major challenge for sustainable resource use in the developing world (Doran et al., 1996). In Asia, adverse effects on soil health and soil quality arise from nutrient imbalance in soil, excessive fertilization, soil pollution and soil loss processes (Zhang et al., 1996; Hedlund et al., 2003).

Fertilizer N recovery equal to 50% to 70% of what is applied can be achieved when N is applied in the proper amount, in the proper form, and at the proper time (Peng and Cassman, 1998). Raun et al. (2002) have calculated that the 67% loss of applied N to cereal crops globally is equivalent to $15.9 billion.

Study Area

Geographically the study area is located at 32º 02'12.15''N latitude and 118º 37' 47.95''E longitude. The field is about 12 km away from Engineering College Pukou, Nanjing Agricultural University, Jiangsu province, P.R. China.

Climate of the area is humid, influenced by the East Asia Monsoon. Summer is usually hot and of rainfall happens throughout the year. The annual mean temperature is 15.9°C (60.6°F) while mean value ranges from 3.0°C (37.4°F) in January to 28.3°C (82.9°F) in July. Lows average slightly below freezing in January. The highest recorded temperature is 40.7°C (105°F) (Aug 22, 1959), and the lowest −14°C (7°F) (Jan 6, 1955). However, average of annual rainfall observed is 1.062 mm (41.8 in). Nanjing is very rich with water resources, both surface (Yangtze River) and groundwater.

Soils of the study area are sandy loam and clay loam. The top layers texture at 0-30 cm depth is sandy clay loam, at 31-45 cm depth, it is clay loam and at 46-75 cm, it is sandy loam. Texture class of sandy clay loam contains 56%sand, 28%silt and 16%clay particles where as clay loam contains 54%sand, 30%silt and 16%clay particles, while sandy loam contains 58%sand, 32%silt and 10%clay particles (Figure 1).

Methodology

Soil sample collection: To determine the different parameters of the soil, representative samples of soil were collected from the selected locations. A Composite sampling of soil was carried out for 7 locations from the plot measuring 1.5 hector; for each location five samples were taken at the depth of 0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm and 60-75 cm with the help of soil augur (Figure 2). The individual soil cores samples of 7 locations were then mixed properly in a clean plastic container because the land area is small and have a similar crop and fertility history. Soil characteristics (color, slope, texture, drainage) were also similar. The soil mixture was used for the analysis of different parameters.

Sample preparation and Analysis: 5.0 g soil sample was weighed in to a volumetric flasks of 100 ml. approximately 50-60 ml of deionized water was added to flask and shaken

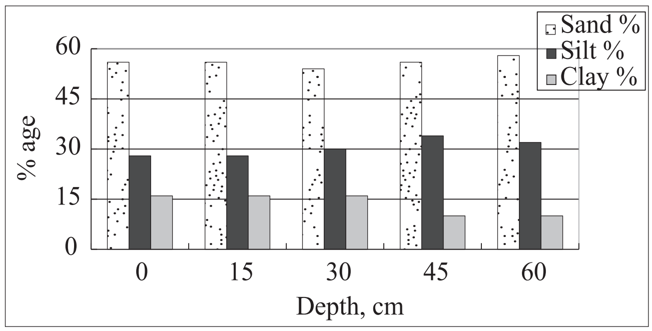

Fig. 1. Status of Soil Structure at different depths

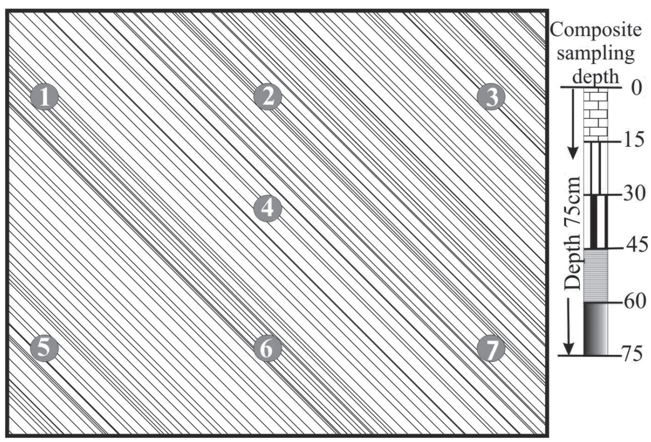

Fig. 2. Shows sample collection defferent location of the experimental plot at the depth of 0-75 cm

on automatic flask shaker for an hour. The constituents of flask were filtered through Whatman # 42 filter paper in 100 ml flask. The filtrate solution was used for the determination of soil pH on Electro Chemical Analyzer, JENCO MODEL 917 Bench Meter.

Texture of the soil was determined by hydrometer method (Bouyoucos, 1927) and for Organic matter assessment the potassium dichromate volumetric method-sulfuric acid (0.4000 mol / l KCr_2O_7-H_2S_O4) external heating method was used (Jackson, 1958). Whereas all N were detected by considering, semi-micro Kjeldahl method (Jackson, 1958) and all P were analyzed by $HClO_4$-H_2SO_4 method. While available zinc, copper, iron and manganese were extracted by using DTPA extract method as explained by Lindsay and Norvell (1978). The concentration of zinc, copper, iron and manganese in the extract was estimated using Atomic Absorption Spectrophotometer (AAS).

Rice variety of wuyungen No. 23 seed was used to its cultivation as this variety is mostly used and easily available in Nanjing. The fertilizers were applied for four times throughout the cropping period (Table 1).

The pesticides were also practiced for four times to control the diseases. Three types of pesticide i.e., Chlorpyritos, Imidacloprid and Jinggangmycin were used. Weeding was carried out for four times throughout the growing period of the crop. SPSS 16.0 was used for analysis of data.

Results and Discussions

Soil pH: The soil of study was found slightly alkaline before rice cultivation and tends towards acidic at the time of harvesting (Figure 3). There are many exceptions causing soils acidic i.e., intensive crop production, rainfall and water percolation through the soil rapidly and organic matter decay. The soils of study area contains 54% Sand which becomes acidic quickly because water percolates rapidly, and sandy soils contain only a small reservoir of bases (buffer capacity) due to low clay and organic matter contents.

Table 1
Detail of fertilizer application to experimental plots

Date	Item	Quantity, kg	Ingredients
8-07-2010	NPK Compound	3.7	18% N, 22%P, 16%k
15-07-2010	N	12	N>46.3%
25-07-2010	N	12	N>46.3%
16-08-2010	N	5	N>46.3%

Organic Matter: The organic matter before cultivation of rice crop was observed 25 g kg^{-1} while after harvesting decreased up to 20g kg^{-1}. However, the R^2 value was near 0.7 for both before cultivation and after harvesting, while it decreases as goes deeper. The mean difference is significant at the 0.05 ($p<0.05$) level (Figure 3). Olk et al. *(*1999) has also reported that the decrease in soil organic matter is positively correlated with increased frequency of cropping, associated with long anaerobic periods.

Macro Nutrients: Two primary nutrients nitrogen (N) and phosphorus (P) were analyzed. A great variation was observed in availability of Nitrogen; it was 1.29 g kg^{-1} at the time of cultivation whereas 1.48 g kg^{-1} nitrogen found at the time of harvesting (Fig. 3). This may be because of the application of N fertilizer. When observed R^2 value was 0.93 before cultivation and 0.77 after harvesting, it also decreases with the depth. The mean difference is significant at the 0.05 ($p<0.05$) level. On other hand the decrease in soil phosphorus was noticed which decreased from 0.554 g kg^{-1}- 0.1 g kg^{-1}.

According to International Fertilizer Industry Association (IFA, 1992) for targeted yield of 1 tone ha^{-1} of rice crop took 20.0 N while for 4 tone ha^{-1} yield, N consumption reaches up to 80.0. Leguminous crops like berseem, alfalfa, etc have ability to fix the atmospheric nitrogen (Zia et al., 2003). This excessive use of N fertilizer has resulted in rice crops highly susceptible to pests and diseases and to lodging, and with high fractions of unfilled grains (Aldrich, 1980). Moreover, excessive N fertilizer application leads to soil pollution (Tilman et al., 2002).

Most of farmers in China have resorted to using higher (550-600 kg N ha^{-1} $year^{-1}$) than the recommended doses of N fertilizers to maintain previously attained yield levels (Wang, 2004), which has resulted in reduced N recovery rate and environment pollution. Cultivation of legume crop is viewed more as a soil fertility improver than as independent crops grown for their grain output. This is because legume crops are self sufficient in N supply (Kanwarkamla, 2000).

This may be because of the prolonged submergence, insufficient soil drying during fallow periods, and soil P depletion were diagnosed as possible causes for the yield decline (Dawe et al., 2000). According to IFA (1992) for targeted yield of 1 tone ha^{-1} of rice crop took 11.0 P_2O_5 while for 4 tone ha^{-1} yield, P_2O_5 consumption reaches up to 44.0. Chibba and Sekhon (1985) found that available N in acid soils varied from 138-295 kg ha^{-1} in the surface sample. The available P status in acid soils ranged from 3.9-86.1 kg ha^{-1} in the surface sample.

Micro Nutrients*:* Four important micronutrients, iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) were analyzed. It was noticed that all the micronutrients decreased. Iron decreased from 84.37-68.24 mg kg^{-1}, copper decreased from 8.03-6.40 mg kg^{-1}, manganese decreased from 19.41-12.93 mg

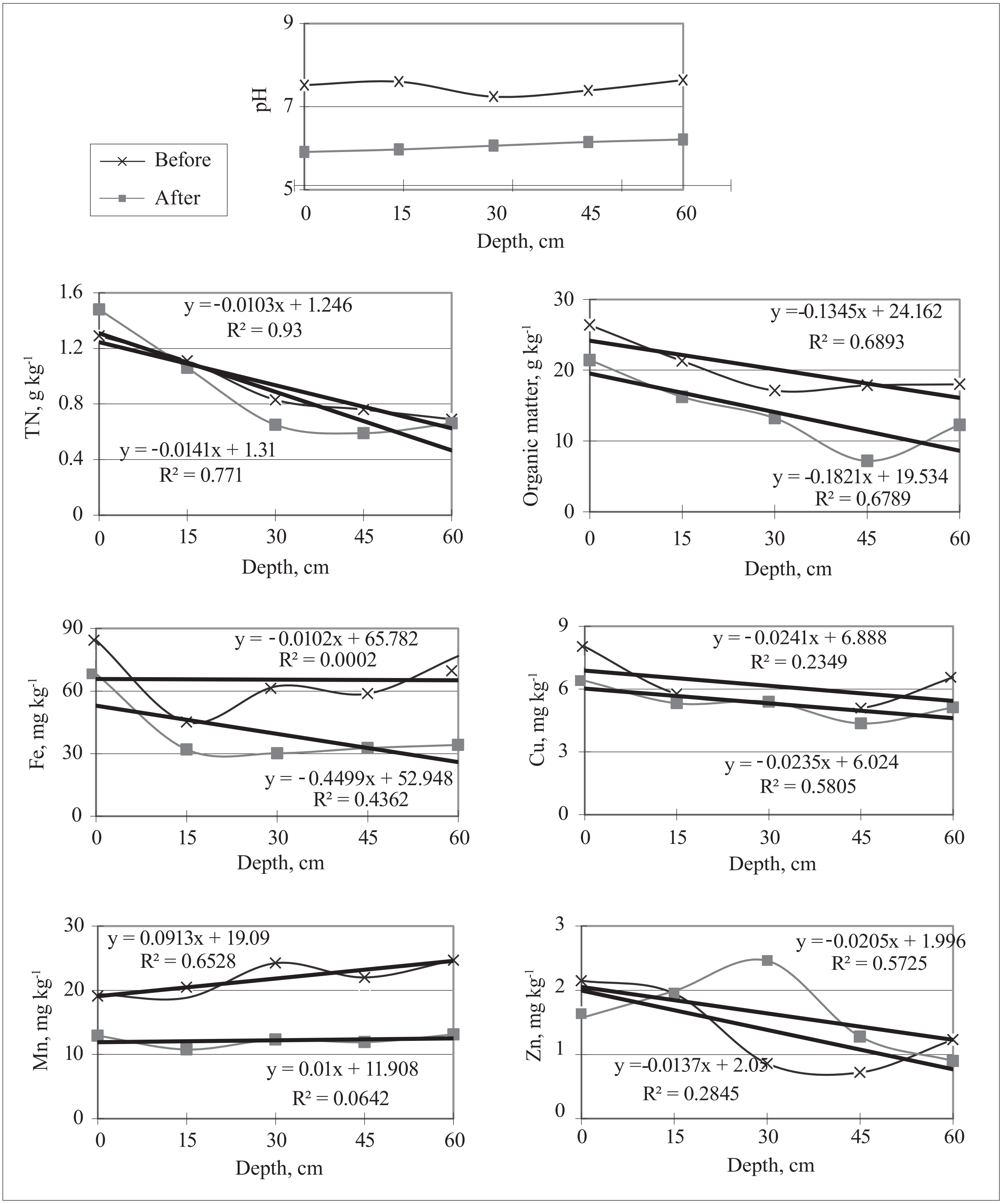

Fig. 3. Shows values of pH, TN, organic matter, Fe, Cu, Mn and Zn before and after rice cultivation at different depths

kg^{-1} and Zn decreased from 2.15-1.57 mg kg^{-1}. Almost same pattern of variations were observed for all nutrients at deeper depths also (Figure 3). When the R^2 value for micronutrients also varied and no direct relation was observed for both before cultivation and after harvesting. However, it decreases after crop cultivation (Figure 3). The mean difference is significant at the 0.05 ($p<0.05$) level.

Conclusion and Recommendations

The original format of soil texture is sandy loam but due to continuous cultivation, silt carried by either irrigation water or by wind, changes upper layer in to sandy clay loam. It is also observed from the texture analysis that there is a clay loam layer at the middle (30-45 cm) depth this seems because of continuous shallow plowing and paddling of the field for crop cultivation. Therefore, it is recommended that deep plowing may also be introduced after every three to five years.

It is also observed that N fertilizers are frequently applied so it is recommended that the application of fertilizers may be reduced by introducing legumes vegetables and pea etc.

It is also recommended that organic manure may also be applied to keep other minerals in balance.

References

Aldrich, S. R., 1980. Nitrogen in relation to food, environment and energy. Special Publication 61. Illinois Agricultural Experiment Station.

Andruszezak, E., 1975. Content of major and minor elements in soil and vegetation of agriculture lands of the Klodrka basin. *Rocznite Gleboznaweze*, **26** (3): 89-119.

Bouyoucos, G. J., 1927. The hydrometer as a new method for the mechanical analysis of soils. *Soil Sci*., **23**: 343-353.

Cassman, K. G. and R. R. Harwood, 1995. The nature of agricultural systems: food security and environmental balance. *Food Policy*, **20:** 439-454.

Chibba, I. M. and G. S. Sekhon, 1985. Effects of pH and organic carbon on availability of nutrients in acid soils. *J. Indian Soc. Soil Sci*., **33**: 409-411.

Dawe, D., A. Dobermann, P. Moya, S. Abdulrachman, B. Singh, P. Lal, S. Y. Li, B. Lin, G. Panaullah, O. Sariam, Y. Singh, A. Swarup, P.S . Tan, and Q. X. Zhen, 2000. How widespread are yield declines in long-term rice experiments in Asia? *Field Crops Res.,* **66**: 175-93.

De Datta, S. K., 1981. Principles and Practices of Rice Production. *Publ. John Wiley & Sons,* Inc.

Dobermann, A., 2000. Future Intensification of Irrigated Rice Systems. In: Sheehy JE, Mitchell PE, Hardy B, editors. Redesigning Rice Photosynthesis to Increase Yield. Makati City, Philipines/Amsterdam: International Rice Research Institute/Elsevier; pp. 229-247.

Dobermann, A., K. G. Cassman, C. P. Mamaril and S. E. Sheehy, 1998. Management of phoshorus, potassium, and sulfur in intensive, irrigated lowland rice. *Field Crops Res*., **56**: 113-358.

Doran, J. W., M. Sarrantonio and M. Liebig, 1996. Soil health and sustainability. In: Sparks, D.L. (Ed.), Advances in Agronomy, Vol. 56. *Academic Press*, San Diego, pp. 1-54.

Dudal, R., 1958. Paddy soils. *Int. Rice Comm. News* l., **7** (2): 19-27.

Gangwar B. and B. Ram, 2005. Effect of crop diversification on productivity and profitability of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system. *Indian J .Agric. Sci.,* **75** (7): 435-438.

Hedlund, A., E. Witter, and B. X. An, 2003. Assessment of N, P by nutrient balances and flows on peri-urban smallholder farms in southern Vietnam. *Eur. J. Agron*., **20:** 71-87.

IFA., 1992. World Fertilizer Use Manual. International Fertilizer Industry Association. Paris. 632 pp.

Jackson, M. L., 1958. Soil chemical analysis Prentice Hall of India Private Limited, New Delhi.

John P. S., M. George and R. Jacob, 2001. Nutrient mining in agro–climatic zones of Kerala. *Fertilizer News*, **46:** pp. 45-52 & pp. 55-57.

Kanwarkamla, 2000. Legumes – the soil fertility improver. *Indian Farming*, **50** (5): 9.

Kumpawat, B. S., 2001. Production potential and economics of different crop sequences. *Indian J. Agron*., **46** (3): 421-424.

Ladha, J. K., 2003. How extensive are yield decline in long-term rice-wheat experiments in Asia? *Field Crops Research*, **82:** 159-180.

Liang, J. and R. E. Karamanos, 1993. DTPA-extractable Fe, Mn, Cu, and Zn. In soil sampling and methods of analysis. (Ed.) Martin R. Carter for Canadian Society of Soil Science, *Lewis Publishers*, pp. 87-90.

Lindsay, W. L. and W. A. Norvell, 1978, Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. America. J.*, **43**: 421-428.

Olk, D. C., G. Brunetti and N. Senesi, 1999. Organic matter in double-cropped low land rice soils: chemical and spectroscopic properties. *Soil Sci*., **164**: 633-649.

Peng, S. and K. G. Cassman, 1998. Upper thresholds of nitrogen uptake rates associated nitrogen fertilizer efficiencies in irrigated rice. *Agronomy J.*

Raun, W. R., J. B. Solie, G. V. Johnson, M. L. Stone, R. W. Mullen, K. W. Freeman, W. E. Thomason and E. V. Lukina, 2002. Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate application. *Agronomy Journal,* **94**: 815-820.

Sanchez, P. A., 2010. Tripling crop yields in tropical Africa. *Nature Geo-Science*; **3**: 299-300.

Sinha, N. P and B. Prasad, 1980. Influence of different fertilizers net gain or loss of soil nitrogen in long-term manure and fertilizer applications. *Plant and Soil Journal*, **57** (2/3).

Sta Cruz, P. C. and G. Wada, 1994. Genetic variation in nitrogen uptake by rice and the effects of management and fertility. P.29-40. In: G.J.D. Kirk (ed.) Rice roots: nutrient and water use. *IRRI Publication*, Manila, Philipines.

Swaminathan, M. S., 2006. An evergreen revolution. *Crop Science*, **46** (5): 2293-2303.

Tilman, D., K. G. Cassman, P. A. Matson, R. Naylor and S. Polasky, 2002. Agricultural sustainability and intensive production practices. *Nature*, **418**: 671-677.

UNU-IAS, 2008. Environment for Africa Development: A Sustainable Future through Science and Technology. UNU-IAS Report.

Wang, D. J., Q. Liu, J. H. Lin, and R. J. Sun, 2004. Optimum Nitrogen use and reduced nitrogen loss in the Yangtze Delta. *Environmental Geochemistry and Health*, **26:** 221-227.

Ying, J., S. Peng, G. Yang, N. Zhou, R.M. Visperas, and K. G. Cassman, 1998. Comparison of high-yieldrice in tropical and sub-tropicalenvironments: II. Nitrogen accumulation and utilization efficiency. *Field Crops Res*., **57:** 85-93

Zhang, W. L., Z. X. Tian, N. Zhang and X. Q. Li, 1996. Nitrate pollution of groundwater in northern China. *Agricult. Ecosyst. Environ.,* **59:** 223-231.

Zia, S. M., F. Hussain, M. Aslam, M. Ehsan Akhtar and A. Hamid, 2003. Review, Basis for Formulation of Fertilizer Recommendations for Crop Production Land Resources Research Program, National Agricultural Research Council, Islamabad–Pakistan National Fertilizer Development Centre, Islamabad–Pakistan.

Received January, 17, 2013; accepted for printing September, 10, 2013.