Journal of AgriSearch 3(2): 87-92
Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
http://dx.doi.org/10.21921/jas.v3i2.11266

Effect of Organic Amendments along with Fly Ash on Soil Quality under Vertisol (*Typic Haplustert*) of India

KAMLESH MALAKAR[1], R SAHA*, VASSANDA COUMAR, J SOMASUNDARAM, AND M MOHANTY

ICAR- Indian Institute of Soil Science, Nabibagh, Bhopal, Madhya Pradesh, India

ARTICLE INFO		
Received on	:	27.05.2016
Accepted on	:	31.05.2016
Published online	:	10.06.2016

ABSTRACT

An incubation study was conducted to characterize soil quality as affected by organic amendments (FYM, biochar and, poultry manure @ 25 t ha^{-1}) along with or without fly ash (@ 22.4 t ha^{-1}) in Vertisol. Physical and chemical parameters of soil quality like pH, EC, bulk density, porosity, moisture content, organic carbon and available N, P, K measured at the end of incubation period *i.e.* 10^{th} week showed that combined application of soil amendments (FYM + fly ash, biochar + fly ash, poultry manure + fly ash) had significantly better results than individual application of the respective soil amendments. Soil microbial biomass carbon (SMBC) and dehydrogenase enzyme activity (DHA) increased steadily up to 6^{th} weeks of incubation with a marginal decrease during last phase. At the end of incubation period (10^{th} week), SMBC and DHA was highest in the soil amended with FYM + fly ash; T_5 (476.6 mg/kg of soil and 10.28 μg TPF g^{-1} soil h^{-1}). The soils treated with organic amendments particularly FYM and poultry manure along with fly ash showed best performance in terms of soil quality improvement in Vertisol.

***Keywords*:** Soil quality, organic amendment, fly ash, vertisol, India

INTRODUCTION

Soil, the basic resource underpinning all terrestrial ecosystems is a dynamic and living entity use to produce goods and services of value to humans but not necessarily with perpetual ability to withstand the degradative processes (e.g. soil erosion, nutrient deletion, compaction, pollution, and salinization) unless appropriately managed. Increase in the human population has increased demands on soil resources for numerous other functions, and has been a principal cause of global deforestation and conversion to agricultural land use (Richards, 1990). Soil degradation has emerged as an important issue with time due to adoption of inadequate or improper management practices. The soil quality reflects a combination of chemical, physical and biological properties. Soil quality is related more to productivity and other functions than the ability of the soil to restore itself after a perturbation. Soil quality, productivity and environmental regulatory capacity affect soil stability. Soil stability affects the remaining parts of the ecosystem – microbial, plant and animal. If a soil is degraded, the ecosystem is impaired. Replacing organic matter within a soil is a means of amending degraded soils. Organic matter helps stimulate microbial populations that are essential to the quality and stability of the soil ecosystem as a whole. Organic matter also helps in soil revegetation and erosion controls (Alexander, 1999).

The black soil (*Vertisol*), internationally known as 'tropical black earth' cover about 73 million ha of the semi-arid tropical regions of India and are most prominent in central parts of India. It is also referred as shrink-swell soils with very high (60-65%) clay content. These soils are calcareous neutral to mild alkaline in reaction, high in cation exchange capacity, and low in organic matter. Black soil possesses low strength to undergo excessive volume changes. Cracks are unique feature in these soils with strong shrink-swell potential. In most cases, the macro pores are destroyed by the compacting force acting on the soil, resulted in restricted movement of air, water and nutrients. Compaction disrupts soil physical integrity by modifying porosity and impeding gas, water, nutrient and root movement in the profile (Greacen and Sands, 1980) leads to decline in soil quality which ultimately affects plant growth. Numerous physical and biological factors contribute to the ambiguous response of microorganisms to compaction. Changes in physical habitat, particularly altered pore-size distribution may benefit the microbial community by increasing the volume of habitable pore space providing protection for larger predators (Hassink *et al.*, 1993).

Black soils are problematic in nature in terms of soil quality without any external input. Ameliorative treatments are required when soil bulk density exceeds pretreatment level by 15% (Powers *et al.*, 1998). Conservative approaches to soil management by addition of organic matter is must for soil microbial growth, water availability, soil quality and ultimately for plant growth. Soil structural Improvement by incorporation of organic manure in soil can help for maintenance of soil quality. Organic matter reduces soil compactibility by increasing its stability and by retaining a greater amount of moisture for soil to rebound against compaction (Paul, 1974). Organic matter increases soil consistency limits and consequently increases the range of soil moisture (Baver *et al.*, 1972). Recent investigations (Glaser *et al.*, 2001) showed that carbonized materials from the incomplete combustion of organic material (i.e. black C, pyrogenic C, charcoal) are responsible for maintaining high

[1]*Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India*
***Corresponding Author Email:** saharitesh74@rediffmail.com

levels of SOM. Yudhbir and Honjo (1991) stated that the fly ashes can advantageously made use to improve the soil properties of black cotton soils. Fly ash improves the plasticity, compaction and strength characteristics of black soil (Phanikumar and Sharma, 2004). Keeping in view of the above-cited problem, the present study conducted to evaluate the effects of various soil amendments on soil quality under black soil (*Vertisol*) of Central India.

MATERIALS AND METHODS

An incubation study was conducted with the experimental soils collected from the upper 15-20 cm at various locations of Indian Institute of Soil Science research farm located at 23°18'N and 77°24' E, 485 m above mean sea level. The area has sub-humid tropical climate with a mean annual air temperature of 25°C and annual rainfall of 1208 mm. The experimental soils were clayey in texture and classified as *Typic Haplustert* having pH 8.08, organic carbon 4.1 g kg^{-1} and bulk density 1.45 Mg m^{-3}. The soils were medium in available N (alkaline permanganate n 200.7 kg ha^{-1}), low in available P (Olsen P 10.4 kg ha^{-1}) and high in available K (ammonium acetate 415.1 kg ha^{-1}). The soils were air dried at 25°C, passed through 2 mm sieve. The processed soil sample of 500 g was taken in each plastic container of 1 kg capacity for incubation study. The soil was first pre-incubated for 5 days at 25 °C under aerobic conditions to allow microbial activity to stabilize. Soil in sets of 3 replicates (container) was prepared for each treatment. The treatments details consisted of: Soil amended with i) FYM; T_1, ii) Biochar; T_2, iii) Poultry manure; T_3, iv) Fly ash; T_4, v) FYM + Fly ash; T_5, vi) Biochar + Fly ash; T_6 and (vii) Poultry manure + Fly ash; T_7 with an absolute control; T_0. The basic properties of the soil amendments used in this experiment *i.e.* FYM, biochar, poultry manure and fly ash were given in Table 1. Among the organic amendments, biochar is having highest total organic carbon (60.64%) followed by poultry manure (31.25%) and FYM (15.55%). Fly ash was collected from Kota Thermal Power station, Rajya Vidyut Utpadan Nigam limited, Rajasthan. The soils were mixed homogenously with these amendments and then transferred to the respective plastic container. After 10 days of interval, distilled water was added (175 ml 500/g of soil) to maintain moisture content at 60% water holding capacity of the soil. The water content was held constant throughout the incubation period by adding distilled water whenever it was needed. Now, the soil treated with various doses of soil amendments will act as sink for changing soil properties through development of microbial community. After 0, 2, 4, 6, and 10 weeks of incubation, the plastic container of each treatment were removed and stored in plastic vials at 4°C until microbial biomass carbon (SMBC) and dehydrogenase enzymatic activity (DHA) were determined. SMBC was determined by the chloroform fumigation-extraction technique (Voroney *et al.*, 1993). Organic carbon in the extracts was measured by dichromate oxidation, and microbial biomass carbon was calculated and the results were expressed in µg C g^{-1} soil. The Dehydrogenase enzymatic activity (DHA) of soil sample was determined and the results are expressed in µg TPF g^{-1} h^{-1} at 37 °C.

Table 1**:** Basic properties of the soil amendments used in the experiment

Basic properties	Soil amendments			
	FYM	Biochar	Poultry manure	Fly ash
pH	6.82	8.40	7.15	7.80
EC (dS m^{-1})	2.990	0.622	5.140	6.530
Total organic carbon (%)	15.55	60.64	31.25	0.35
Total N (%)	0.56	0.85	1.20	0.10
Total P (%)	0.37	0.09	0.73	0.08
Total K (%)	0.67	0.12	0.95	0.02

Subsequently, the laboratory analyses of various soil parameters were done. Soil pH and electrical conductivity (EC) were measured by following the standard methods (Jackson, 1973). The organic C content of the soil was determined by Walkley and Black's wet-digestion method (Walkley and Black, 1934). Bulk density of the soil samples were analysed following the clod method. Soil moisture content was measured by gravimetric method (Jackson, 1973). Total porosity was determined as suggested by Jalota *et al.* (1998). Dispersion ratio of the soils under various treatments was calculated based on following equation given by Bryan (1968):

Dispersion ratio = Suspension percentage/ (silt + clay) under dispersed condition

Where, Suspension percentage is the percentage of silt and clay under undispersed condition after 5 minutes of soaking.

Available nutrients N, P and K in the soil were analysed by the procedures outlined by Subbiah and Asija; 1956, Olsen *et al.*, 1954 and Jackson; 1973, respectively.

All the measurements are the mean value of three separate replicates. Data was subjected to an analysis of variance. The mean values were grouped for comparisons and the least significant differences among them were calculated at $P < 0.05$ confidence level using SPSS version 9.0 statistical package.

RESULTS AND DISCUSSION

Effect of soil amendments on soil physical properties

Results (Table 2) showed that the pH of the soils under various treatments ranged between 8.13-8.39 after 10 weeks of incubation period. The only salient point was that the soils treated with fly ash only had the highest pH value (mean 8.39) followed by the treatment with biochar only (8.35). This finding corroborates with the findings of Cox *et al.* (2001). The amendments like FYM and poultry manure reduced the pH value of the soils as compared with the control. However, the effect of soil amendments on soil pH was not statistically significant (P > 0.05). The trend was reverse in case of the EC as compared to pH of the soils under various treatments. The treatments with FYM and poultry manure alone resulted higher EC values (0.315 and 0.259 dS m^{-1}, respectively) as compared to the soil EC under the treatments with fly ash and biochar only (0.240 and 0.250 dS m^{-1}, respectively). The results corroborated with the findings from Jin-Hua Yuan *et al.* (2011) that incorporation of the biochar increased the soil pH. These results suggest that the amelioration effects depend on not only the alkalinity of the biochar/fly ash but also on their alkali forms. The carbonate concentration of biochar and fly ash facilitates liming in soils and can raise soil pH of neutral or acidic soil (Van Z weiten *et al.,* 2007).

Organic carbon content of the soil among all treatments (Table 2) significantly increased with maximum SOC content is under FYM + fly ash; T_5 (4.9 g kg^{-1}) followed by poultry manure + fly ash; T_7 (4.5 g kg^{-1}), biochar + fly ash; T_6 (4.5 g kg^{-1}), FYM; T_1; (4.4 g kg^{-1}), poultry manure T_3 (4.2 g kg^{-1}), biochar; T_2 (4.1 g kg^{-1}), control; T_0 (4.0 g kg^{-1}), least being in Fly ash; T_4 (3.2 g kg^{-1}). The higher SOC content among the amended soils might be due to the nature of carbon sources present in amended material. FYM had higher oxidizable carbon than biochar material; this might be the reason for higher SOC content in FYM amended soil over biochar amended soil. The results from several long-term field experiments have shown greater increases in soil organic C in treatments receiving organic amendments (Witter *et al.,* 1993).

The data related to effect of soil amendments on bulk density under incubation study at 10 weeks presented in Table 2. Results showed that the BD values among the various treatments varied in between 1.20 and 1.48 Mg m^{-3}, highest being treatment with only fly ash; T_4 (1.48 Mg m^{-3}). The behavior of black soil is controlled by diffuse double layer. The addition of fly ash in small quantity results in decrease of repulsive forces of soil particles. This in turn reduces the resistance to compactive effort and the mix gets compacted resulting higher densities (Hakari and Puranik, 2012). Otherwise, BD values decreased with incorporation with organic amendments like FYM, poultry manure and biochar etc. The decreasing trend in BD under various treatments as compared to control is as follows: FYM + Fly ash; T_5 (17.2%), followed by FYM; T_1 (13.8%), Poultry manure + Fly ash; T_7 (13.1%), Poultry manure; T_3 (7.6%), Biochar + Fly ash; T_6 (7.6%), Biochar; T_2 (2.8%). However, BD values increased by 2.1% under T_4 (with fly ash only) as compared to control. BD is indirectly proportional to organic carbon content of the soil. It was reported that SOC contents increased by manuring, in turn improved its aggregation status and decreased the bulk density, dispersion ratio and soil strength correspondingly.

Table 2: Effect of soil amendments on soil physico-chemical properties

Treatments	Soil physico-chemical properties						
	pH	EC (dS m^{-1})	Organic C (g kg^{-1})	Bulk density (Mg m^{-3})	Porosity (%)	Moisture content (%)	Dispersion ratio
T_0: Control	8.21	0.227	4.0	1.45	45.29	33.32	6.48
T_1: FYM @ 25 t ha^{-1}	8.20	0.315	4.4	1.25	52.83	34.57	3.66
T_2: Biochar @ 25 t ha^{-1}	8.35	0.250	4.1	1.41	46.79	33.47	4.22
T_3: Poultry manure @ 25 t ha^{-1}	8.13	0.259	4.2	1.34	49.23	34.16	4.07
T_4: Fly ash @ 1% weight basis	8.39	0.240	3.2	1.48	44.15	34.54	7.25
T_5: T_1+ Fly ash @ 1% weight basis	8.25	0.248	4.9	1.20	54.72	35.81	2.35
T_6: T_2+ Fly ash @ 1% weight basis	8.37	0.263	4.5	1.26	49.43	33.32	3.87
T_7: T_3+ Fly ash @ 1% weight basis	8.16	0.245	4.5	1.34	52.45	35.16	3.68
SEm ±	0.22	0.01	0.11	0.05	1.31	0.91	0.83
CD at 5 %	NS	0.02	0.32	0.15	3.90	NS	1.63

The porosity of the soils under various treatments ranged between 44.15 and 54.72% after 10 weeks of incubation. Total porosity of the soils were significantly (P<0.05) increased with addition of soil amendments. The highest porosity among the treatments was under T_5: FYM + fly ash (54.72%) followed by T_1: FYM only (52.83%), T_7: poultry manure + fly ash (52.45%) and lowest being under T_4: fly ash only (44.15%). However, there was no significant variation in soil moisture content among the various treatments. The soil moisture content among the treatment varied from 33.32 to 35.81% (Table 2). It was found that soil bulk density reduced by addition of organic amendments, while total porosity and moisture content were improved. The organic matter contributed by the manure led to improvement of soil physical properties. The organic matter might have stabilized soil structure thereby reducing soil bulk density, increasing porosity, and infiltration rate and water retention. The favourable soil physical condition by addition of organic manure is consistent with earlier findings of Bahremand *et al.* (1999).

The dispersion ratio, an erodibility index varied from 2.35 to 7.25 (Table 2) and was lowest in the treatment T_5: FYM + fly ash. The other treatments followed the pattern: T_1: FYM only (3.66) < T_7: biochar + fly ash (3.68) < T_6: biochar + fly ash (3.87) < T_3: poultry manure (4.07) < T_2: biochar (4.22) < T_0: control (6.48)

< T_4: fly ash only (7.25). This may be explained by the silt and clay proportion under dispersed and undispersed conditions and organic C content of these soils. It indicates that soils treated with organic amendments either with fly ash or without fly ash are less susceptible to erosion. The lower degree of dispersion ratio under the treatments with organic amendments could be attributed to higher organic C content which in turn improves soil aggregation. Fullen (1991) reported that even a small reduction in the organic matter content of soil markedly increased soil erodibility.

Effect of soil amendments on nutrient availability

The data related to effect of soil amendments on available nitrogen (N), phosphorus (P) and potassium (K) under incubation study at 10^{th} week presented in Table 3. Available nitrogen, phosphorus, potassium had significantly (P<0.05) increased due to amendment addition over control after 10^{th} week of incubation study. Study showed that combined application of soil amendments (FYM + fly ash, biochar + fly ash, poultry manure + fly ash) had higher available N, P, K content than individual application of the respective soil amendments (FYM, biochar, poultry manure, fly ash) and was found to be statistically significant. Among the treatment, application of poultry manure along with fly ash showed higher available N, P, K (432.49, 45.73 and 590.11 kg/ha, respectively) and found to be significantly (P<0.05) higher over the other applications. The available N, P, K content in soil under other treatments ranged between 240.93-432.49, 13.32-45.73 and 415.15-590.11 kg/ha, respectively. There was no significant change in the treatment T_4; fly ash (0.5 -2.0%) as compared to control. Addition of Biochar to soil has shown definite increases in the availability of N, P and K concentrations. Higher nutrient availability for plants is the result of both the direct nutrient additions by the Biochar and greater nutrient retention (Glaser *et al.,* 2002). Longer-term benefits for nutrient availability include a greater stabilization of organic matter, concurrent slower nutrient release from added organic matter, and better retention of all cations due to a greater CEC (Lehmann *et al.,* 2003).

Table 3: Effect of soil amendments on nutrient availability in soil

Treatments	Nutrient availability in soil		
	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_0: Control	240.93	13.32	415.15
T_1: FYM @ 25 t ha^{-1}	304.11	27.02	490.35
T_2: Biochar @ 25 t ha^{-1}	345.91	24.44	462.93
T_3: Poultry manure @ 25 t ha^{-1}	417.94	38.88	558.51
T_4: Fly ash @ 1% weight basis	242.18	17.40	423.36
T_5: T_1+ Fly ash @ 1% weight basis	312.84	29.74	536.69
T_6: T_2+ Fly ash @ 1% weight basis	395.07	36.28	499.89
T_7: T_3+ Fly ash @ 1% weight basis	432.49	45.73	590.11
SEm ±	9.09	0.82	5.22
CD at 5 %	27.18	8.44	15.61

Effect of soil amendments on microbial growth (SMBC and DHA)

It is evident from the results (Fig. 1 & 2) that microbial biomass carbon content (SMBC) and dehydrogenase activity (DHA) increased steadily up to 6^{th} weeks of incubation with a marginal decrease during last phase i.e. 8-10 weeks irrespective of the treatments. The improvement in SMBC and DHA was more under combined application of amendments (FYM + fly ash; T_5, biochar + fly ash; T_6, poultry manure + fly ash; T_7) as compared to application of FYM, biochar, poultry manure and fly ash alone. At the end of incubation period (10^{th} week), microbial biomass carbon was greater in the soil amended with FYM + fly ash; T_5 (476.6 mg/kg of soil), followed by poultry manure + fly ash; T_7 (454.3 mg/kg of soil), biochar + fly ash; T_6 (448.9 mg/kg of soil), FYM; T_1 (408.9 mg/kg of soil), poultry manure; T_3 (397.4 mg/kg of soil), biochar; T_2 (395.0 mg/kg of soil) and fly ash; T_4 (383.8 mg/kg of soil). The DHA under various treatments at 10^{th} week followed the same trend as SMBC. The increase in SMBC and DHA values at 10^{th} week under various treatments followed the pattern: FYM + fly ash; T_5 (65.8 and 46.4 5, respectively), followed by poultry manure + fly ash; T_7 (58.1 and 40.0, respectively), biochar + fly ash; T_6 (56.2 and 34.5, respectively), FYM; T_1 (42.3 and 35.2, respectively), poultry manure; T_3 (38.3 and 24.4, respectively), biochar; T_2 (37.4 and 23.4, respectively) and fly ash; T_4 (33.5 and 18.4, respectively). The increase in SMBC and DHA after additions of soil amendments either alone (FYM, biochar, poultry manure, fly ash) or in combination (FYM + fly ash, biochar + fly ash, poultry manure + fly ash) to soils had been generally attributed to the fact that enzyme activities directly associated to organic matter and to microbial response to soluble sugars of the added materials. Organic amendments provide a suitable habitat for a large and diverse group of soil microorganisms. It was found that the enzyme activity in organic amended soil increased by an average 2-4 folds as compared with the unamended soil.

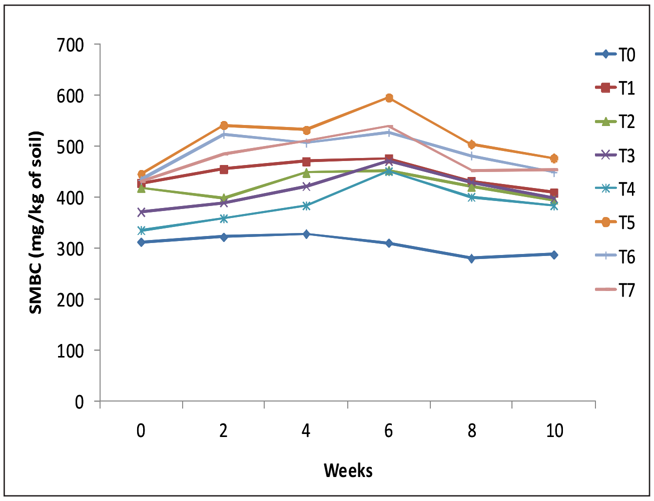

Fig.1: Effect of soil amendments on periodical soil microbial biomass carbon (SMBC) content in Vertisol

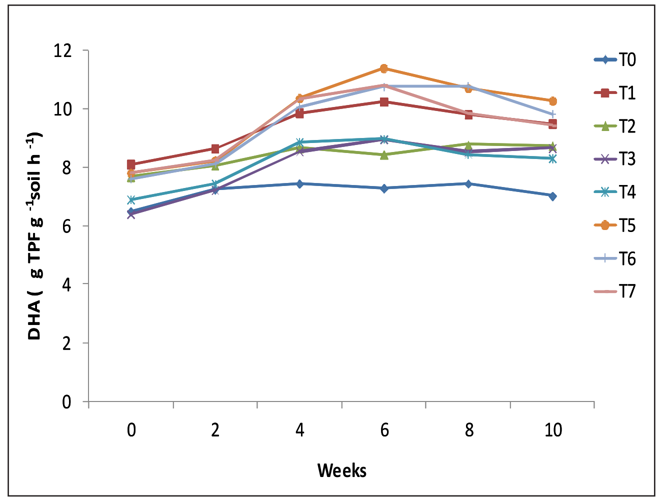

Fig.2: Effect of soil amendments on periodical Dehydrogenase enzyme (DHA) activity in Vertisol

CONCLUSION

The study indicated that soil physic-chemical properties like SOC; available N, P, K bulk density etc. were significantly improved with combined application of amendments (FYM + fly ash; T_5, biochar + fly ash; T_6, poultry manure + fly ash; T_7) as compared to control. The soil microbial biomass carbon and dehydrogenase enzyme activity as a measure of microbial activity showed its maximum peak at 6^{th} weeks of incubation period in the soil amended with various amendments (FYM, biochar, poultry manure and fly ash). The soils treated with organic amendments along with fly ash showed better performance in terms of soil quality improvement.

REFERENCES

Alexander R. 1999. Compost markets grow with environmental applications. *Biocycle* **40**:43-8.

Bahremand RR, Burwell RE and Hoit RF. 1999. Short and mid-term effects of organic fertilizers on some soil physical properties. In: Proceedings of the 6^{th} Iranian Congress of Soil Science, Mashad, Iran. pp. 288-89.

Baver LD, Gardner WH and Gardner WR. 1972.*Soil Physics*. Wiley, New York. pp 498.

Bryan RB. 1968. The development, use and efficiency of indices of soil erodibility. *Geoderma* **2**: 5-26.

Cox D, Bezdicek D and Fauci M .2001. Effects of compost, coal ash, and straw amendments on restoring the quality of eroded Palouse soil. Biology and Fertility of Soils. **33**:365-72

Fullen MA. 1991. Soil organic matter and erosion processes on arable loamy sand soils in the West Midlands of England. *Soil Technology* **4**: 19-31.

Glaser B, Haumaier L, Guggenberger G and Zech W. 2001. The Terra Preta phenomenon – a model for sustainable agriculture in the humid tropics. Naturwissenschaften **88**:37-41.

Glaser B, Lehmann J and Zech W. 2002. Ameliorating physical and biological properties of highly weathered soils in the tropics with charcoal- A review. *Biology and Fertility of Soils*. **35**:219-30.

Greacen EL and Sands R. 1980. Compaction of forest soils - A review. *Australian Journal of Soil Research* **18**: 163-89.

Hakari UD and Puranik SC. 2012. Stabilisation of Black Cotton Soils Using Fly Ash, Hubballi- Dharwad Municipal Corporation Area, Karnataka, India. *Global J Res Engg Civil Struc Engg*. **12**(2): 21-9.

Hassink J, Bouwman LA, Zwart KB and Brussard L. 1993. Relationships between habitable pore space, soil biota and mineralization rates in grassland soils. *Soil Biology and Biochemistry* **25**: 47-55.

Jackson ML 1973. Soil chemical analysis, Prentice Hall of India Pvt. Ltd., New Delhi, India.

Jalota SK, Khera RK and Ghuman BS. 1998. *Methods in soil physics*. Narosa Publishing House, 6, Community center, Panchshil Park, New Delhi, India.

Jin-Hua Yuan, Ren-Kou Xu and Hong Zhang .2011. The forms of alkalis in the biochar produced from crop residues at different temperatures. *Bioresour. Technol.*, **102**:3488-97.

Lehmann J, Pereira da Silva Jr, Steiner JC, Nehls T, Zech W and Glaser B. 2003. Nutrient availability and leaching in an archaeological Anthrosol and a Ferralsol of the Central Amazon basin: fertilizer, manure and charcoal amendments. *Plant Soil*.**249**: 343-57.

Olsen SR, Cole CV, Watanabe FS and Dean LA. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular. 939.

Paul CL. 1974. Effects of filter press mud on the soil physical conditions in a sandy soil. *Tropical Agriculture Trinidad Journal* **51**: 288-92.

Phanikumar BR and Sharma RS. 2004. Effects of fly ash on engineering properties of expansive soils. *Journal of Geotechnical and Geoenvironmental Engg*. **130**(7): 764-7.

Powers RF, Tiraks AE and Boyle JR. 1998. Assessing soil quality practicable standards for sustainable forest productivity in United States of America. In: Adams *et al*. The contribution of soil science to the development of and implementation of criteria and indicators of sustainable forest management. Soil Science Society of America

special publication No. 53, SSSA, Madison, USA. pp. 53-80.
Richards JF. 1990. Land transformation. In *The Earth as transformed by human action* (ed. B. L. Turner, W. C. Clark, R. W. Kates, J. F. Richards, J. T. Mathews & W. E. Meyer), pp. 163-178. Cambridge University Press.

Subbiah BV and Asija GL. 1956. A rapid procedure for determination of available N in soils. *Current Sci.* **25**:259-63.

Van Zwieten L, Kimber S, Downie A, Chan KY, Cowie A, Wainberg R and Morris S. 2007. 'Papermill char: Benefits to soil health and plant production' in Proceedings of the Conference of the International Agrichar Initiative, 30 April – 2 May 2007, Terrigal, NSW, Australia.

Voroney RP, Winter JP, Beyaert RP.1993. Soil microbial biomass C and N. In: Carter, M.R., (Ed.), Soil Sampling and Methods of Analysis, Lewis, Boca Raton, pp. 277-86.

Walkley A and Black IA.1934. An examination of Degtjareff methods for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci*. **37**:29-38.

Witter E, Martensson AM and Garcia FV .1993. Size of the soil microbial biomass in a long-term field experiment as affected by different N-fertilizers and organic manures. *Soil Biology and Biochemistry* **25**: 659-69.

Yudhbir and Honjo Y. 1991. Applications of Geotechnical engineering to environmental control. Theme lecture5, ARC, Bangkok, Thailand. **2**: 431-69.

Citation:
Malakar K, Saha R, C Vassanda, Somasundaram J, Somasundaram and Mohanty M. 2016 Effect of organic amendments along with fly ash on soil quality under vertisol (*Typic Haplustert*) of India. *Journal of AgriSearch* **3** (2): 87-92