Journal Crop and Weed, 11(1):132-137(2015)

Soil physical fertility and performance of potato crop as affected by integration of organic and inorganic fertilizers in new alluvial soil of West Bengal

A. DEY, S. DASGUPTA, S. BHATTARCHARYA[1], A. K. CHAITANYA, S. PATI AND B. PAL

Department of Agricultural Chemistry and Soil Science,
[1]Department of Spices and Plantation Crops
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741252, West Bengal

Received:12-05-2015, Revised:20-05-2015, Accepted: 21-05-2015

ABSTRACT

A field experiment was conducted for the consecutive two years (2011-12 and 2012-13) to study the effect of organic manures and chemical fertilizers on different soil physical properties for surface (0-15 cm) as well as sub-surface (15-30 cm) layers in an intensely cultivated new alluvial soil, taxonomically classified as Typic Hapludalf of West Bengal. The effect of different levels and combinations of organics viz. crop residue, bio-fertilizer, FYM alone and in combination with chemical fertilizers viz., 0, 50, 100 and 150% of recommended dose of fertilizer (RDF) were tested. Addition of inorganic fertilizers along with organic manure, crop residue, and bio-fertilizers increased soil organic carbon (SOC) content, water holding capacity (WHC), capillary and non-capillary pore space and aggregate stability indices of the soil while reducing bulk density in both 0-15 cm and 15-30 cm soil depths. SOC content was strongly correlated with bulk density, WHC and structural co-efficient of the studied soil. The mean effect of different organic treatments on improvement of soil physical properties is nearly similar in treatments with 50% organics + 50% inorganic (INM). Thus, we can conclude that integrated use of a balanced inorganic fertilizer with organics i.e. organic manure-crop residue-bio fertilizer helps to maintain a good soil physical environment which is better for achieving higher crop productivity under potato based intensive cropping systems.

Keywords: Aggregate stability indices, bio- fertilizers, soil organic carbon, soil physical property,

Potato demands high level of soil nutrients due to relatively poor developed and shallow root system. Compared to cereal crops, potato produces more dry matter in a shorter time period resulting huge nutrient removal per unit time which makes soil deficient in nutrients day by day (Singh *et al.,* 1998); hence, potato yield could be increased by 50% only using improved nutrient management (Grewal *et al.,* 1980, Samui *et al.,* 2007). On account of continuing world energy crisis and spiraling price of chemical fertilizer, the use of organic manure as a renewable source of plant nutrients is assuming importance (Devi *et al.,* 2011). In this endeavor proper blend of organic and inorganic fertilizer is important not only for increasing yield but also for sustaining soil health (Weber *et al.,* 2007 and Pullicinoa *et al.,* 2009).Use of organic manure helps in mitigating multiple nutrient deficiencies at the same time it provides better environment for growth and development of crops by improving physical, chemical, biological properties of soil (Avitoli *et al.,* 2012). Moreover, the addition of organic materials to soil through FYM, compost and organic residues will not only choke serious deterioration of soil health, but also will check cumulative negative nutrient balance which causes declining soil fertility and productivity. Sustainable production of crops cannot be maintained solely by using expensive chemical fertilizers, since they deteriorate soil physical and biological environment (Khan *et al.,* 2008). So, organics like crop residue, FYM, bio-fertilizers were chosen as component of INM as they improve soil physical, biological environment, as well as they are eco-friendly and cost effective inputs. Bhadoria *et al.* (2006) reported that application of FYM influence the yield and uptake of different nutrients. Therefore, this study was initiated to investigate the effect of INM through different forms and combinations of organics and chemical fertilizers on various soil physical properties which are critical to maintain the soil's ability to function sustainably in intense potato growing areas of West Bengal.

Email: a.ar_d@hotmail.com

MATERIALS AND METHOD

The field experiment was conducted at the farmers field of Adisaptagram Block, Hooghly district of West Bengal (22°76'N, 88°21'E and elevation 9.75 m above MSL) with groundnut-fallow-potato cropping sequence with potato variety Kufri Jyoti during irrigated cold season (December -March) of 2012 and 2013. The experimental site encompasses new alluvial zone, belong to the Order *Inceptisol*, Great Group *Haplaquepts,* Sub Group *Typic Eutrochrept,* with sandy loam texture, initial soil properties were pH- 7.15, bulk density- 1.51 Mg m^{-3}, porosity- 48.42%, electrical conductivity- 0.15 dSm^{-1}, organic carbon- 0.65%, and available N, P_2O_5 and K_2O as 244, 65 and 181 kg ha^{-1}, respectively. The experiment was laid down with 4 x 3m plot size, in randomized block design with three replications, with 11 treatment combinations *i.e.* T_1 (Control, native nutrient), T_2 (Full N as crop residue; rice straw), T_3 (Full N as crop residue + Bio-fertilizer), T_4 (50% N as crop residue + bio-fertilizer + 50% N as bio dynamics, enmite), T_5 (50% N as crop residue + bio-fertilizer + 50% N as FYM), T_6 (full N as FYM), T_7 (100% RDF), T_8 (1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 50% RDF), T_9 (1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 75% RDF), T_{10} (1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 100% RDF) and T_{11}(1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 150% RDF). The seed of potato tubers were inoculated with bio-fertilizer (*Azotobacter*) @10g kg^{-1} potato seed as per the treatments before planting in both years. The recommended fertilizer dose for winter potato was 150-100-100 kg ha^{-1} of N-P_2O_5-K_2O. Three-fourth (3/4th) of N and full dose of P_2O_5 and K_2O were applied as basal and the remaining one-fourth (1/4th) N was top dressed at first earthing up. Recommended amount of FYM (0.6% N, 0.23% P_2O_5 and 0.5% K_2O)@ 25 t ha^{-1}, Enmite (3.7% N, 2% P_2O_5, 1.5% K_2O) @ 3.2 t ha^{-1} and crop residue (0.37% N, 0.08% P_2O_5, 0.69%K_2O) @32.5 t ha^{-1} were applied at the time of final land preparation as per the treatments. After harvesting in each year, the composite soil samples from 0 – 15 cm and 15 – 30 cm depths from each plot were collected and prepared.

Soil physical properties of each layer were measured using standard protocols, bulk density, water holding capacity (Piper, 1966) capillary and non-capillary pore space and various indices of soil structure like mean weight diameter, water soluble aggregates, structural coefficient through soil aggregate analysis (Black, 1965) and soil organic carbon (Walkley *et al.,* 1934) was employed as indicator of soil structural status as it regulates various physical, chemical and biological processes to know the impact of different organic treatment combinations under INM on those properties. The pooled data were statistically analyzed using randomized block design by applying the technique of analysis of variance (ANOVA) prescribed for the design to test the significance at 5% probability levels (Gomez *et al.,* 1984).

RESULTS AND DISCUSSION

Bulk density

Physical parameters of each soil layer were significantly improved over the initial value due to application of organics or combination of inorganic fertilizers + organic manures (Table 1). Bulk density of soil in both the layers in each year decreased in the plots which received organics either alone or in combination with inorganic than the plots those received only 100% N, P and K treatment (T_7) or without any fertilizer treatment (T_1). Significantly, lowest bulk density was recorded in surface layer of T_5 (1.40 Mg m^{-3}) and in the treatments T_6 and T_9, bulk density reduced to a great extent compared to other treatments. In sub-surface soil layer, bulk density also varied significantly among the treatments but the magnitude was more pronounced in the treatments with solely organic sources and the significant superior values were found in T_5 and T_6 compared to other treatments (Table 1). Similar results were obtained in an experiment conducted by Rai *et al.* (2014).

Water Holding Capacity

Pooled result of two years depicted that the treatments which received nutrients through fully organic sources (T_2 to T_6) showed higher water holding capacity to the tune of 17-25% and 19-33% for surface and sub-surface layers over control plot. The significant effect of various treatments on WHC was found in the order T_5>T_6>T_4>T_9>T_{10}>T_{11} for both soil layers and the values were 33.6%, 31.3%, 28.8%, 22.8%, 21.9%, 21.6% respectively over control (Table 1). The integration of inorganic, organic sources of nutrients (T_8 to T_{11}) might have improved the soil physical condition, resulted maximum 17% and 22% superior than only inorganic treated plot (T_7) for surface and subsurface layers respectively. The results are in accordance with the findings of Datt *et al*. (2013).

Capillary and non-capillary pore space

So far as capillary (CPP) and non capillary pore space (NCPP) are concerned, maximum value was found in T_5 (0-15 cm-38.72, 15-30 cm- 39.72) and T_6 (0-15 cm- 40.47, 15-30 cm- 36.13) respectively although other nutrient management options were very close to the highest without significant differences except only mineral fertilizer treated (T_7) and control (T_1) . This might be due to increased biomass production with consequent increase of organic matter content along with better root proliferation in more pulverized soil. The pulverization caused a favorable change in porosity. Application of higher levels of inorganic fertilizers (T_8-T_{11}) did not influence the pore space although, it significantly enhances the pore space than sole inorganic (T_7) with the range of 6-10% and 4.1-4.5% for surface and sub-surface in CPP, likewise maximum 1% and 16% increased for surface and sub-surface soil in NCPP. Comparable results are also reported by Patil *et*

Table 1: Effect of integrated nutrient management on different physical parameters of soil after harvest of potato (Pooled data)

Treatments	Bulk density (Mg m^{-3})		Water holding capacity (%)		Capillary pore space (%)		Non capillary pore space (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 - Control	1.56	1.59	48.77	44.83	33.72	34.07	30.17	27.33
T_2 - Full N as crop residue; rice straw	1.49	1.48	57.44	53.92	36.98	38.54	38.05	34.43
T_3 - Full N as crop residue + bio-fertilizer	1.44	1.46	57.58	53.66	37.91	38.60	38.65	34.67
T_4 - 50% N as crop residue + bio-fertilizer +50% N as bio dynamics, enmite	1.43	1.46	59.96	57.76	37.22	38.96	39.07	35.01
T_5 - 50% N as crop residue + bio-fertilizer + 50% N as FYM	1.40	1.43	61.21	59.93	38.76	39.72	39.93	36.49
T_6 - Full N as FYM	1.42	1.42	60.86	58.91	38.66	39.03	40.47	36.13
T_7 - Only 100% recommended dose of N, P and K	1.55	1.57	49.74	45.05	35.09	36.73	39.74	29.79
T_8 - 1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 50% RDF	1.46	1.46	58.27	54.99	37.29	38.40	40.13	34.43
T_9 - 1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 75% RDF	1.42	1.47	58.26	55.07	37.29	38.36	39.01	34.66
T_{10} - 1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 100% RDF	1.43	1.47	58.08	54.69	38.56	38.34	38.70	34.05
T_{11} - 1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 150% RDF	1.44	1.47	57.71	54.54	37.29	38.24	38.55	34.14
SEm(±)	**0.011**	**0.017**	**0.338**	**0.325**	**0.216**	**0.222**	**0.529**	**0.642**
LSD (0.05)	**0.031**	**0.049**	**0.967**	**0.930**	**0.617**	**0.635**	**1.511**	**1.834**
Initial	1.51	1.59	48.42	45.93	33.71	34.08	27.30	28.12

Note : *RDF = 150-100-100 kg ha^{-1} of N-P_2O_5-K_2O*

Table 2: Effect of integrated nutrient management on different aggregate stability indices of soil after harvest of potato (Pooled data)

Treatments	Mean weight diameter (mm)		Water stable aggregates (%)		Structural coefficient	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 - Control	0.57	0.57	43.99	40.00	0.56	0.53
T_2 - Full N as crop residue; rice straw	0.68	0.59	48.82	42.40	0.60	0.54
T_3 - Full N as crop residue + bio-fertilizer	0.68	0.58	48.92	42.54	0.61	0.55
T_4 - 50% N as crop residue + bio-fertilizer +50% N as bio dynamics, enmite	0.68	0.59	49.35	42.71	0.61	0.56
T_5 - 50% N as crop residue + bio-fertilizer + 50% N as FYM	0.68	0.6	50.19	44.58	0.62	0.56
T_6 - Full N as FYM	0.68	0.6	50.95	44.41	0.63	0.57
T_7 - Only 100% recommended dose of N, P and K	0.60	0.56	45.12	37.71	0.57	0.51
T_8 - 1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 50% RDF	0.67	0.58	48.64	42.54	0.60	0.54
T_9 - 1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 75% RDF	0.68	0.58	48.61	42.44	0.59	0.56
T_{10} - 1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 100% RDF	0.64	0.57	48.97	42.22	0.61	0.55
T_{11} - 1/3rd crop residue + 1/3rd FYM + bio-fertilizer + 150% RDF	0.69	0.57	49.04	42.13	0.60	0.54
SEm (±)	**0.059**	**0.006**	**0.281**	**0.354**	**0.003**	**0.007**
LSD(0.05)	**0.169**	**0.017**	**0.803**	**1.012**	**0.01**	**0.019**
Initial	0.593	0.544	43.17	39.82	0.559	0.512

Note : *RDF = 150-100-100 kg* ha^{-1} *of* N-P_2O_5-K_2O

Table 3: Pearson's coefficients of correlation (r) amongst SOC and different physical parameters of the cultivated soils after harvest of potato (Pooled data)

Soil parameter	Bulk density	Water holding capacity	Capillary Pore Space	Non-Capillary Pore Space	Mean Weight Diameter	Water Stable Aggregates	Structural Co-efficient
Organic carbon Surface soil (0-15 cm)	-0.89**	0.93**	0.86**	0.53*	0.77**	0.56*	0.86**
Organic carbon Sub-surface soil (15-30 cm)	-0.98**	0.97**	0.89**	0.96**	0.79**	0.96**	0.90**

Note : ** Significant at 5% level, ** Significant at 1% level* *al.* (2003). We also found very strong negative correlation (r = -0.92, -0.92) between CPP and bulk density of soil samples for both soil depths although with NCPP (r = -0.63, -0.97), relationship was not so significant in surface soil.

Aggregates stability indices

Aggregate properties as indicators of favorable soil structure also influenced by the application of various combinations of inorganic as well as fertilizer treatments for both the years under study (Table 2). Data from the experiment exhibited that the highest mean weight diameter was found in T_{11} (0.69) and all organic treated plots (0.68) are very close to the highest in surface soil. In sub-surface soil, no significant variations were observed among the treatments and its magnitude were higher in T_5 and T_6 (0.60). Strong negative correlation exists with BD (r = -0.67) in surface soil which is in conformity of the findings of Hati *et al.* (2002), whereas in lower depth relationship is not so strong (r= -0.49). The value of percent water stable aggregates was increased maximum from 43.99 (T_1) to 50.95 (T_6) and 40.00 (T_1) to 44.58 (T_5) for surface and sub-surface layers respectively. The mean values of percentage water stable aggregates in different organic treated plots (T_2 to T_6) were 49.646, 43.328 and for the treatments where INM is followed, mean values (T_2 to T_6) were 48.81, 42.33 for upper and lower depths respectively which are *at par* with all treatments except T_7 (45.12, 37.17) and T_1 (43.99, 40) where lower values were found. Very strong negative correlation exists with BD (r = -0.91, -0.93) in surface and sub-surface soil respectively. It might be due to polysaccharides, microbial gum synthesis, resulted from organic matter decomposition. The products of microbial decomposition being resistant to further decomposition act as binding agents; this might help in soil aggregation resulting lower bulk density of soil (Aziz *et al.,* 2015). Maximum value of structural coefficient (SC) was noticed in T_6 (0.63, 0.57) for both the layers respectively, T_4 and T_5 are *at par* with the T_6 although the plot where solely inorganic fertilizers were applied (T_7), values lowered down to 0.57, 0.50 for 0-15 cm and 15-30 cm soil depths. Mean values of SC for the treatments where 50% of organic materials were replaced by inorganic fertilizers (T_8-T_{11}) were 0.60 and 0.55 for upper and sub-soil layers. These mean values were very close to the mean of SC in organic treatments (T_2-T_6) *i.e.*, 0.62 and 0.56 for both the layers. Very strong correlation was found with CPP and SC for surface layers (r =0.84) but not significant for lower depth (r =0.55).

Correlation between organic carbon and physical parameters of soil

The coefficients of correlation between soil organic carbon (SOC) and the different physical parameters of soil for all the treatments and both soil layers are given in table 3. All the variables showed higher correlation with SOC in sub-surface (0-15 cm) layer. It has been observed that bulk density (r = -0.89**,-0.98**) and water holding capacity (r = 0.93**, 0.97**) had a very strong correlation with SOC, whereas capillary pore space (r =0.86**, 0.89**) resulted more strong correlation with SOC than non-capillary pore space. Between all 3 aggregate indices, the index water stable aggregates is weakly correlated (r = 0.56**) with SOC in surface soil. The increasing percentage of structural coefficient was attributed to the higher proportion of SOC which yielded maximum correlation (r = 0.86**, 0.90**) than other two indices for both the soil depths. Thus SOC accumulation may be achieved by establishing proper management practices that increase the proportion of water stable macro aggregates and capillary pores, which result in higher water infiltration, better aeration and better microbial growth.

Decrease in the bulk density with the addition of organic matter of soil might be attributed to the fact that there was better aggregation and increased water holding capacity, higher porosity and higher aggregate stability by the addition of organic matter in surface and sub-surface soil layers. The plots which were managed with reduced rate of inorganic fertilizer, balanced farm waste or compost and bio fertilizers resulted significant improvement in soil physical health indices. Hence, we can conclude that adoption of INM system can increase soil macro aggregation and total C accumulation in macro aggregates, which may improve soil C sequestration and others soil quality indices in the intensive agricultural region of alluvial West Bengal. These observations suggest judicious combination of inorganic fertilizer with organic manure along with bio fertilizer can create favorable impact for improvement of soil physical properties associated with increased availability of plant nutrients resulting better yield and improvement of crop quality as well as residual soil fertility.

REFERENCES

Avitoli, K., Singh, A.K., Kanaujia, S.P. and Singh, V.B. 2012. Quality production of kharif onion (*Allium cepa L.*) in response to bio fertilizers inoculated organic manures. *Indian J. Agric. Sci.,* **82**: 236-40.

Aziz, M.A., Mushtaq, T., Ali, T., Islam, T. and Rai, A.P. 2015. Effect of integrated nutrient management on soil physical properties using soybean (*Glycine max* L. *Merill*) as indicator crop under temperate conditions. *J. Env. Sci. Comp. Sci. Engg. Tech.*, **4**: 56-64.

Black, C.A., 1965. *Method of Soil Analysis*. Amer. Soc. Agron. Madison, USA.

Datt, N., Dubey, Y.P. and Chaudhary, R. 2013. Studies on impact of organic, inorganic and integrated use of nutrients on symbiotic parameters, yield, quality of French-bean (*Phaseolus vulgaris* L.) vis-à-vis soil properties of an acid Alfisol. *African J. Agric. Res.,* **8**: 2645-54.

Devi, K. N., Singh, M. S., Singh, N. G. and Athokpam, H. S. 2011. Effect of integrated nutrient management on growth and yield of wheat *(Triticum aestivum* L.). *J. Crop Weed,* **7***:* 23-27.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedure for Agricultural Research,* 2nd Ed. Jhon Wiley and Sons. New York. Inc, pp. 680.

Grewal, J.S. and Singh, S.N. 1980. Effect of potassium nutrition on the frost damage to potato plants and yield in alluvial soils of Punjab. *Pl. Soil.* **57**: 105-10.

Hati, K.M. and Swarup, A. 2002. Assessment of influence of long-term application of fertilizers and manures under continuous cropping on some physical properties of soil. *IISS Annual Report 2002 – 2003*. IISS. Bhopal. India, pp. 49 – 50.

Khan, M.S., Shil, N.C. and Noor, S. 2008. Integrated nutrient management for sustainable yield of major vegetable crops in Bangladesh. *Bangladesh J. Agric. Env.,* **4**: 81-94.

Patil, P.V., Chalwade, P.B., Solanke, A.S. and Kulkarni, V.K. 2003. Effect of fly ash and FYM on physico-chemical properties of Vertisol. *Soil Crops,* **13**: 59 – 64.

Piper, C.S. 1966. *Soil and Plant Analysis*. Asian Reprint, Hans. Publishers, Bombay.

Pullicinoa, D. S., Massaccesia, L., Dixonb, L., Bolb, R. and Gigliottia, G. 2009. Organic matter dynamics in a compost-amended anthropogenic landfill capping-soil. *European J. Soil Sci.,* **61**: 35-47.

Rai, S., Rani, P., Kumar, M., Rai, A.K. and Shahi, K.S. 2014. Effect of Integrated use of Vermicompost, FYM, PSB and *Azotobactor* on Physico-chemical properties of soil under onion crop. *Env. Eco.,* **32**: 1797-803.

Singh, J.P. and Trehan, S.P. 1998. Balanced fertilization to increase the yield of potato. *Paper presented at the IPI-PRII-PAU Workshop on Balanced Fertilization in Punjab Agriculture,* PAU, Ludhiana, India, 15-16 Dec. 1997. pp 129-39.

Walkley, A. and Black, I.A. 1934. An examination of the Degti-jareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.*, **37**: 355-58.

Weber, J., Karczewska, A., Drozd, J., Licmar, M., Licznar, S. and Jarnroz, E. 2007. Agricultural and ecological aspects of a sandy soil as affected by the application of municipal solid waste composts. *Soil Biol. Biochem.,* **39**: 1294-02.

Bhadoria, P.B.S., Prakash, Y. S. Kar, S. and Rakshit, A. 2003. Relative efficacy of organic manures on the performance of rice in a lateritic soil. *Soil Use Manag.*, UK.**19**: 80-82.

Samui, R.C. and Roy, A. 2007. Effect of growth regulators on growth, yield and natural enemies of potato. *J. Crop Weed*, **3**: 35-36.