RESEARCH ARTICLE

EFFECT OF ORGANIC MATTER AND SOIL-MICROBIAL COMMUNITY ON PHYSICAL, CHEMICAL AND BIOLOGICAL PROPERTIES OF SOIL

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Abstract: A field experiment was conducted at Varanasi, Uttar Pradesh during rainy (*kharif*), winter (*rabi*) and summer (*zaid*) season of 2004 and 2005 to find out the effect of various sources (farmyard manure, vermicompost and poultry manure) and rates of organic manures (100%, 125%, 150% RND) on yield, quality and economics of scented rice on a sandy clay-loam soil low in available N and medium in available phosphorus and potassium. Pooled data analysis revealed that the application of organic manure significantly influenced the yield attributes and grain yield of rice over 100% RND as urea (control). Progressive increase in dose of all the organic manures significantly increased the organic matter, soil microbial population, physical, chemical and biological properties of soil.

Keywords: Origin matter, Physical, Chemical, Biological, Soil

INTRODUCTION

The soil was sandy clay loam in texture with pH 7.12, 0.45% organic carbon and 180.5, 18.2 and 202.4 kg/ha available N, P and K, respectively. The experiment was carried out in randomized block design in fixed plots lay out replicated with 10 treatment combinations involving 3 sources of organic manures, viz. farmyard manure, vermicompost and poultry manure adopting 3 different rates i.e. 100, 125 and 150% of recommended nitrogen dose and 100% recommended nitrogen dose through urea (control).

The organic manures were applied as per their nutrient content on oven dry weight basis. The farmyard manure, vermicompost and poultry manure contained 0.50, 2.30 and 2.80% N, 0.20, 0.75 and 2.20% P_2O_5 and 0.50, 1.23 and 1.30% K_2O, respectively.

Organic manures were applied as per treatment at sowing and mixed thoroughly in 15cm top soil layer. In control treatment, recommended nitrogen dose through urea was drilled 10 cm deep and 5 cm away from the seed or seedling.

The Pusa Sugandha-3 scented rice was transplanted at 20×10cm. Early Apoorva of tablepea and Pusa red varieties of onion were sown/transplanted at the spacing of 30x10 cm and 30x10 cm, respectively.

Soil organic matter

The second major component of soil is organic matter produced by different soil organisms. The total organic matter in the soil, except identifiable undecomposed or partially-decomposed biomass, is called humus. This solid, dark-coloured component of the soil plays a significant role in the control of soil fertility, in the cycling of nutrients and in the detoxification of hazardous compounds. Humus consists of biological molecules such as proteins and carbohydrates as well as the humic substances (polymeric compounds produced through microbial action that differ from metabolically active compounds).

The processes by which humus is formed are not understood fully, but there is an agreement that four stages of development occur in the transformation of soil biomass into humus : (i) decomposition of biomass into simple organic compounds (ii) metabolization of the simple compounds by microbes; (iii) cycling of carbon, hydrogen, nitrogen and oxygen between organic matter of the soil and the microbial biomass and (iv) microbe-mediate polymerization of the cycled organic compounds. The investigation of molecular structure in humic substances is of special interest in current research. Although it is not possible to describe the exact molecular configuration of humic substances, these molecules essentially contain hydrogen ions dissociate in fresh water to form molecules bearing a net negative charge.

Much of the molecular framework of soil-organic matter, however is not electrically charged. The uncharged portions of humic substances can react with synthetic organic compounds such as pesticides, fertilizers, soild and liquid waste materials and their degradation products. Humus, either as separate solid phase or as a coating on mineral surfaces, can immobilize these compounds or in some instances detoxify them significantly.

Soil organic matter virtually runs the life processes in the soil and is taken as the indicator of soil health and fertility. Organic C content of the soil varies widely,

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depending on the nature of soil, prevailing weather (temperature and water) and plant geography. In general, temperate soils have higher organic C (1.2-2.5%) than the tropical or subtropical soil (0.5-0.6%). However, it is not easy to increase the organic C content in the subtropical environment of Indo-Gangetic plains. Long-term fertility experiments in this region of India have indicated that green manuring improves the organic C status and thereby increases the use and efficiency of applied N, P and K, but the prevailing weather parameters (moisture and temperature) hinder the accumulation of high soil organic C for long period (Yadav and Prasad, 1992; Nambiar, 1994; Singh *et al*., 1994; Abrol *et al*., 1997).

The availability and quality of organic C play the key role in the soil health, which in turn plays the crucial role in crop productivity. The organic C component may be divided into three broad categories: (i) that contributed by plants during root growth; (ii) humus-reserved organic C in soil in terms of left-over plant residues over time and microbial biomass and (iii) the added organic materials in the soils in terms of plant residues and organic manures.

Soil-microbial Community

Biological environment of fertile soils is teeming with life on all size scales, from microfauna (with body widths less than 0.1 mm) to mesofauna (upto 2mm) and macrofauna (upto 20 mm). The most numerous soil organisms are the unicellular microfauna. It has been estimated that 1 kg soil may contain 500 billion bacteria, 10 billion actinomycetes (filamentous bacteria) and nearly 1 billion fungi besides the members from animal kingdom. The microbial community (Table-1) plays a decisive role in the sustenance of crop productivity, as many of them have evolved along with and have established a mutalistic/symbiotic relationship over the years, helping plants to increase their fitness and adaptability in diverse ecosystems (Subba Rao, 1986). Mining and gainful employment of these micro-organisms in crop production systems will shape the agriculture of this century, and this may be termed as 'The century of microbes'. The well-being of humans will surely rest on them. In general, these microbes are heterotrophs and fulfil their energy requirements from plant source. The bulk of these microbes are saprophytes and their proliferation needs adequate supply of organic matter in the soil.

The soil flora and fauna play an important role in soil development. Micro-biological activity in the root zone is important to soil acidity and for nutrient cycling. Soil particles and pore spaces provide micro-niches for the action of micro-ogranisims responsible for carbon and nitrogen cycling. Soil humus provides the nutrient reservoirs, and soil biomass provides the chemical pathways for cycling (Subba Rao, 1986; Lynch, 1990). With the active involvement of micro-organisms, the carbon in dead biomass is converted to CO_2 under aerobic condition and to organic acids or alcohols in anaerobic conditions. Under highly anaerobic conditions, methane (CH_4) is formed. The production of methane in rice ecosystem is a recognised contributor to global warming. The CO_2 produced can be used by photosynthetic micro-organisms or by higher plants to create new biomass and thus initiate the carbon cycle again.

The most common soil bacteria come under the genera Pseudomonas, Bacillus, *Clostridium, Arthobacter, Flavocabterium, Chromobacterium, Sarcina, Mycobacterium, Achromobater* etc. However in the ecological niche of rhizosphere the dominant bacterial genera are : *Pseudomonas, Bacillus, Clostridium, Arthobacter, Flavobacterium, Chromobacterium, Sarcina, Mycobacterium, Achromobater* etc. Amino acid-requiring bacteria dominate in this niche. Thus the composition of bacteria around rhizosphere is infuluenced by the crop plant in question, soil amendments, rhizo-ceposition (influenced by foliar application of agrochemicals) and artificial introduction of other microorganisms. For soil health and fertility, abundance of N_2- fixing bacteria has greater significances.

N_2 – fixers

Beijerinck was the first to isolate N_2- fixing bacteria from root nodules in 1888, and by 1895 Nobbe and Hiltner produced the first laboratory culture of *Rhizobia* under the trade name Nitragin. The systematic study of biofertilizers in India was started in 1920 by N.V. Joshi. The work of De (1939) introduced the blue-green algae for N_2 fixation in the rice ecosystem. Since then a lot of progress has been made in this direction and presently biofertilizer-producing industries have come up to meet the growing need.

The N_2- fixing bacteria may be broadly classified into two groups-free living and symbiotic. In the symbiotic nature N_2 fixation is assured, and much work in this direction has been carried out on *Rhizobium*. These bacteria live freely in the soil and in the rhizosphere of both leguminous and non-leguminous plants, but can have symbiotic association only with leguminous plants by forming nodules in the root. However, the origin of leguminous plants and the evolution of bacterial symbiosis have still remained speculative. Of late association of *Rhizobium* with plants other than those from Leguminoceae, as an endophyte has opened-up new arena of research to harness benefit from such associations.

It has been shown by various workers that in the soil with low N status, plant encourages nodulation, whereas in soil having adequate N availability or foliar feeding of urea, nodulation gets affected. One has to strike a balance between fertilizer application and use of N_2- fixing bacteria without compromising the productivity and profitability of the system.

The free-living forms like *Azotobacter*, *Clostridium* etc. provide enough opportunity for their gainful employment in this regard. Moreover, these bacteria produce growth hormones and other plant growth-promoting substances and also guard against several pathogens through antibiosis. However, due to their free-living nature, they require adequate supply of organic matter in the soil for their proliferation and realisation of benefit. The population of *Azotobacter* in rhizosphere of crop plants and in uncultivated soil is generally low. Many a times inoculation of soil does not yield the desired result, and therefore repeated applications have to be made to improve their population.

Recently the role of endophytic acetic acid bacteria in plant health has come in prominence. These bacteria like *Gluconacetobacter* reside in plant (sugarcane) as an endophyte and help not only N_2 fixation but also in growth promotion and plant defence (Suman *et al*., 2005).

The blue-green algae (*Cyanobacteria*) are another group of atmospheric N_2- fixers that help in the N economy in the various crop-production systems. Rice ecosystem provides a congenial environment for the growth of N_2-fixing blue-green algae. Moreover, they also produce several growth promoting substances that also help to boost up the growth of rice plant. Some blue-green algae also exist in association with other organisms. The association of *Anabaena* with the aquatic tern *Azolla* is of special significance in rice system. The blue-green algae, *Anabaena azollae* fixes atmospheric N_2. The advantage of *Azolla* lies in its fast multiplication and its higher green-compost yield than the green-mauring crops like *dhaincha* and sunnhemp.

Phosphnate and sulphate solubilizers

Solubilization of phosphates by micro-organisms depends on the soil pH. In neutral and alkaline soils having high content of Ca, precipitation of calcium phosphates take place. Micro-organisms readily dissolve such phosphates and make these available to the root. On the contrary, acid soils are generally poor in Ca and the phosphates get precipitated as the compound of Fe or Al, which are not easily mineralized by the soil microflora. Many bacteria (*Bacillus, Pseudomonas*) and fungi (*Aspergillus, Penicillium*) actively take part in the process of solubilization of soil P (Gaur, 1985).

These micro-organisms, which actively help in P solubilization and increase the availability of P to roots, modify their activities when P is easily available through the application of fertilizer P. Therefore to utilize full potential of P solubilizers, P application through fertilizers should be avoided. Increasing response to P application over the years indicates a decreasing availability of P through the microbial route. This microbial mining needs to be strengthened to reduce the burden of fertilizer P application.

Mycorrhiza is a symbiotic fungus-root association, which increases the P-gathering capacity of plant roots from the soil. Frank (1885) was the first to notice such an association in forest trees. Today it has been realised that mycorrhiza is of very common occurrence in plants, and it is estimated that 90% of terrestrial plants have such associations. There are two kinds of mycorriza, viz. ecto and endo-mycorrhiza. In the ecto-type the fungus forms a mantle of hyphae around the root; only a few haustoria go inside the root cortex for food. This type of mycorrhiza is prevalent with trees and, in general, trees growing in mountainous region have such an association (Brundrett, 2002). In the other type, i.e. endo-mycorrhiza, the fungus enters the cells and forms vesicle-arbuscule; and hence it is termed as vesicular arbuscular mycorrhiza (VAM). The nutrition benefit to the host plants arising from mycorrhiza has received considerable attention due to their positive influence in the uptake of P. The fungal hyphae increase the absoring surface for P and ensure prolonged supply, because the root epidermis behind the root hairs has limited capability of P uptake due to the absence of the critical enzyme. Limitation of mature root portion in P uptake has led to increase in P availability through symbiotic association with fungi (mycorrhiza) and in P-deficient soil this has become the norm. The other advantage of the mycorrhiza is the barking effect; they deter several pathogenic fungi and bacteria by blocking their access to root directly and indirectly through antibiosis (Brundrett, 2002; Jones *et al.* 2004).

The inorganic component of the soil S is in the form of SO_4^{-2}, which constitutes only a minor-portion of the total S content in the soil. The bulk of soil S comes from organic matters in the form of S-containing amino acids and vitamins. Micro-organism play a major role in the process of mineralization of sulphates and their availability to roots.

Soil physical parameters viz. bulk density and water stable aggregates did not showed any profound effect due to addition of organic materials (Table-1). The values of chemical properties of soil like organic carbon, available N, P and K increased significantly from initial stage and over control treatment on the completion of 2- year’s cycle of rice-table pea-onion sequence. The maximum organic carbon build up was accrued (0.54%) when 150% recommended nitrogen dose was supplied through poultry manure (T_9) while the least value (0.40%) was noticed with the 100% recommended nitrogen dose through urea (T_{10}). The organic carbon of the soil increased over its initial status (0.38%) under nitrogen supply through organic sources. The nutrient status of the experimental site was also affected significantly by the application of different organic manures along with their varying rates. Results clearly indicated improved fertility status of soil due to increased values of available N, P and K in all organic treatments over its initial value as well as control. Application of organic manures with increased rate enhanced soil fertility over their lower doses. At the end of 2-year cycle, 150% recommended nitrogen dose applied as poultry manure maintained higher values of organic carbon and available N, P and K. Next best treatments in this respect were also found when poultry manure applied with reduced rates of 125% and 100% recommended nitrogen dose, respectively. Continuous application of organic manures in sufficient quantities have been reported to improve the soil organic carbon and available N, P and K in soil thereby sustaining the soil health (Tiwari *et al*. 2002).

Soil biological properties showed improvement in the soil microbial counts over its initial values at the end of 2-years cropping sequence due to supplementation of organic sources. Poultry manure applied @ 150% recommended nitrogen dose was best which lead into higher counts of bacteria (82.45×10^3), fungi (37.82×10^3) and actinomycetes (58.23×10^3) closely followed by the treatments where poultry manure was applied with reduced rates (T_8 & T_7), respectively. The control treatment (T_{10}) had relatively lower values of soil microbial count than the organic treatments. The favourable effect of organics on soil biological properties is a proven fact which helped in providing ideal conditions and presumably increased the microbial activity because of the available high organic matter. Hati *et al.* (2001) and Shanmei *et al.* (2002) also reported favourable effect of organic manures on soil biological properties. These results are in conformity with the findings of Bohra (2005).

Table 1. Effect of organic matter and soil-microbial community on physical, chemical and biological properties of soil at the end of two years cycle of rice-tablepea-onion cropping sequence.

Treatments	Bulk density	Porosity	Water stable aggregates	Organic carbon	N	P	K	Viable count (cfu/g)		
								Bacteria ($x10^3$)	Fungi ($x10^3$)	Actinomycetes ($x10^3$)
T_1 - 100% RND as FYM	1.36	40.32	18.01	0.44	184.34	24.43	154.41	62.82	22.50	33.73
T_2 - 125% RND as FYM	1.37	40.38	18.18	0.45	185.46	24.61	154.87	63.63	23.03	34.74
T_3 -150% RND as FYM	1.39	41.34	18.20	0.46	186.72	25.44	155.44	66.92	24.00	35.43
T_4 -100% RND as VM	1.38	40.30	18.01	0.47	187.73	26.52	157.42	72.34	25.31	36.25
T_5 -125% RND as VM	1.40	40.36	18.20	0.48	189.44	27.82	158.84	77.94	27.94	37.44
T_6 -150% RND as VM	1.41	41.18	18.50	0.49	189.95	28.00	160.42	78.65	28.63	43.18
T_7 - 100% RND as PM	1.39	40.20	18.04	0.50	190.44	28.42	161.72	79.54	29.45	46.94
T_8-125% RND as PM	1.41	40.22	18.32	0.52	191.43	28.84	162.43	80.44	32.11	54.46
T_9 -150% RND as PM	1.42	40.95	18.65	0.54	192.98	29.43	164.12	82.45	37.82	58.23
T_{10} - 100% RND as urea	1.35	40.02	18.00	0.40	178.95	22.44	152.44	41.85	11.49	33.44
Initial	1.35	40.00	18.00	0.38	178,43	22.41	151.24	41.45	11.25	32.41
SEm ±	0.11	0.29	0.23	0.04	3.29	0.19	3.01	-	-	-
C.D. (0.05)	0.33	0.86	0.68	0.12	9.78	0.56	8.94	-	-	-

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