Shivam Anand Sharma *et al*, International Journal of Advances in Agricultural Science and Technology,
Vol.3 Issue.7, December- 2016, pg. 21-34 **ISSN: 2348-1358**
Impact Factor: 6.057

Effect of Long-Term Integrated Plant Nutrition System (IPNS) in Rice-Wheat Sequence on Soil Biological Health

Shivam Anand Sharma, Rajinder Kumar, SS Rana, Gunjan Guleria, S.C. Negi
Department of Agronomy, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh 176062
Corresponding author: ranass_dee@yahoo.com

Abstract: Rice - wheat is the predominant cropping system especially in the mid hills zone of the state. The system is over-exploitative of the natural resources and consequently leads to degradation in soil health and fertility. Assessment and regular monitoring of soil health is essential for sustainability and minimal environmental degradation. Soil quality consists of physical, chemical and biological components and their interaction with one another. The biological component of soil has been largely ignored so far, though is an important aspect to manage sustainable agriculture, soil health and ecosystem. Numerous studies have been carried out on soil physical and chemical aspects. But in depth analysis of the soil biological health has rarely done. Therefore, the present study was carried out in a long-term experiment on IPNS in rice – wheat cropping system during 2013-14 at the Bhadiarkhar farm of the university. Twelve treatment combinations viz. T_1 - Control (No fertilizer, no manure), T_2 - 50% NPK to both rice and wheat, T_3 - 50% NPK to rice and 100% NPK to wheat, T_4 - 75% NPK to both rice and wheat, T_5 - 100% NPK to both rice and wheat, T_6 - 50% NPK + 50% N (FYM) to rice and 100% NPK to wheat, T_7 - 75% NPK + 25% N (FYM) to rice and 75% NPK to wheat, T_8 - 50% NPK + 50% N (wheat cut straw) to rice and 100% NPK to wheat, T_9 - 75% NPK + 25% N (wheat cut straw) to rice and 75% NPK to wheat, T_{10} - 50% NPK + 50% N (green manure) to rice and 100% NPK to wheat, T_{11} - 75% NPK + 25% N (green manure) to rice and 75% NPK to wheat and T_{12} -Farmers' Practice (40% NPK and FYM 5 t/ha to both the crops) were evaluated in a randomized block design with four replications. The application of organics viz FYM, wheat straw and green manure and chemical fertilizers increased the number of heterotrophic bacteria, fungi, actinomycetes, and nitrogen fixing bacteria significantly over the control. A definite build up of organic carbon and thereby microbial biomass carbon over its initial value of 0.6% was observed in all the treatments. The highest increase in organic carbon content over control and initial status was observed under T_6 where 50% N was substituted through FYM during kharif followed by 100% NPK through fertilizers in rabi. The highest microbial biomass carbon was found under T_8 where 50% N was substituted through wheat cut straw during kharif followed by 100% NPK through fertilizers in wheat. Both dehydrogenase and phosphatase activities were stimulated by the application of organic manures and inorganic fertilizers over control. Organic fertilizers were more effective than inorganic fertilizers in increasing the microbial activity. Among the organic sources, FYM and wheat straw were superior to green manure. Microbial index of the soil increased with increase in the level of fertilization. The effect was more pronounced with organics than with inorganics. T_6 where 50% NPK through fertilizers and 50% N through FYM to rice and 100% NPK through fertilizers to wheat was applied had highest microbial index of soil. This was followed by T_8 (50% NPK through fertilizers and 50% N through wheat straw to rice and 100% NPK through fertilizers to wheat).

Key words: IPNS, soil microbiological indicators, yield attributes, yield, rice-wheat sequence

Introduction

Soil biological health is a fundamental consideration in maintaining the vital soil functions and ensuring agricultural and environmental sustainability. Soil organisms control the decomposition of plant and animal residues, are involved in biogeochemical cycling of elements, including nitrogen fixation; contribute to the formation of soil structure; transform the organic and inorganic applied to soils and regulate the production and consumption of green house gases in soils. Soils and their biodiversity thus play a critical role in maintaining soil health. Manna et al. (2013) were of the opinion that the assessment and regular monitoring of soil health under different crop production systems provide opportunity to evaluate land use management systems for sustainability of crop production and minimal environmental degradation. The cause of deterioration of soil health are extensive mining of nutrients from soil, huge gaps between nutrient demand and supply; emerging deficiency of micro and secondary nutrients in plants and soil; insufficient use of organic inputs in soil; development of acidity; salinity and alkalinity; build up of heavy metal toxicity and development of soil sickness due to undesirable microorganisms. Monitoring of soil health is important but the usefulness of the data will only be realized if it is used in management decisions to correct deficiencies or improve the quality of the soil resources.

To assess soil health minimum data sets of physical, chemical and biological properties that can be used as quantitative indicator of soil quality/health have assumed crucial significance. Soil quality consists of physical, chemical and biological components and their interaction with one another. Until recently, the major emphasis on soil quality investigations has been given on the use of chemical and physical attributes of soil to define soil quality (Arshad and Coen, 1992), since its biological component is a bit complicated, thus, difficult to quantify. However, these two soil features are the only part, which may impart to a soil for its essence or characteristics. The biological component of the soil is responsible for humus formation, cycling of nutrients, soil tilth, structure and a myriad of other functions (Lynch and Bragg, 1985; Tisdall, 1991). This biological component of soil has been largely ignored so far, though is an important aspect to manage sustainable agriculture, soil health and ecosystem. A healthy soil has more soil beneficial organisms than an unhealthy soil of the same type. Soil health allows for abundant, healthy root growth and good crop establishment. Crops grown on healthy soils have less disease, insect-pest and weed pressure than crops grown on soils with health limitations. We can assess biological health in the field by checking for organisms, soil organic matter and microbial biomass carbon.

Materials and Methods

The present investigation was undertaken during 2013-14 in an ongoing long – term experiment which was initiated during kharif 1991 with rice – wheat cropping system at the Bhadiarkhar farm of the university (32^{o}6´ N latitude, 76^{o}3´ E longitude and 1223.7 m altitude). The soil of the experimental site was silty clay loam in texture, acidic in reaction (pH 5.5), high in available nitrogen (675 kg/ha), medium in available P (22 kg/ha) and K (221 kg/ha) with CEC of 11.5 c mol (p$^{\pm}$). Taxonomically the soils of the region are classified as 'Typic Hapludalf'. The field experiment was established with rice and wheat as test crops. And a part of nitrogen (25-50%) was substituted through different organic sources viz. FYM, wheat cut straw and green manure (sunhemp or daincha as ex-situ). Use of 100% NPK corresponds to the state level recommended dose of N, P and K for respective crops, which was 90:17:33 and 120:26:25 kg/ha for rice and wheat, respectively. The same set of 12 treatments was repeated in the permanent laid out plots over the years with following treatment details:

	Kharif	Rabi
T_1	Control	Control
T_2	50% NPK (Fertilizers)	50% NPK (Fertilizers)
T_3	50% NPK (Fertilizers)	100% NPK (Fertilizers)
T_4	75% NPK (Fertilizers)	75% NPK (Fertilizers)
T_5	100% NPK (Fertilizers)	100% NPK (Fertilizers)
T_6	50% NPK (Fertilizers) + 50% N (FYM)	100% NPK (Fertilizers)
T_7	75% NPK (Fertilizers) + 25% N (FYM)	75% NPK (Fertilizers)

T_8	50% NPK (Fertilizers) + 50% N (Wheat Cut Straw)	100% NPK (Fertilizers)
T_9	75% NPK (Fertilizers) + 25% N (Wheat Cut Straw)	75% NPK (Fertilizers)
T_{10}	50% NPK (Fertilizers) + 50% N (Green Manure)	100% NPK (Fertilizers)
T_{11}	75% NPK (Fertilizers) + 25% N (Green Manure)	75% NPK (Fertilizers)
T_{12}	Farmers' Practice	Farmers' Practice

Under farmers practice 40% NPK were supplied through fertilizers to each crop plus 5 t FYM/ha on dry weight basis to rice. Green manure crop (*Sesbania aculeata*, dhaincha or *Crotalaria juncea*, sunhemp) was grown as an ex-situ crop during summer (May-June for 55-60 days) and was cut and chopped off into small pieces of 4-6 cm. The required green matter was incorporated into soil by a power operated rotavator at the time of puddling before transplanting of rice.

In rice, half N and entire quantity of P and K was applied as basal dose through urea, single super phosphate and muriate of potash, respectively. The remaining half dose of N was applied at tillering stage. FYM, green manure and wheat cut straw were applied to rice crop each year in specified treatments. In wheat one-third of N and whole P and K were applied as basal dose through urea, single supper phosphate and muriate of potash, respectively. The remaining N was applied in two equal splits at tillering and grain filling stages. Nursery of rice was sown during May end to June start and transplanted during end of June or start of July. The crop was harvested during first fortnight of October. Wheat crop was sown during 1-20 November and harvested during the first fortnight of May.

Soil samples were collected from 0-0.15depth from each plot after the harvest of rice and wheat crop (2013-14), processed and stored in polythene airtight bottles for subsequent microbiological and chemical analysis. Microbial population was determined by plate count technique of Wollum (1982) through serial dilution using respective media for each group. The dehydrogenase activity was determined by method of Casida et al. (1964).The phosphatase activity was determined by the method of Tabatabai and Bremner (1969). Microbial biomass carbon was determined by fumigation-extraction method of Vance et al. (1987). Organic carbon was determined by Jackson (1973).The microbial index (Kang et al. 2005) was calculated by determining the following microbial parameters: bacterial, fungal, actinomycetes and azotobacter population, microbial biomass carbon, dehydrogenase and phosphatase activity and organic carbon. In calculating the microbial index, each parameter value was divided by the respective threshold value (arithmetic mean value of treatments for a parameter in field experiment). The index value of parameter (Iij) calculated by dividing the value by the respective threshold of a parameter is given as:

$$A_{ij} = \frac{A_{ij}}{Th_j}$$

Where Iij is the index value for ith treatment corresponding to jth parameter in an experiment, Aij is the actual measured value for ith treatment and jth parameter in an experiment and Thj is the threshold value for jth parameter.

The microbial index was calculated as an average of index values (Iij) of all the eight parameters in an experiment:

$$MI_i = \frac{1}{8}\sum_{i}^{8} I_{ij}$$

Where MIi is the microbial index for ith treatment and j is the number of parameters considered in deriving microbial index.

Results and Discussion

Soil microbiological indicators

The measured microbial parameters of soil health were bacterial, fungal, actinomycetes and azotobacter population (Table 1), dehydrogenase and phosphatase activity, microbial biomass cabon and organic carbon (Table 2). Application of organics *viz* FYM, wheat straw and green manure and chemical fertilizers increased the number of heterotrophic bacteria, fungi, Actinomycetes, nitrogen fixing bacteria and phosphate solublising microorganisms significantly over the control (Table 2). Thus all these parameters were positively associated with available organic C of soil (bacterial 0.808**and 0.837**, fungal 0.746** and 0.756**, actinomycetes 0.818** and 0.909**; Azotobacter 0.698** and 0.715**, Phosphate solublising microorganisms 0.766** and 0.875**, **indicates significance at 1% level of significance). The increase in microorganism numbers in response to chemical fertilizers may be attributed to a better nutrient status of soil. The effect was greater in the treatment where 50% substitution of N was made through FYM or wheat straw in rice. Martynuik and Wagner (1978), Doran (1980), Bolton et al. (1985), Ramsay et al. (1986) and Alleoni et al. (1995) also reported increases in microbial counts in response to fertilization.

The lower effect of no or low fertilization may be attributed to the increased respiratory activity by microbes because of low microbial efficiency in lower organic matter under N stress (Houot and Chaussod 1995). The effect of wheat straw or FYM in improving the microbial population was more pronounced than by green manure treatments, probably because green manure degrades faster than FYM and wheat straw (Beri *et al*. 1989). As microbial populations were assessed by the completion of crop cycle in rice – wheat system and organics were applied to rice, the lower microbial status in the green manure treatment, therefore, was obvious.

A definite build up of organic carbon and thereby microbial biomass carbon over its initial value of 0.6% was observed in all the treatments except in T_1. Application of chemical fertilizers alone or along with organic manures increased the organic carbon content of the soil over control. The microbial biomass carbon was found to be positively associated with total organic carbon (r= 0.687** and 0.811** after kharif and rabi, respectively; *significant at 1% level of significance). The highest increase in organic carbon content over control and initial status was observed under T_6 where 50% N was substituted through FYM during *kharif* followed by 100% NPK through fertilizers in *rabi*. The highest microbial biomass carbon was found under T_8 where 50% N was substituted through wheat cut straw during *kharif* followed by 100% NPK through fertilizers in wheat. Improvement in soil organic carbon and microbial biomass carbon status in plots treated with different organics continuously for 23 cropping cycles may be due to the stimulating effect of organics on growth and activity of microorganisms (Babhulkar *et al*. 2000).

Both dehydrogenase and phosphatase activities were stimulated by the application of organic manures and inorganic fertilizers over control. These increases may be attributed to the increase of microbial processes, whereas the lower dehydrogenase activity in under-chemical fertilization treatments may be due to poor physical conditions and lack of organic substrates in soils. Houot and Chaussod (1995), Gianfreda and Bollag (1996), Manna and Ganguly (1998) and Kandeler et al. (1999) reported the stimulation of microbial biomass and enzyme activities with the application of chemical fertilizers, farmyard and green manures. Organic fertilizers were more effective than inorganic fertilizers in increasing the microbial activity. Among the organic sources, FYM and wheat straw were superior to green manure probably because of having more residual activity. Green manure had more available C and N, therefore degraded faster by the activities of microbes. The population of microbes and their activities are therefore, expected to be lower by the end of the rice-wheat cycle.

Table 1. Long-term effect of IPNS on microbial population (cfu*x10^4 g^1 soil) during kharif 2013 and rabi 2013-14

Treatment			Bacteria		Fungi		Actinomycetes		Nitrogen fixing bacteria (Azotobacter)		Phosphate Solublising Microorganisms	
	Rice	**Wheat**	Kharif	rabi	Kharif	rabi	kharif	rabi	kharif	rabi	kharif	rabi
T_1	Control	Control	187.5	169.7	39.0	40.3	28.8	32.0	47.7	43.75	36.5	39.50
T_2	50% NPK	50% NPK	190.9	175.3	36.0	42.8	33.5	37.5	59.7	55.95	47.5	50.70
T_3	50% NPK	100% NPK	200.6	176.6	61.3	50.5	37.3	38.0	63.5	60.51	52.5	56.01
T_4	75% NPK	75% NPK	197.4	187.4	55.8	55.5	35.8	39.3	60.2	59.27	50.3	52.52
T_5	100% NPK	100% NPK	231.1	214.3	67.0	59.3	56.0	51.5	66.5	64.79	59.0	64.04
T_6	50% NPK + 50% N (FYM)	100% NPK	233.8	218.8	65.5	63.5	59.0	56.5	69.4	65.36	56.9	68.86
T_7	75% NPK + 25% N (FYM)	75% NPK	231.6	222.1	57.3	58.3	54.0	52.5	57.5	58.52	51.8	66.02
T_8	50% NPK + 50% N (WCS)	100% NPK	235.8	220.3	70.3	57.5	55.5	50.5	70.0	64.27	62.3	64.02
T_9	75% NPK +25% N (WCS)	75% NPK	220.0	224.0	62.0	64.0	53.5	49.3	59.6	61.09	47.8	59.34
T_{10}	50% NPK +50% N (GM)	100% NPK	221.0	227.8	60.5	65.5	50.3	53.8	66.3	62.77	55.5	60.02
T_{11}	75% NPK+ 25% N (GM)	75% NPK	218.0	230.5	51.8	61.8	45.0	51.3	50.5	60.01	49.5	58.01
T_{12}	Farmers' practice	Farmers' practice	200.5	205.7	55.8	59.5	52.5	47.5	62.9	56.95	57.2	57.70
	LSD (P=0.05)		10.8	4.8	7.0	4.5	7.9	5.82	8.8	4.74	5.4	7.60

*cfu, colony forming units

Shivam Anand Sharma *et al*, International Journal of Advances in Agricultural Science and Technology,
Vol.3 Issue.7, December- 2016, pg. 21-34 ISSN: 2348-1358
Impact Factor: 6.057

Table 2. Long-term effect of IPNS on microbial biomass carbon, enzymatic activities and organic carbon during kharif 2013 and rabi 2013-14

	Treatment		Microbial biomass carbon (µg/g)		Dehydrogenase activity (µgTPF/g/h)		Phosphatase activity (µg/g/h)		Organic carbon (%)		Microbial index (soil)		
	Rice	Wheat	kharif	rabi	kharif	rabi	kharif	rabi	kharif	rabi	kharif	rabi	Overall
T_1	Control	Control	692.7	680.6	1.22	1.18	15.80	14.8	0.63	0.62	0.752	0.740	0.746
T_2	50% NPK	50% NPK	735.8	727.33	1.43	1.37	17.73	16.48	0.69	0.68	0.842	0.841	0.841
T_3	50% NPK	100% NPK	770.8	755.58	1.57	1.65	18.55	17.55	0.72	0.67	0.945	0.901	0.923
T_4	75% NPK	75% NPK	823.8	813.55	1.92	1.99	22.49	20.99	0.74	0.69	0.970	0.961	0.966
T_5	100% NPK	100% NPK	844.7	826.73	1.95	2.03	23.60	21.35	0.76	0.75	1.101	1.059	1.080
T_6	50% NPK+50% N (FYM)	100% NPK	872.3	851.80	2.32	2.42	23.88	22.63	0.89	0.89	1.154	1.146	1.150
T_7	75% NPK+25% N (FYM)	75% NPK	821.7	843.78	2.02	2.09	22.88	21.88	0.77	0.84	1.045	1.078	1.061
T_8	50% NPK+50% N (WCS)	100% NPK	891.6	826.63	1.98	2.03	21.92	20.92	0.81	0.87	1.129	1.071	1.100
T_9	75% NPK+25% N (WCS)	75% NPK	873.4	817.69	1.86	1.98	20.29	19.79	0.74	0.77	1.022	1.043	1.032
T_{10}	50% NPK+50% N (GM)	100% NPK	767.1	807.08	1.95	2.02	23.52	22.02	0.77	0.84	1.052	1.086	1.069
T_{11}	75% NPK+ 25% N (GM)	75% NPK	734.1	802.33	1.92	1.98	22.37	22.12	0.76	0.76	0.966	1.051	1.008
T_{12}	Farmers' practice	Farmers' practice	720.6	810.58	2.15	2.16	20.47	21.97	0.75	0.73	1.021	1.024	1.023
	LSD (P=0.05)		10.9	17.13	0.14	0.133	0.50	0.18	0.04	0.05	-		

Microbial index of the soil increased with increase in the level of fertilization. The effect was more pronounced with organics than with inorganics. T_6 where 50% NPK through fertilizers and 50% N through FYM to rice and 100% NPK through fertilizers to wheat was applied had highest microbial index of soil. This was followed by T_8 (50% NPK through fertilizers and 50% N through wheat straw to rice and 100% NPK through fertilizers to wheat), T_5 (100% NPK through fertilizers to each rice and wheat), T_7 (75% NPK through fertilizers and 25% N through FYM to rice and 75% NPK through fertilizers to wheat), T_{10} (50% NPK through fertilizers and 50% N through green leaf manure to rice and 100% NPK through fertilizers to wheat), T_9 (75% NPK through fertilizers and 25% N through wheat straw to rice and 75% NPK through fertilizers to wheat) and T_{12} (Farmers' practice). The other treatments had lower microbial index of the soil than the threshold (1.0). The control plot where no fertilizer and manure was applied had lowest microbial index of the soil.

Yield attributes and yield

The results (Table 4) revealed that when 50% NPK (fertilizers) + 50% N (FYM) was applied to rice and 100% NPK through fertilizers to wheat (T_6), total grain productivity of 9300 kg/ha during 2013-14 was significantly higher over all the other treatments. This was attributed to higher rice and wheat yields in sequence because of higher yield contributing characters (Table 3) as a sequel of favourable soil microbiological properties. The superiority of integrated nutrient management in babycorn-Chinese sarson has been reported (Negi et al. 2016). However, this was statistically at par to T_5 (100% NPK both to rice and wheat) and T_7 (25% N substitution through FYM). Rice grain yield was found to be positively associated with grain weight/panicle (r=0.634*) and microbial index after rice harvest (r=0.601*). The wheat yield was positively correlated with 1000-seed weight (r= 0.779**) and microbial index after wheat harvest (r= 0.881**). It is interesting to note that rice yield under control (4032 kg/ha) after 23 years of continuous cropping was as good as T_2, T_3 and T_4. The weed flora in the control plot was dominated by leguminous weed *Vicia sativa* during *rabi* season. Was it the contribution of such plants and processes? If so, it can be very rightly said that the nature is taking care of its creation with the means it possesses. That's why we have the concept of motherland and not simply the land. The plots receiving 50% N substitution with different organics resulted in higher or equal grain yield as 25% N substitution in rice. Among different organics, FYM was found superior over rest of the sources. The additive effect of FYM application on crop yield was greater on rice than on wheat, which might be due to the fact that FYM was applied only to the rice crop every year, while in case of wheat no fresh application of FYM was made, and whatsoever be the effect on wheat yield, it was due to its residual effect over the years. Use of FYM might have improved the physico-chemical properties of soil that resulted in increased productivity (Chaudhary and Thakur 2007; Kumar et al. 2016). Further, the organic matter supplies macro and micronutrients and several other complexing agents, which maintain balanced supply of nutrients to crop. These results are also in conformity with the earlier findings (Gupta et al. 2006; Sharma et al. 2005; Urkurkar et al. 2010).

Table 3. Effect of treatments on yield attributes of rice (2013) and wheat (2013-14) in rice-wheat cropping sequence

	Treatment		Rice		Wheat		
	Rice	Wheat	Panicles/ m^2	Grain weight/ panicle	Spikes/ m^2	Grains/ spike	1000-seed weight (g)
T_1	Control	Control	164.1	4.36	341.3	24.8	43.6
T_2	50% NPK	50% NPK	188.8	5.29	321.3	34.9	46.4
T_3	50% NPK	100% NPK	245.8	5.31	357.5	35.3	48.6
T_4	75% NPK	75% NPK	195.6	4.71	301.3	29.7	47.7
T_5	100% NPK	100% NPK	186.4	5.2	345	28.4	51
T_6	50% NPK + 50% N (FYM)	100% NPK	205.4	5.37	291.3	35.6	49.6
T_7	75% NPK + 25% N (FYM)	75% NPK	198.3	5.37	316.3	22.7	50
T_8	50% NPK + 50% N (WCS)	100% NPK	224.1	4.93	315	36.9	48.3
T_9	75% NPK + 25% N (WCS)	75% NPK	221.6	5.44	306.3	32.9	51.3
T_{10}	50% NPK + 50% N (GM)	100% NPK	230.6	5.2	320	37.3	52.9
T_{11}	75% NPK + 50% N (GM)	75% NPK	208.3	4.86	323.8	31.9	51.5
T_{12}	Farmers' Practice	Farmers' Practice	212.3	5.4	333.8	31.2	49.2
	LSD (P=0.05)		39.4	NS	NS	8.8	NS

Table 4. Grain and straw yield (kg/ha) of rice and wheat as affected by different treatments during 2013-14

	Treatment		Rice		Wheat		Total (Rice + Wheat) grain yield
	Rice	Wheat	Grain	Straw	Grain	Straw	
T_1	Control	Control	4032	3822	1165	2178	5198
T_2	50% NPK	50% NPK	4377	3856	2282	3127	6658
T_3	50% NPK	100% NPK	4536	4410	3127	4937	7664
T_4	75% NPK	75% NPK	4368	4116	2650	4529	7019
T_5	100% NPK	100% NPK	5040	5460	3560	5193	8601
T_6	50% NPK + 50% N (FYM)	100% NPK	5494	5612	3806	5458	9300
T_7	75% NPK + 25% N (FYM)	75% NPK	5162	5087	3250	4716	8413
T_8	50% NPK + 50% N (WCS)	100% NPK	4343	4477	3142	4726	7485
T_9	75% NPK + 25% N (WCS)	75% NPK	4326	4536	2950	4229	7277
T_{10}	50% NPK + 50% N (GM)	100% NPK	4486	4335	3300	4765	7785
T_{11}	75% NPK + 50% N (GM)	75% NPK	4259	4141	2867	4313	7126
T_{12}	Farmers' Practice	Farmers' Practice	5439	5271	2670	3919	8109
	LSD(P=0.05)		643	906	813	1164	1006

References

[1] Alleoni LRF, Maia NB, Caceres NT and Oliveira PSR. 1995. Effect of green manuring on chemical, physical and biological attributes of the soil. *Unimar Cienc* 4: 100-114.

[2] Arshad MA and Coen GM. 1992. Characterization of soil quality: physical and chemical criteria. *American Journal of Alternative Agriculture* 7: 25-31.

[3] Babhulkar PS, Wandile RM, Badole WP and Balpande SS. 2000. Residual effect of long-term application of FYM and fertilizers on soil properties (Vertisols) and yield of soybean. *Journal of Indian Society of Soil Science* 48(1): 89-92.

[4] Beri V, Meelu OP and Khind CS. 1989. Biomass production, N accumulation, symbiotic effectiveness and mineralization of green manures in relation to yield of wetland rice. *Tropical Agriculture* 66:11–16.

[5] Bolton H, Elliot LF, Papendick RI, Bezdicek DF. 1985. Soil microbial biomass and selected soil enzyme activities: effect of fertilization and cropping practices. *Soil Biology and Biochemistry* 17: 297– 302.

[6] Casida LE, Klein DA and Sautor T. 1964. Soil dehydrogenaseactivity. *Soil Science* 98, 371-376.

[7] Chaudhary SK and Thakur RB. 2007. Efficient farmyard management for sustained productivity of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agricultural Sciences* 77: 443-444.

[8] Doran JW. 1980. Soil microbial and biochemical changes associated with reduced tillage. *Soil Science Society of AmericaJournal* 44:765–771.

[9] Gianfreda L and Bollag JM. 1996. Influence of natural and anthropogenic factors on enzyme activity in soil. In: Stotzky G, Bollag JM (eds) Soil biochemistry, Vol IX. Marcel Dekker, New York. p 123–193.

[10] Gupta V, Sharma RS and Vishvakarma SK. 2006. Long-term effect of integrated nutrient management on yield sustainability and soil fertility of rice (*Oryza sativa*) -wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agronomy* 51(3):160–164.

[11] Houot S and Chaussod R (1995) Impact of agricultural practices on the size and activity of the microbial biomass in a long-term field experiment. *Biology and Fertility of Soils* 19:309–316

[12] Jackson ML. 1973. Soil chemical Analysis. Prentice Hall of India, Ltd. New Delhi.

[13] Kandeler E, Stemmer M, and Klimanek EM. 1999. Response of soil microbial biomass, urease and xylanase within particle size fractions to long-term soil management. *Soil Biology and Biochemistry* 31:261–273.

[14] Kang GS, Beri V, Sidhu BS, Rupela OP. 2005. A new index to assess soil quality and sustainability of wheat based cropping systems. *Biology and Fertility of Soils*41: 389-398.

[15] Kumar Anil, Sandeep Manuja and SS Rana. 2016. Nutrient management through organics in pea-buckwheat cropping system under dry temperate conditions of North western Himalayas. International Journal of Advances in Agricultural Science and Technology 3(6): 16-24.

[16] Lynch JM and Bragg E. 1985. Microoganisms and soil aggregate stability. *Advances in Soil Science* 2: 133-171.

[17] Manna MC and Ganguly TK. 1998. Influence of inorganic and in situ phosphocompost on soil microbial biomass activity in typic Haplustert under rice (*Oryza sativa*)-wheat (*Triticum aestivum*) system. *Indian Journal of Agricultural Science* 68: 732-733.

[18] Manna MC, Rao AS and Mandal A. 2013.Maintenance of soil biological health under different crop production systems. *Indian Journal of Soil Conservation* 41(2): 127-135.

[19] Martynuik S and Wagner GH. 1978. Quantitative and qualitative examination of soil microflora associated with different management systems. *Soil Science* 125: 340-343.

[20] Negi SC, Rana SS and Meenakshi. 2016. Productivity, profitability and energetic of babycorn-Chinese cabbage-onion cropping system as influenced by nutrient management. International Journal of Advances in Agricultural Science and Technology 3(6): 01-15.

[21] Ramsay AJ, Stannard RE and Churchman GJ. 1986. Effect of conversion from ryegrass pasture to wheat cropping on aggregation and bacterial populations in a silt loam soil in New Zealand. *Australian Journal of Soil Research* 24: 253-264.

[22] Sharma SP, Singh MV, Subehia SK, Jain PK, Kaushal V and Verma TS. 2005. Long-Term Effect of Fertilizer, Manure and Lime Application on the Changes in Soil Quality, Crop Productivity and Sustainability of Maize-Wheat System in Alfisol of North Himalaya. AICRP on Long-Term Fertilizer Experiments, Research Bulletin No 2, IISS, Bhopal (MP) and Department of Soils, CSK HPKV, Palampur, HP. p 1-88.

[23] Tabatabai MA and Bremner JM. 1969. Use of p-nitro phenyl phosphate for assay of soil phosphatase activity. *Soil Biology and Biochemistry* 1: 301-307.

[24] Tisdall JM. 1991. Fungal hyphae and structural stability of soil. *Australian Journal of Soil Research* 29: 729-743.

[25] Urkurkar JS, Tiwari A, Shrikant C and Bajpai RK. 2010. Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Inceptisols. *Indian Journal of Agricultural Sciences* 80(3): 208–212.

[26]Vance ED, Brookes PC and Jenkinson DS. 1987. An extraction method for measuring soil microbial biomass carbon carbon. *Soil Biology and Biochemistry* 19: 703-706.

[27] Wollum AG. 1982. Cultural methods for soil microorganisms. In *Methods of Soil Analysis* Part 2. p781-813. American Society of Agronomy, Madison, Wisconsin, USA.