ISSN 1023-1072

Pak. J. Agri., Agril. Engg., Vet. Sci., 2015, 31 (2): 159-170

EFFECTS OF ORGANIC AND INORGANIC FERTILIZATION ON RICE CROP PERFORMANCE, SOIL ANIMAL POPULATION AND MICROBIAL DIVERSITY IN ORGANIC AND CONVENTIONAL SOILS

N. Chhogyel[1,4], O. B. Zamora[2], B. M. Espiritu[3] and Y. Bajgai[4]

[1]Graduate School, [2]Crop Science Cluster, [3]Agriculture Systems Cluster, University of the Philippines, Los Banos, Philippines
[4]RNR-Research and Development Centre, Bajo, DoA, MoAF, Wangdue Phodrang, Bhutan

ABSTRACT

A pot experiment was conducted under greenhouse to determine the crop performance and the effects of compost on soil animals and microorganisms in two lowland rice soils. The two soils were: (a) organic lowland soil that had been applied with carabao manure for about 12 years, and (b) conventional lowland soil that had been applied with chemical fertilizers for many years. The aim of the study was to determine the short-term effects of organic and chemical fertilizers application on rice crop performance, soil animal population and microbial diversity. The fertilizers used were decomposed commercial composts at 4.5 t ha^{-1} and chemical fertilizers at recommended NPK level of 90-30-30 kg ha^{-1} with a control and the experiment was laid out as completely randomized design. The compost used as organic fertilizer in this experiment was as effective as the commercial chemical fertilizer on crop growth and yield. The average crop yields per hill were not significantly different at 47.4 g $hill^{-1}$ and 41.1 g $hill^{-1}$ for the chemical fertilizer and compost, respectively. Moreover, the organic soil had higher diversity, number of soil animals and microbe counts than the conventional soil. There were gradual changes in microbial population during the three crop growth stages (initial, active to maximum tillering, and harvest). Application of organic materials stimulated the population of soil organisms, plant growth and development in both organic and conventional soils. The results indicate the potential of organic fertilizers in improving degraded conventional lowland rice soils.

Keywords: Carabao manure, compost, decomposition, fertilizers, soil microbes.

INTRODUCTION

The soil biota plays an important role in the decomposition and mobilization of organic matter in the soil that affects crop performance. Soil organisms (i.e. soil

Corresponding author: cngawang11@gmail.com

invertebrates and microorganisms) maintain soil health which in turn influences crop management practices and input use required for proper plant growth and development. Soil organisms are also very important in organic farming as an index of soil health. Long-term chemical fertilizer application without organic matter amendment could result into the deterioration of soil health and quality (Dahama, 1997). Soil organisms play a key role in soil fertility management but there is not much studies being conducted especially in the lowland rice soils. Soil flora and funna play an important role in the below soil surface conditioning in the forest, rangeland, or farm land as they are most important part of energy, nutrient and water cycling (USDA, 2004). Therefore, researches are needed to relate below ground soil health and above ground crop performance. Studies on use of some of the organic sources such as green manures, composts, farm yard manures, poultry manures, vermi-compost, etc. has yielded good results in rice production. Plots treated with farmyard manure in groundnut showed higher microbial biomass and enzymatic activities as compared to those applied with chemical fertilizers and the unfertilized control plots (Lalfakzuala *et al.*, 2008). Proper management of crop residues and organic material incorporation can ensure improved soil properties and sustainability in crop productivity (Mandal *et al.*, 2004; Bajgai *et al*., 2014a). Studies along this line could help in identifying soil animals required for decomposition of organic residues that could help promote organic farming.

Soil organisms decompose organic residues and mobilize plant nutrients. The interaction of soil organisms and organic matter in the soil help to improve the ecosystem of rhizosphere by improving the physico-chemical and biological properties of the soil (Roca-Perez *et al.*, 2009). The organic fertilizer application could reduce nutrient loss to the environment because of the slower nutrients releasing mechanism compared with the chemical fertilizers (Bajgai *et al.*, 2015). Soil organic matter (SOM) supplies varying levels of nutrients besides acting as soil conditioner for better root growth and plant development (PCARRD, 2008).

This study was conducted: (a) to compare the effects of organic compost and chemical fertilizers on crop performance; (b) to identify common soil animals in lowland rice soils that play important role in residue decomposition; (c) to estimate the changes in microbial population of bacteria, fungi and actinomycetes, during three crop growth stages of rice (initial stage, mid- to active tilling and at harvest).

MATERIALS AND METHODS

Experimental design and statistical analysis

A green house pot experiment was conducted at the Experimental Station, University of the Philippines, Los Banos, Philippines, during the dry season from April to July 2010. Arai, a popular early-maturing (90-day) Bangladeshi rice variety obtained from IRRI, was used in the study. There was no specific reason for choosing this variety as the objective was to determine the changes in soil microbes and soil arthropods which are referred to as soil animals as they relate to crop performance. Two types of soils (organic and conventional) collected from two different sites were used in the experiment. Fourteen days old rice seedlings raised through *dapog* method were planted in plastic pails, which were then treated with commercial compost and chemical fertilizer. Commercial compost was applied at 4.5 t ha^{-1}, and recommended chemical fertilizer (NPK) was applied at 90-30-30 kg ha^{-1}.

The experiment was laid out in completely randomized design with three replicates. Four pots were used per treatment, and data were subjected to analysis of variance (ANOVA) and per cent coefficient of variation (CV%) was calculated to compare means between the treatments.

The organic soil was collected from the sustainable agricultural farm that has been into organic production since 1998. However, the area was not cultivated continuously as it remained fallow once after every one or two cropping seasons. The organic soil has been maintained with organic inputs such as carabao manure, green leaf manure (legumes) and rice straw. The conventional soil was collected from the lowland field of the University of Philippines, Los Banos that has been into chemical fertilizers for many years. Although the plot was applied with chemical fertilizers, azolla had been used earlier in some experiments prior to this study to control weeds and improve soil quality.

Microbial population determination

The basic soil properties of the two soils are shown in Table 1. Estimation of microbial count was made using the Most Probable Number (MPN) method. This method examined populations of bacteria, fungi and actinomycetes during three crop stages (at transplanting, mid- to active tillering and at harvest). In the MPN, microbes present in the samples were dispersed into ten-fold dilutions which were then incubated in a growth medium for detection. Peptone Dextrose Agar plus Rose Bengal with streptomycin was used as growth medium for fungi; Asparagine-mannitol agar medium for the bacteria and Glycerol agar medium for actinomycetes. The colony- forming units (cfu) were counted after incubation and estimates of the total populations were calculated using standard statistical tables and formulae.

There were variations in microbial counts of fungi, bacteria and actinomycetes in the two soils. Organic soil had more fungi (22×10^3 cfu g^{-1} soil) than the conventional soil (3.2×10^3 cfu g^{-1} soil), while both the soils had similar levels of actinomycetes population. Both soils supported high bacterial population. In general, organic soil had higher microbial counts than the conventional soil and it could be due to the application of organic residues and non-use of chemicals.

Among the soil chemical properties, the conventional soil had higher N % and C %. This could be due to heavy use of fertilizer and residual organic materials in the soil. It was learnt that, the conventional soil had been into intensive cultivation with heavy application of rice straws and animal manures.

Table 1. Baseline soil properties and microbial populations of the soil samples.

Soil properties	Organic soil	Conventional soil
Chemical properties		
pH	6.60	6.90
N (%)	0.22	0.50
P (ppm)	53.00	33.00
K (cmol)	0.24	0.37
C (%)	2.63	3.06
Microbial population (cfu g^{-1}soil)		
Bacteria (x 10^4)	14.50	9.30
Fungi (x 10^3)	22.00	3.20
Actinomycetes (x 10^5)	1.90	2.20

Soil animal diversity assessment

The Berlese funnel extraction method was used to assess the diversity and number of soil micro-arthropods which are referred to collectively as soil animals. About 11'' x 11'' x 2'' of sample soil (two replicates per treatment) was marked at the site from where the samples were collected (organic and conventional fields), and slowly cut into pieces like cakes, side first and bottom last. The soil cakes or the lumps were brought to the laboratory which included plant litter on the surface. In the laboratory, the clods of soil samples were gently broken and placed in a Berlese funnel extractor. A 40 W light bulb placed at the mouth of hopper of the funnel was turned on. The assumption was that the soil under glowing bulb gets hotter and soil animals move down, then eventually fall into the beaker (ethanol trap) placed below the funnel. This set up also shows that soil organisms are photonegative and move away from the light. Extraction was done for 48 hours after which the soil animals were sorted out and identified using the insect identification keys. Since the soil animals were mostly small, a low power microscope was used for their identification. Organic soil had greater diversity and number of soil animals than conventional soil at the start of the experiment (Table 2).

Table 2. Baseline soil animals population extracted by the Berlese funnel extractor (numbers).

Soil	Animals							
	Spring tails	Ants	Mites	Bristle tails	Termites	Bugs	Spiders	Centipedes
Organic	59	32	30	19	6	10	3	2
Conventional	19	19	14	15	0	7	0	0

Agronomic parameters

Agronomic parameters assessed to relate crop performance included plant height, number of leaves on main culm, days to heading, days to maturity, and crop yield and its components. Plant height of ten plants per treatment was measured at four day interval after transplanting. Crop yield was measured after the harvest and its yield components such as 1000-grain weight, grains per panicle, percent filled grains, number of spikelet per panicle were assessed manually.

RESULTS AND DISCUSSION

Rice growth and development

Plant height

A little increase in plant height of rice was recorded in all treatments until 12-16 days after transplanting (DAT), and a linear increase (Figure 1) in the same was noted afterwards in all treatments. There was significant difference between height of the plants applied with chemical fertilizer and compost with the maximum plant height (145 cm) where chemical fertilizer was applied and the shortest in unfertilized control (127 cm). Plant height in both the organic and conventional soils was affected by fertilizer treatment. The same trend of increased plant height of rice plants was noted when grown with high amount of organic manure (Usman *et al.*, 2005). However, in this study, plants with chemical fertilizers were taller than those with either compost or unfertilized control. This could be attributed to the fairly high amount of organic matter in the soil used. Modern high- yielding rice ideotypes are short-statured and resistant to lodging with efficient partitioning to grains (IRRI, 1994).

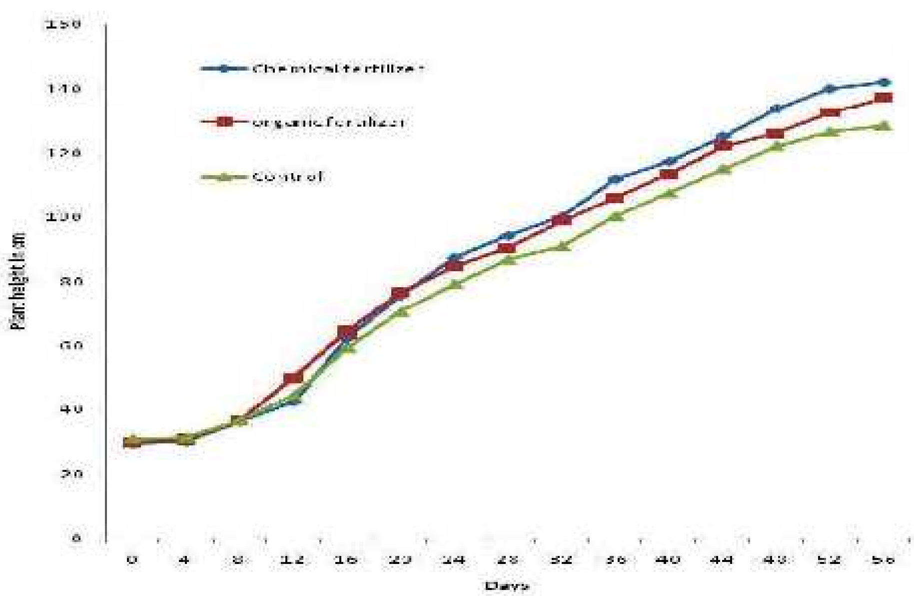

Figure 1. Increase in plant height in response to chemical and organic fertilizers.

Grain yield and its components

Percent filled grains, 1000-grain weight and number of panicles per hill was significantly lower in the unfertilized control than those with chemical and organic fertilizers for both organic and conventional soils (Table 3). The range of number of grains per panicle recorded in the present experiment in both the organic and conventional soils was 64.7 to 80.3. This is lower than those reported by Bisht *et al.* (2006) with more than 100 grains per panicle. This could be due to reduced light level in the glasshouse that resulted in increased number of unproductive tillers (Table 3). Further, Singh *et al.* (2010) observed the reduction in grains per panicles by as much as 9% under shaded conditions.

Table 3. Rice grain yield components as affected by types of fertilizer in organic and conventional soils.

Soil Type	Yield Component						
	Treatments	% filled grains	Spikelets (panicle^{-1})	1000-grain weight (g)	No of panicles (hill^{-1})	Panicle length (cm)	Grains (panicle^{-1})
Organic	Chemical fertilizer	84.7a	94.7a	21a	36.7 a	20a	80.3a
	Organic fertilizer	88.3a	82.7a	20a	33.7 a	20a	73.7ab
	Control	72.2b	83a	17b	21.7 b	18a	64.7c
Conventional	Chemical fertilizer	86.3a	80.0a	24a	36.7 a	18.7a	69.3a
	Organic fertilizer	86.0a	75.3a	22a	32.7 a	19.3a	66.3a
	Control	74.6b	64.3b	17b	22.0 b	17.7b	67.3a
CV (%)		7.3	15.2	108	7.3	15.2	10.8

Column means followed by same letters are not significant at 0.05 level

Table 4. Number of tillers and grain yield per hill under organic and chemical fertilizer treatments in organic and conventional soils.

Soils	Number of tillers (hill^{-1})			Grain yield (g hill^{-1})			CV (%)
	Chemical fertilizer	Organic fertilizer	Control	Chemical fertilizer	Organic fertilizer	Control	
Organic soil	43.0a	37.3b	24.0d	47.4a	41.1a	17.1b	9.7
Conventional soil	44.3a	36.0c	24.3d	46.8a	43.1a	18.4b	11.7

Means followed by common letter are not significantly different at 5% level.

The highest 1000-grain weight was 24 g in chemical fertilizer-treated plants and the lowest was 17 g in the unfertilized control. The 1000-grain weight in chemical fertilizer and compost treatments were not significantly different but were significantly higher than those of the unfertilized control. This agrees with the result of Sarwar *et al.* (2008) who found that the application of organic residues could give grain weight heavier than those of unfertilized control. Shading is detrimental to the full development of the kernels in rice which ultimately affect the grain weight and the yield (Samarajeewa *et al*., 2005).

The grain yield $hill^{-1}$ was 47.4 g $hill^{-1}$ for chemical fertilizer, 41.1 g $hill^{-1}$ for compost and 17.1 g $hill^{-1}$ for the control, for the organic soil and the similar for the conventional soil (Table 4). This grain yield between the compost applied plants and the chemical fertilizer applied plants was similar but significantly higher than those of unfertilized control. Organic residues and composts are as good as the chemical fertilizers if managed properly (Naing *et al.*, 2010; Bajgai *et al*., 2014b). The crop yield in the current experiment was way above that of experiment performed in Pakistan on high yielding lowland rice (Baloch *et al.*, 2002) which showed grain yield per hill ranging between 14.3 g to 28.3 g $hill^{-1}$. However, the grain yield on per panicle basis was quite low. Under hot and shaded condition, the plants tend to invest more assimilates to the production of vegetative parts as evidenced by the increased plant height in the present experiment.

Effects of organic compost on the population of soil animals

Initially, both organic and conventional soils had high number and diversity of soil animals; collembolans (springtails) dominated in number, followed by dipurans (bristletails) and ants. The soils also had high population of mites which play an important role as predators of parasites and pathogens in the soil. Higher numbers of soil animals were found in the treatments with chemical or organic fertilizers than the unfertilized control (Figure 2). Soil applied with chemical fertilizer had higher number of spring tails (51) in organic soil while the soil treated with compost only had 41, and the unfertilized control had 9. Springtails which were the dominant soil animal species have a great role in residue decomposition along with the microbes and nematodes in lowland rice paddies. Springtails are most abundant in many agricultural and rangeland soils, or in organic matter-rich soils and feed on decomposing plants, pollens, grains, nematodes and fungi (Ingham, 2008). The anaerobic flooded conditions may have been detrimental for most of the soil animals, but the results show that springtails can thrive well under reduced level of oxygen and continue to take part in organic matter mineralization.

The number of bristletails was higher in the organic soil than in the conventional soil. There were some pill bugs in the compost treated soils but not in the chemical fertilizer-applied soil or in control, indicating that chemical fertilizer is detrimental for their growth. This shows that organic fertilizer is more specifically important for the growth and proliferation of bristletails and pill bugs. The ants were found to be more in the conventional soil; their numbers were almost the same in the organic and control plots. Pill bugs, also called sow bugs or woodlice, mostly feed on decaying vegetative matter. Pill bugs are the only crustaceans which have adopted to live on dry habitat and they are mostly found in moist environment with good moisture content (ISU, 2005).

The higher count of soil animals in the chemical fertilizer-treated soil is associated with higher levels of organic carbon and N indicating that these elements are required for soil animals to proliferate, whether the source is organic or inorganic. Edwards and Lofty (1977), in a long term experiment in England, compared the effects of artificial and organic fertilizers on the soil fauna and found that plots fertilized with animal dung supported higher number of mites and springtails as compared to plots treated with inorganic fertilizers. However, their results were for upland soil while the present results were on lowland water-saturated soil. It is interesting to study the populations of such soil animals in lowland rice paddies and be able to relate them with sustainable agriculture that focuses on building soil organic matter.

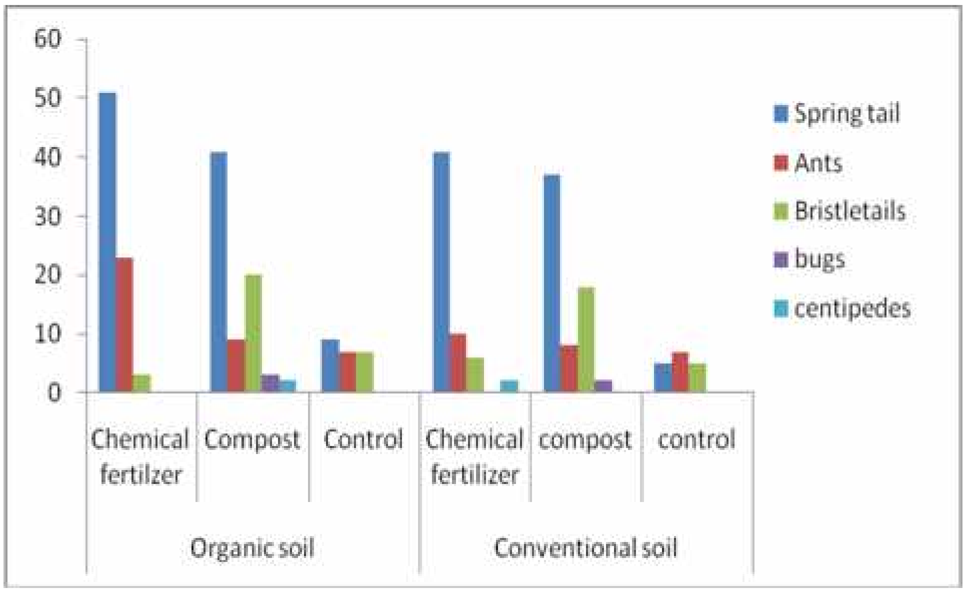

Figure 2. Soil animal population after crop harvest in the organic and conventional soils.

Changes in soil microbial population at three stages of growth

There were no consistent trends on the populations of soil microbes (fungi, bacteria and actinomycetes) at three stages of growth (initial stage, mid- to active tilling and at harvest) due to compost application (Tables 1 and 5). The populations of the bacteria, fungi and actinomycetes were significantly different among the three fertilizer treatments. Initially, the organic soil had higher counts of microorganisms (Table 1), but at active tillering stage, bacteria and fungal counts were higher in conventional than organic soil. The reverse was true for the actinomycetes population (Table 5).

The population of actinomycetes increased two-fold in the compost-treated soils relative to the initial counts before the experiment. However, at harvest in both the compost and chemical fertilizer-treated soils, the population of actinomycetes decreased. From this it was clear that management practices and disturbance can impact soil biological function as it could enhance or degrade microbial habitat; add or remove food resources; directly add or kill soil organisms (USDA, 2005). Chhogyel *et al*. (2015) also reported that water management regimes and organic compost application had major effect on soil microbial counts in lowland soils.

Table 5. The levels of microbial populations at active tillering stage (63 DAS) and harvest (107 DAS) as affected by the application of compost and chemical fertilizer

Microbial population in cfu g^{-1} dry soil						
63 DAS	Bacteria (x 10^5)		Fungus (x 10^4)		Actinomycetes (x 10^5)	
	Organic	Conventional	Organic	Conventional	Organic	Conventional
Chemical fertilizer	2.0b	3.7a	4.0ab	5.6a	2.8bc	1.3b
Organic fertilizer	1.0c	1.3bc	4.1ab	3.0bc	4.8a	2.0b
Unfertilized Control	0.7c	0.7c	1.7c	2.0c	3.3b	1.4b
CV (%)	30		27		30.6	

107 DAS	Bacteria (x 10^5)		Fungus (x 10^4)		Actinomycetes (x 10^5)	
	Organic	Conventional	Organic	Conventional	Organic	Conventional
Chemical fertilizer	12.0c	9.6c	0.57b	0.50b	1.6c	0.9c
Organic fertilizer	8.5 c	85.3b	0.43b	94.00a	1.9c	8.0b
Unfertilized Control	9.8c	120.0a	0.30b	2.03b	1.3c	2.0.0a
CV (%)	7.49		15.7		33.9	

Means with the same letters among treatments and organisms are not significant at 5% level.

There was an increase in the bacterial and fungal populations from the initial to the active tillering stage. At harvest, the dominant microorganisms were the bacteria, followed by the actinomycetes, and the least were the fungi in both fertilizer treatments. Since bacteria are smaller in size and have rapid multiplication ability, their population increased in a shorter time compared to the other microorganisms. The fungi population was lowest in both organic and conventional soils (Table 5). Conventional soil with pH of 6.9 and with higher nitrogen favored the multiplication of bacteria and fungi.

Compost application resulted in a rapid rise in bacterial and fungal populations (Table 5). However, the actinomycetes population declined after a rise in population (Tables 5). The rise in microbial populations at harvest under organic fertilizer application could be due the gradual release of nutrients from the organic source (Bajgai *et al*., 2015). It also indicates that the soil nutrients were not yet depleted at that stage of crop growth. The higher count of microorganisms in those soils applied with chemical fertilizer and organic fertilizers could be attributed to higher initial OM and N contents (Lafakzuala *et al.*, 2008). With crop maturity, there were phase changes in the microbial populations which could dictate changes in the soil environment that affects availability of nutrients to crops. Application of organic materials could have resulted in substantial amount of residual N and other nutrients in the soil for the succeeding crop which improves the microbiological properties of soil (Satyanarayana *et al.*, 2002; Bajgai *et al*., 2015).

CONCLUSION

Compost as source of organic matter and plant nutrients is a good substitute to chemical fertilizer in lowland rice farming. Our data shows that applying compost at 4.5 t ha^{-1} supports plant growth and performance similar to the recommended chemical fertilizer. Compost application significantly promoted better plant growth than the unfertilized control in both organic and conventional soils. The compost applied pot gave grain yield of 41.16 g $hill^{-1}$ which was at par with that of NPK applied pots at 47.4 g $hill^{-1}$, and both the grain yields were higher than that of unfertilized pots at 17.1 g $hill^{-1}$. The effect of compost on the microbial populations relative to those of the unfertilized control was also significant. The soil applied with compost supported higher diversity and number of soil animals that interact with the microorganisms and plant residues that could improve the soil physical environment and nutrient cycling. The presence of high numbers of soil animals such as springtails, mites, pill bugs and different types of ants indicated that they play a major role in the biotransformation of organic inputs and maintenance of soil nutrient pool. Thus, organic farming which makes use of organic inputs is important for increasing the number and diversity of soil organisms and hence, the soil fertility.

ACKNOWLEDGMENTS

Authors are grateful to Nancy G. Bayot, laboratory technician for technical assistance, and to Deodato Darwin, Gregorio T. Canape and Antonio C. Pascua for their support with the field work.

REFERENCES

Bajgai, Y., P. Kristiansen, N. Hulugalle and M. McHenry. 2014a. Effect of residue management and conventional and organic soil management systems on crop yields and weed biomass. Acta Hortic. (I.S.H.S.), 1018: 227-234.

Bajgai, Y., P. Kristiansen, N. Hulugalle and M. McHenry. 2014b. Changes in soil carbon fractions due to incorporating corn residues in organic and conventional vegetable farming systems. Soil Res., 52 (3): 244-252.

Bajgai, Y., P. Kristiansen, N. Hulugalle and M. McHenry. 2015. Comparison of organic and conventional managements on yields, nutrients and weeds in a corn–cabbage rotation. Renew. Agric. Food Syst., 30 (2): 132-142.

Baloch, A. W., A. M. Soomro, M. A. Javed, M. Ahmed, H. R. Bughio, M. S. Bughio and N. N. Mastoi. 2002. Optimum plant density for high yield in rice (*Oryza sativa* L.). Asian J. Plant Sci., 1 (1): 25-27.

Bisht, P. S., R. Puniya, P. C. Pandey and D. K. Singh. 2006. Grain yield and yield components of rice as influenced by different crop establishment methods. International Rice Research Notes (IRRN). 32 (2).

Chhogyel, N., O. B. Zamora and B. M. Espritu. 2015. Soil microbial counts and the performance of low land rice (*Oryza sativa* L.) under two water regimes and two organic soil amendments. J. Org., 2 (1): 33-48.

Dahama, A. K. 1997. Organic farming for sustainable agriculture. 2nd Ed. Agrobotanica Publishers, Bikaner (Rajastan), India.

Edwards, C. A. and J. R. Lofty. 1977. Biology of earth works. Chapman and Hall Ltd., UK.

Ingham, E. R. 2008. Soil biology: The soil biology primer. Natural Resource Conservation Services (NRCS QS) of United States Department of Agriculture (USAD). New York.

IRRI (International Rice Research Institute). 1994. Breaking yield barrier: Rice yield potential in favourable environments proceedings. International Rice Research Institute, Los Banos. Philippines.

ISU (Iowa State University). 2005. Sowbugs and pillbugs. Iowa Insect Information Notes. Department of Entomology. Ames, Iowa, United States.

Lalfakzuala, R., H. Kayang and M. S. Dkhar, 2008. The effects of fertilizers on soil microbial components and chemical properties under leguminous cultivation. Am-Eurasian J. Agric. Environ. Sci., 3 (3): 314-324.

Mandal, K. G. 2004. Rice residue management options and effects on soil properties and crop productivity. Food Agric. Environ., 2 (1): 224-231.

Naing, A., P., Banterng, A. Polthanee and V. Trelo-Ges. 2010. The effects of different fertilizer management strategies on growth and yield of upland black glutinous rice and soil property. Asian J. Plant Sci., 9: 414-422.

PCARRD (Philippine Council for Agriculture, Forestry and Natural Resources Research and Development). 2008. The Philippines recommends for organic fertilizer production and utilization. 2nd Ed. Department of Science and Technology. Los Banos, Philippines.

Samarajeewa, K., N. Kojima, J. Sakagami and W. Chandani. 2005. The effects of different timings of top dressing of nitrogen application under low light intensity on the yield of rice. J. Agron. Crop Sci., 191 (2): 99-105.

Sarwar, G., N. Hussain, H. Schmeisky and S. Suhammad. 2008. Efficiency of various organic residues for enhancing rice-wheat production under normal soil conditions. Pakistan J. Bot., 40 (5): 2107-2113.

Satyanarayana, V. and V. V. Prasad. 2002. Influence of integrated use of farmyard manure and inorganic fertilizers on yield and components of irrigated lowland rice. J. Plant Nutr., 25 (10): 2081-2090.

Singh, S., P. K. Aggrawal and R. N. Yadav. 2010. Growth and yield response of rice under heat stress during vegetative, reproductive, and ripening growth phases. Crop management and physiology, International Rice research Notes (0117-4185), Indian Agricultural Research Institute, New Delhi.

USDA (United States Department of Agriculture). 2004. Soil quality-soil biology technical Note No. 4. Natural Resource Conservation Service, USDA. USA.

USDA (United States Department of Agriculture). 2005. Management of insects on your farm: A guide to ecological strategies, Handbook Series Book 7, Sustainable Agriculture Network Publishers, Baltimore, USA.

Usman, M., E. Ullah, E. A. Warriach, M. Farooq and A. Liaqat. 2005. Effect of organic and inorganic manures on growth and yield of rice variety "Basmati". Int. J. Agric. Biol., 4: 481-483.

(Accepted: July 07, 2015)