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IMPACT OF RICE STRAW BURNING METHODS ON SOIL TEMPERATURE AND MICROORGANISM DISTRIBUTION IN THE PADDY SOIL ECOSYSTEMS

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ABSTRACT

This paper presents the impact of rice straw burning methods (dispersive and intensive) on soil temperature and microorganisms. The results showed that, burning methods have different impact on the soil microorganisms. The direct burning method on rice field increased the soil temperature, especially at the topsoil layer. Nowadays, rice straws are commonly burnt by two methods, which are here named as intensive (piled) and dispersive burning. These both methods had decreased the number of soil microorganisms. The soil temperature caused by intensive was higher than dispersive burning. Consequently, the impact on microorganism by the intensive is stronger than dispersive burning. However, due to the intensive burning should be on a small dot, the recover of microorganisms after intensive burning was better than dispersive burning.

Keywords: rice straw burning, soil temperature, soil microorganism.

1. INTRODUCTION

Rice is the most important crop in Vietnam, with an approximate area of 4 millions ha and the total production of 40 million tons annually (Nguyen Xuan Cu, 2013). The annual amount of rice straw is very big, estimated 70 million tons. In the past, rice straws were used for house roof, fuel, livestock food, green manure, and other usages. Nowadays, they are unused and directly burnt in the field or on roadside. Burning of rice straw is one of the causes for increasing air pollution in the countryside, and affect human health (Nguyen Xuan Cu *et al*., 2011). It is a simple method to clear the ground for following next crop seasons.

In general, rice straw burning has decreased the number of soil microorganisms, and negatively affected their distribution and activities (Mubyana-John *et al*., 2007; Stefan H. *et al*., 2005). However, prior to this study, there was no assessment of rice burning impact on soil ecosystem. In order to provide scientific basis for proper management of post-harvest rice straw, this paper presents the impact of rice straw burning in the field on soil temperature and number of microorganisms (bacteria, actinomycet and fungi).

2. MATERIALS AND METHODS

The field experiments were implemented at Hoai Duc district, Hanoi, belonging to the Red River Delta of Vietnam. The study focused on two straw burning methods: intensive (piled) burning and dispersive burning. All rice straw of the experimental area was burnt with an approximate amount of 4.5 tons per hectare, equivalent.

Time for intensive and dispersive burning was 35 minutes and 15 minutes, respectively. Soil temperature was immediately measured after the burning at the soil layers of 0-1 cm, 4-6 cm, and 8-10 cm. The microorganism composition was determined at the same layers with that of temperature measurement, i.e., 0-2 cm, 4-6 cm, and 8-10 cm for assessment of each burning method. Soil samples were collected from the same locality before and just after the burning.

The experiments were conducted within the paddy rice field during three continuous rice seasons from June 2011 to October 2012. They were implemented following randomized block designs with three times repeated; with fertilizer amount of 225 kgN, 80 kg P_2O_5 and 60 kg K_2O/ha. Soil samples were collected before the experiments (June 2011), and after three harvests (October 2011, June 2012, and October 2012) for assessments of microorganism composition. Typical characteristics of soil are given in the Table-1.

Table-1. Characteristics of the soil.

Depth (cm)	**pH** (KCl)	**SOM** (%)	**CEC Cmol/kg**	**Total N** (%)	**Total P_2O_5** (%)	**Total K_2O** (%)	**Soil texture**
0-20	6.13	2.85	14.8	0.21	0.13	0.94	Silty clay loam

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3. RESULTS AND DISCUSSIONS

3.1. Impact of rice straw burning on soil temperature

In natural habitat, soil temperature always depends on the air temperature. However, soil temperature is more stable than air temperature. Rice straw burning clearly caused a sudden change of soil temperature. Study results regarding the impact of different burning methods on soil temperature are given in the Table-2. In general, all burning methods had influenced soil temperature, particularly within the topsoil layer of 0-2 cm. The natural temperature of the topsoil, 4-6 cm layer and 8-10 cm layer are 30.2^{o}C, 28.5^{o}C and 26.0^{o}C, respectively. The difference of pre-burning temperature among the soil layers is small (Table-2).

Table-2. Impact of rice straw burning on soil temperature.

Burning methods	Layer (cm)	Temperature (^{o}C)	
		Pre-burning	Post burning
Dispersive	0-2	30.2	75.5±1.32
	4-6	28.5	45.5±3.5
	8-10	26.0	30.0±0.87
Intensive	0-2	30.2	89.0±1.50
	4-6	28.5	82.0±2.29
	8-10	26.0	41.0±0.5
CV (%)	0-2	-	1.72
	4-6	-	4.64
	8-10	-	1.99
LSD	0-2	-	3.58
	4-6	-	7.50
	8-10	-	1.79

The intensive straw burning increased the soil temperature at the topsoil of 0-2 cm from 30.2^{o}C to 75.5^{o}C, layer 4-6 cm from 28.5^{o}C to 45.5^{o}C, and layer 8-10 cm from 26.0^{o}C to 30.0^{o}C. The soil temperature was increased more rapidly with higher values in the case of intensive burning, as follows: from 30.2^{o}C to 89.0^{o}C at the topsoil of 0-2 cm, from 28.5^{o}C to 82.0^{o}C at the layer of 4-6 cm, and from 26.0^{o}C to 41.0^{o}C at the layer of 8-10 cm. These study results fit well with previous findings by Liexiang Li *el al*. (2012), which suggested that, while burning, the temperature at surface soil was rapidly increased, then gradually decreased until the end of burning. However, the maximum soil temperature at the layer deeper than 1 cm is lower than 100^{o}C.

3.2. Impact of rice straw burning on the soil microorganisms

Results from analyzing of the soil samples collected from the rice field before and after the burning showed a great change of microorganism number due to the change of soil temperature (Table-3).

The number of bacteria from the study soil is in a range of 5.10^5 and 5.10^6 CFU/g soil. Before burning, bacteria distributed equally within the whole study area at the topsoil layer of 0-6 cm, with smaller number in the deeper layers. After intensive straw burning, the number of bacteria was decreased as follows: from 5.10^6 CFU to $2.4x10^5$ (at 0-2 cm layer), from $4.2x10^6$ to $8.2x10^5$ CFU/g (4-6 cm) while the number of bacteria still remained at the layer of 8-10 cm.

After intensive straw burning methods, the number of bacteria was remarkably decreased: from $5x10^6$ CFU to $2x10^4$ CFU/g soil at the layer of 0-2 cm, from $4.2x10^6$ to $1.1x10^5$ CFU/g (4-6 cm), and from $5x10^5$ to $1.4x10^4$ CFU/g soil (8-10 cm).

Table-3. Impact of rice straw burning on soil microorganisms (CFU/g soil).

Burning methods	Layer (cm)	Bacteria		Actinomycet		Fungi	
		Pre-burning	Post burning	Pre-burning	Post burning	Pre-burning	Post burning
Dispersive	0-2	$5.0x10^6$	$2.4x10^5$	$2.7.10^5$	$5.1x10^4$	$4.0x10^3$	$8.8x10^2$
	4-6	$4.2x10^6$	$8.2x10^5$	$7.0.10^4$	$2.5x10^3$	$2.0x10^3$	$6.4x10^2$
	8-10	$5.0x10^5$	$4.6x10^5$	$2.7.10^3$	$2.5x10^3$	$1.8x10^3$	$1.5x10^3$
Intensive	0-2	$5.0x10^6$	$2.0x10^4$	$2.7.10^5$	$4.9x10^3$	$4.0x10^3$	$1.2x10^2$
	4-6	$4.2x10^6$	$1.1x10^5$	$7.0.10^4$	$2.2x10^3$	$2.0x10^3$	$2.1x10^2$
	8-10	$5.0x10^5$	$1.4x10^4$	$2.7.10^3$	$2.0x10^3$	$1.8x10^3$	$1.0x10^3$
CV (%)			22.99		15.97		11.19
LSD			$2.24x10^5$		$6.09x10^3$		$2.85x10^2$

In comparison with bacteria, the number of actinomyces is much smaller, in a range of $2.7x10^3$ - $2.7x10^5$ CFU/g soil. Actinomyces mostly distributed at the topsoil and their numbers gradually decreased following the depth of soil layers. The change of actinomycet number is similar to that of bacteria. It means that the actinomycet numbers were also decreased after all rice straw burning methods, but in smaller amplitude to compare to bacteria.

With dispersive straw burning, number of actinomyces was just decreased from $2.7x10^5$ to $5.1x10^4$ CFU/g soil at the 0-2 cm layer, from $7x10^4$ to $2.5x10^3$ CFU/g soil (4-6 cm), and mostly remained at 8-10 cm layer. With intensive (piled) straw burning method, their number was decreased as follows: from $2.7x10^5$ to $4.9x10^3$ CFU/g soil at 0-2 cm layer, and from $7x10^4$ to $2.2x10^3$ CFU/g soil (4-6 cm), and there was inconsiderable change in the number of actinomyces at 8-10cm layer. These results showed that the impact of rice straw burning on actinomyces is lesser than on bacteria.

In comparison with bacteria and actinomyces, the total number of soil fungi is smaller, with a range between $1.8x10^3$ and $4x10^3$ CFU/g soil. The distribution of fungi in soil environment is more or less similar to those of bacteria and actinomyces. It also means that their numbers is gradually decreased following the depth of soil layers. In general, rice straw burning method also decreased the fungus number but at a lesser impact in comparison with that on bacteria and actinomyces. Results showed that, with dispersive straw burning, actinomycet number was just decreased from $4x10^3$ to $8.8x10^2$ in 0-2 cm layer, equivalent 5 times, while with intensive rice straw burning, actinomycet number was decreased from $4x10^3$ to $1.2x10^2$ (40 times), while they were 20 and 250 times in bacteria number.

William *et al*. (2010) mentioned that intensive straw burning strongly influenced the physical and chemical properties of soil. According to that study, bacteria and fungi will be died at the temperature up to 50-160°C. Therefore, rice straw burning influenced not only the number and richness of microorganisms, but also caused a change of the distribution of soil microorganisms (Satyam Verma and S. Jayakumar, 2012). Prieto-Fernandez *et al*. (1998) indicated that rice straw burning generally decreased the biomass of microorganisms, but the impact on bacteria is greater than that on fungi (Bollen, 1969; Dunn *et al*., 1979; Sharma, 1981; Deka and Mishra, 1983).

3.3. Impact of rice straw repeat burning on soil microorganisms

3.3.1. Impact of repeat burning on the number of soil bacteria

Results from analyzing the total number of bacteria indicated that the impact of rice straw burning on microorganisms depends on the burning methods. The total numbers of bacteria were decreased gradually by both burning methods (Table-4).

Table-4. Impact of repeat burning on soil bacteria (CFU/g soil).

Burning method	Prior to experiment	After first burning	After second burning	After third burning
Dispersive	$4.8x10^6$	$3.7x10^5$	$4.2x10^4$	$2.9x10^4$
Intensive	$4.8x10^6$	$1.8x10^6$	$1.8x10^5$	$2.5x10^5$
CV (%)	-	19.58	25.58	18.30
LSD	-	$5.39x10^5$	$7.2x10^4$	$6.5x10^4$

The number of bacteria was $4.8x10^6$ before the experiment, but it was down to $2.9x10^4$ CFU/g soil (170 times by dispersive burning) and $2.5x10^5$ (20 times by intensive burning) over three rice crop seasons. These results indicated that the impact by dispersive straw burning on bacteria stronger than by intensive straw burning. It is clear that the intensive straw burning happened within a small area so that microorganisms would move from surrounding to the burning area. This finding also indicates that intensive straw burning is better than dispersive straw burning.

3.3.2. Impact of repeat burning on the number of soil actinomycet and fungi

Results of the numbers of soil actinomycet and fungi affected by burning methods are given in the Table-5 and Table-6, respectively. The changing trend of number of soil actinomycet is similar to fungi. They are only different in affected level, which is greater on fungi.

Table-5. Effect of repeat burning on soil actinomycet (CFU/g soil).

Burning method	Prior to experiment	After first burning	After second burning	After third burning
Dispersive	$3.2x10^4$	$2.7x10^3$	$1.1x10^3$	$5.3x10^3$
Intensive	$3.2x10^4$	$5.2x10^3$	$4.5x10^3$	$7.9x10^3$
CV (%)	-	8.40	8.75	4.42
LSD	-	$8.40x10^2$	$6.21x10^2$	$7.39x10^2$

The data in the Table-5 and Table-6 showed that there is no considerable difference in decrease of soil actinomycet and fungus numbers by different burning methods. The reason of that is actinomycet and fungi depend mostly on soil organic matter (SOM). By both burning methods, in fact the organic matter was not added so that decreases their food sources and then the numbers of soil microorganisms. This result is explainable by the above data and the survival ability in high temperature of actinomycet is better than fungi.

Table-6. Effect of repeat burning on fungi in soil (CFU/g soil).

Burning method	**Prior to experiment**	**After first burning**	**After second burning**	**After third burning**
Dispersive straw burning	$2.6x10^4$	$4.1x10^2$	$3.5x10^2$	$1.4x10^2$
Intensive straw burning	$2.6x10^4$	$1.8x10^3$	$9.3x10^2$	$4.6x10^2$
CV (%)	-	23.21	6.25	11.5
LSD	-	$6.50x10^2$	$1.01x10^2$	$5.88x10^2$

4. CONCLUSTIONS

Results from this study showed that burning methods clearly affected the number of soil microorganisms. Direct burning in the rice field strongly changed soil temperature, especially on the topsoil layer. The increase of soil temperature in 0-2 cm layer respectively increased up to 75^oC and 89^oC by dispersive and intensive rice straw burning, these cause considerably decrease of the number of soil microorganisms. The increase of soil temperature by intensive is higher than dispersive rice straw burning. Consequently, impact on the number of microorganism by the dispersive is stronger than intensive rice straw burning. The microorganism was recovered better after intensive than dispersive rice straw burning.

REFERENCES

Bollen GJ. 1969. The selective effect of heat treatment on the microflora of a greenhouse soil. Neth J. Plant Pathol. 75: 157- 163.

Dunn PH, DeBano LF and Eberlein GE. 1979. Effects of burning on chaparral soils: II. Soil microbes and nitrogen mineralization. Soil Sci Soc Am J. 43: 509-514.

Deka HK and Mishra RR. 1983. The effect of slash burning on soil microflora. Plant Soil. 73: 167-175.

Liexiang Li, Yuta Ishikawwa and Machito Mihara. 2012. Effects of Burning Crop Residues on Soil Quality in Wenshui, Shanxi of China. IJERD- International Journal of Environmental and Rural Development.

Mubyana-John Wutor, V. C., Yeboah S. O. and Ringrose S. 2007. Fire and its influence on microbial community structure and soil biochemical properties in the Okavango Delta, Botswana. Scientific Research and Essay. 2(2): 047-054.

Nguyen Xuan Cu. 2013. Analysis of land use changes and the scientific basis of the protection of rice land in Vietnam, Research solutions to ensure the performance target of 3.8 million hectares of land planted rice in 2020, Union of scientific and technical Vietnam-Vietnam-Society of Soil Science, Hanoi. pp. 56-64 (in Vietnamese).

Nguyen Xuan Cu, Nguyen Thi Hue and Nguyen Song Tung. 2011. Assess the effectiveness of using agricultural residues (rice straw) to improve the content and quality of humus in the Red River alluvial soils. Journal of Science, Natural Sciences and Technology, Vietnam National University, Hanoi. 27(5S): 16-23, (in Vietnamese).

Prieto-Fernandez A, Acea MJ and Carballas T. 1998. Soil microbial and extractable C and N after wildfire. Biol Fertil Soils. 27: 132-142.

Satyam Verma and S. Jayakumar. 2012. Impact of forest fire on physical, chemical and biological properties of soil: A review. Proceedings of the International Academy of Ecology and Environmental Sciences. 2(3): 168-176.

Stefan H. Doerr and Artemi Cerda. 2005. Fire effects on soil system functioning: New insights and future challenger. International Journal of Wildland Fire. p. 14.

William J., Massman John, M. Frank1 and Sacha J. 2010. Mooney, Advancing investigation and physical modeling of first-order fire effects on soils. Fire Ecology. 6(1). DOI: 10.4996/fireecology.0601036.