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Impact of Rice Stubble Management on Soil Microorganisms : 1- Soil Temperature and Microbial Status

R.E.A. Sabrah*, Y.A. Nasr*, Sh.I. Abdel Aal*, M. El-Bassiouny and F. Hamouda*****

**Soil Science Department, Faculty of Agriculture, Cairo University, **Soil, Water and Environment Research Institute, Giza and ***Department of Soil Microbiology, Sakha Agriculture Research Station, Kafr El-Sheikh Governorate, Egypt.*

MUCH ATTENTION has been diverted to the ecological effects of rice straw burning. However, its effects on soil microflora is little understood. Therefore, a field experiment of two successive seasons for the impact of rice stubble burning on soil temperature as well as some soil microorganisms was carried out at the Experimental Farm of Tani-El-Nataf, Sakha Agriculture Research Station, Kafr El-Sheikh Governorate, Egypt.

Statistical analysis shows that rice stubble burning has a significant influence on increasing soil temperature up to 7.5 cm depth. Behind this depth no significant influence was obtained for burning practice on soil temperature. The results also, indicate that cooling rate was more rapid under the upper soil depth (0-1 cm) than the second ones (1-2.5 cm). Cooling rate of the surface layer (0-1 cm) was between 2.61-2.77 °C/ min, meanwhile it was between 1.69 to 1.75 °C /min for the second layer. The surface layer took about 40 min to reach the initial temperature.

Burning treatment, or non-tillage + rice stubble burning (NT+RSB) resulted in a significant reduction in the counts of total bacteria, *Azotobacter* and *Rhizobium*. This was obviously clear up to the depth of 10 cm in both seasons of 96/97 and 97/98. The total counts of bacteria, *Azotobacter* and *Rhizobium* in the upper soil depth (1 cm) were permanently diminished after burning by> 70%, >90% and > 90% of their initial count, respectively. Meanwhile, the corresponding reductions at the deepest soil depth (10-15 cm) were 31.6%, 53.2 %

and 34.9%, respectively, (mean values of the two seasons). On the other hand, the study showed that soil microorganisms were reached their initial population densities within 2 months after berseem cultivation.

Key words: Rice stubble burning, Soil temperature, Soil microorganisms.

Heating of soil by burning plant residues is a very old practice. When residue on or above a soil surface burns, a heat pulse penetrates the soil. The resulting high soil temperature can alter soil properties and kill roots, seeds and soil microbes.

Biederbeck *et al.* (1980) reported the following observations: a) The effect of burning temperature on soil was very superficial and it merely increased below the first one cm soil depth. b) At the soil surface, burning temperature attained maximum values between 338 to 422 °C. c) The maximum burning temperature was reached in 120 second, meanwhile, the soil surface cooled off exponentially taking about 5 to 15 min depending on the weather conditions. On the other hand, they observed that d) the bacterial and fungal populations decreased immediately and substantially only in the top 2.5 cm of soil upon burning. e) Burning in the field permanently diminished the Bacteria population by more than 50 % but the fungi appeared to recover. f) Burning had no effect on microbial population in the 2.5 to 15 cm soil depth. In this concept, Rasmussen *et al.* (1986) and Bhagat and Verma (1991) noticed that burning had no effect on the temperature of the soil surface below 2.5 cm, while soil surface temperature during burning were highly variable, seldom exceeding 120° when the litter burn was incomplete, but ranging between 170 and 330° when the litter was completely burned. Also, Singh *et al.* (1993) reported that burning of wheat straw increased the temperature at the soil surface, 5 and 10 cm surface below 92.5, 67.0 and 58.0°, respectively.

Burning reduces bacterial and fungal numbers. The extent of soil sterilization is related to fire intensity, fire duration and soil water content. Deka and Mishra (1983) mentioned that fungal population reached preburn densities within1 month, while bacteria and actinomycetes were recovered in about 20 days. Also, Dunn *et al.* (1985) observed that microbial groups differed significantly in their sensitivity to temperature: fungi > nitrite oxidizers > heterotrophic bacteria. Hernandez *et al.* (1997) reported that the microbial biomass C content of burnt soils 9 months after fire was significantly lower than that of their respective unburnt soils, and ranging from 50 % to 79 % of the unburnt soil value.

The present study was undertaken to follow up: a) The changes in soil temperature with depth immediately after burning (AB period), b) The decline of soil temperature with time (*i.e.* cooling rate) at two successive soil depth, and c) The density changes of total bacterial counts asymbiotic nitrogen-fixing bacteria (*Azotobacter*) and symbiotic nitrogen-fixing bacteria (*Rhizobium*) in the soil after burning and after berseem cultivation.

Material and Methods

A field experiment was conducted at the Experimental Farm of Tani El-Nataf, Sakha Agriculture Research Station, Kafr El-Sheikh Governorat, Egypt. The experiment was carried out in two successive seasons of 1996-97 and 1997-98 in the same area.

The investigated area was divided into equal plots. Each plot area was 5 x 32m (160 m^2). These plots separated from each other by fireproof tracks (1 x 32 m). Two treatments of rice stubble management were achieved:

1- Non tillage (NT){control}: rice stubble was removed and berseem (*Trifolium alexandrinum*) seeds were sown on soil surface directly without any tillage operation.

2- Non tillage + rice stubble burning (NT + RSB), rice stubble was burnt on the surface of soil plots and berseem seeds were sown directly without any tillage operation.

A randomized complete block design with four replicates for each treatment was implemented in the experimental area. The soil characteristics of the experimental site indicate that the soil is classified as clayey, non-saline, non-alkali soil.

Soil samples were taken at 3 intervales, after rice harvesting and before burning (BB), after burning (AB) and after the first cut of berseem (AC 1) [2-months from planting]. Undisturbed soil samples were collected to represent four successive layers of (0 - 1), (1 - 5), (5 - 10) and (10-15) cm soil depths for microbial population.

Prior to burning operation, soil thermometers (Taylor, Bi-Therm Dial thermometer Fletcher, NC 28732) were incerted in the soil at six successive depths of 1, 2.5, 5, 7.5, 10 and 15 cm. Thermometer readings were recorded before and immediately after the fire practice was done. Also, soil thermometers were used to measure the rate of cooling for about 60 minutes in two soil depths of 1 and 2.5cm.

Total bacterial count. The agar-plate method recommended by Black (1965) was used.

Count of *Rhizobium* by plant infection method, the method recommended by Somasegaran and Hoben (1985) was used.

Counting of *Azotobacter spp.* Preparation of the dilution series and calculation were carried out according to Somasegaran and Hoben (1985).

Results and Discussion

The average values of soil temperature before rice stubble burning (Table 1) indicate that soil surface being slightly hotter than the subsequent soil layers. Soil surface temperature was 27.0 and 29.3°, meanwhile it was 18.5 and 17.5° at 15 cm soil depth in the two seasons, respectively. This difference may be explained as the surface soil layer is exposed to solar radiation which is the main source of heating for both air and soil [Solar radiation = 1.94 cal. Min^{-1} cm^{-2}]. On the other hand, surface soil layer contains less amount of water than successive lower layers. Increasing water content in the soil leads to a lower increase in soil temperature as a result of the higher value of the specific heat of water. The mean values of soil temperature measured immediately after burning (Table 1) clearly show that, the effect of burning on soil temperature was very superficial and it merely increased below the first 7.5 cm soil depth, while it was hotter at the soil surface, where, the mean values of maximum soil temperature for a depth of 1 cm were 128 and 132° in the two studied seasons, respectively.The increments in the soil temperature after burning at 1.0, 2.5, 5.0, 7.5, 10 and 15 cm soil depths were multiplied to 4.74, 2.59,1.64, 1.26, 1.03 and 1.0 folds, the corresponding values before burning, respectively.This means that the differences in soil temperature were conditioned by soil depth, i.e., the impact of burning was very superficial and it become negligible behind the upper 10 cm depth.

TABLE 1. Changes of soil temperature values (°C) with depth befor and after rice stubble burning.

Season	Depth cm	Before burning (BB)					After burning (AB)					L.S.D at 0.05
		R_1	R_2	R_3	R_4**	Mean	R_1	R_2	R_3	R_4	Mean	
1996	1.0	26	28	25	29	27.0 B*	120	128	135	130	128 A	7.95
	2.5	27	26	28	27	27.0 B	70	75	62	73	70 A	7.06
	5.0	23	24	21	22	22.5 B	41	36	35	35	37 A	3.85
	7.5	22	17	19	21	19.8 B	23	26	27	23	25 A	3.70
	10.0	18	20	19	21	19.5 A	18	21	20	20	20 A	2.21
	15.0	19	20	18	17	18.5 A	20	18	18	17	18 A	2.21
1997	1.0	30	27	29.	31	29.3 B	124	128	140	136	132.0 A	9.18
	2.5	29	28	28	29	28.5 B	73	75	70	73	72.8 A	2.62
	5.0	22	22	25	23	23.0 B	40	38	36	36	37.5 A	2.91
	7.5	21	22	19	18	20.0 B	23	25	27	23	24.5 A	3.24
	10.0	17	19	18	18	18.0 A	20	20	18	19	19.3 A	1.54
	15.0	17	17	18	18	17.5 A	17	17	18	18	17.5 A	1.00

* Means with the same letter are not significantly different.

** Replication.

The changes in the soil temperature against time at the burnt plots (Fig. 1) indicate that cooling rate is more rapid at the first depth than second ones. It tooks about 40 minutes in both seasons to reach the initial soil temperature, i.e., the rate of cooling ranged between 2.61-2.77 ° /min. While the time needed to attain the initial soil temperature in the second depth was 25 and 30 minutes in the two seasons, respectively. This means that cooling rate at the second soil depth ranged between 1.69 to 1.75° /min. The above mentioned observations may be attributed to the loss of heat from the surface layer by radiation.

The periodical changes of the mean values of total bacteria, *Azotobacter,* and *Rhizobium* counts are listed in Table 2. The density of bacterial population

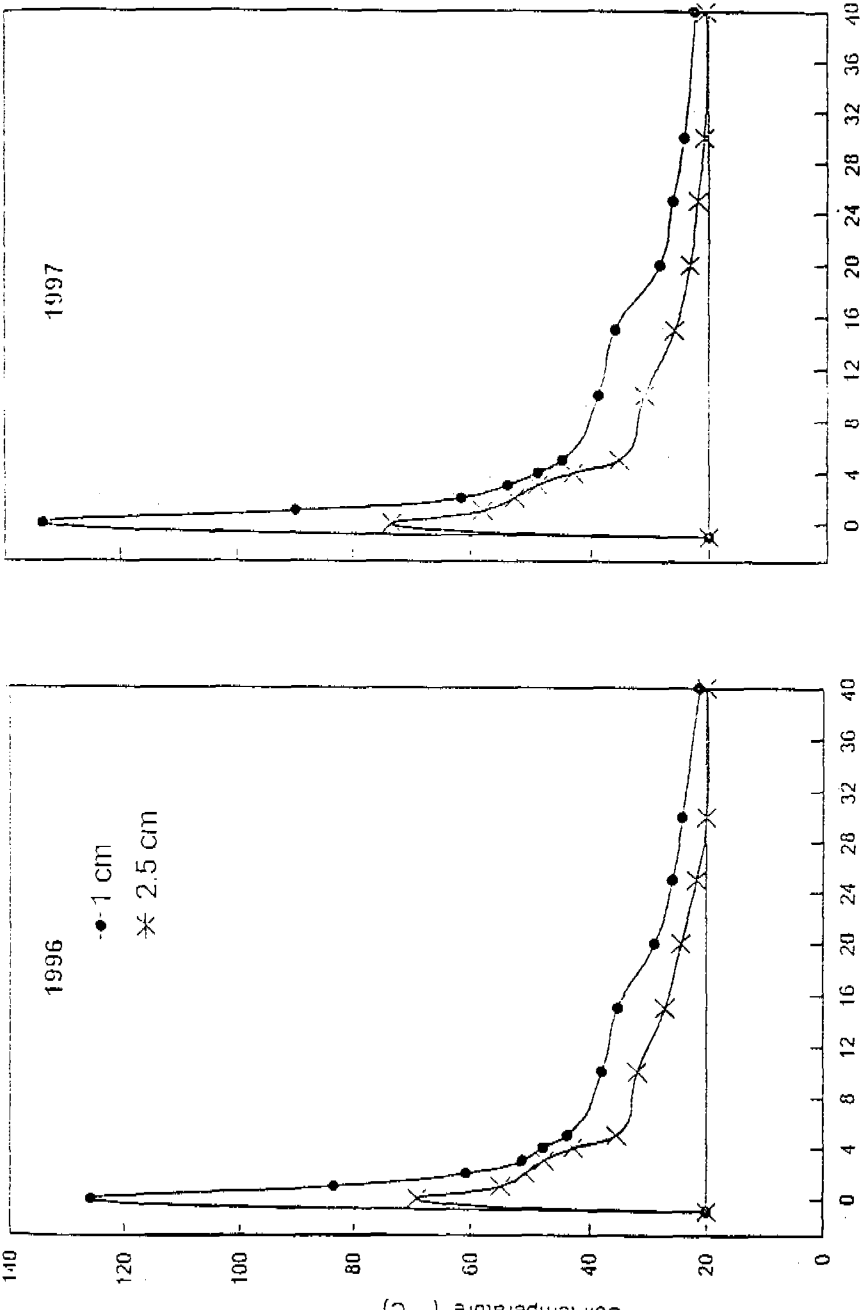

Fig. 1. Changes of soil temperature with time of the two studied soil depths after stubble burning (cooling curve).

ranged between 10^2 (*Azotobacter* and *Rhizobum*) and 10^7 (total bacteria) cells/g dry soil. Also, the noticeable variations in the soil bacterial counts is mainly due to the nature of soil bacteria, the method of stubble management, the period of sampling, as well as soil depth. At the initial state (BB =before burning) total counts of soil bacteria show a visible increase with depth. This increase is mainly considered as a result of the activity of saprophytic bacteria on the dead root materials, and to the activation of the soil bacteria on the fungal hypha producing gummy substances which combine with the clay particles (Sabrah. 1975). On the other hand, sun rays do partial sterilization of soil surface. In contrast, the upper two soil depths (0-1 and 1-5 cm) maintain higher number of *Azotobater* and *Rhizobium*. The numbers then decreased sharply with increasing soil depth. The relative higher numbers of *Azotobater* and *Rhizobium* at the two surface layers are natural since, both bacterial genera are aerobic and need to sufficient amounts of oxygen (Dunn *et. al.*, 1985).

TABLE 2. Mean values of the total counts of soil bacteria, *Azotobater* and *Rhizobium*.

Soil Depth (cm)	1996			1997		
	Period			Period		
	BB	AB	AC_1	BB	AB	AC_1
Total bacteria (x 10^7 / g oven dry soil)						
0-1	3.14	6.7	42.8	28.8	8.8	39.6
1-5	33.4	12.4	30.0	27.6	11.5	26.0
5-10	42.3	29.6	38.7	43.9	27.9	34.4
10-15	43.5	30.8	38.8	47.0	31.0	39.2
Azotobacter (x 10^2 / g oven dry soil)						
0-1	22.64	0.50	50.85	17.45	0.49	6.40
1-5	44.37	0.61	51.61	42.67	1.10	46.91
5-10	9.69	1.20	21.19	10.42	1.18	16.48
10-15	6.50	2.73	9.75	5.27	2.72	11.81
Rhizobium (x 10^2 / g oven dry soil)						
0-1	30.27	0.25	104.07	33.28	0.57	114.43
1-5	8.87	0.44	49.68	7.14	1.17	47.27
5-10	5.63	0.62	22.77	5.04	1.60	21.49
10-15	2.77	1.26	13.52	2.50	2.12	16.45

Respecting the impact of burning treatment (NT+SB) on the total bacteria, *Azotobacter* and *Rhizobium* counts, the data indicate a definite suppression effect. This effect is seen as a net decrease in the numbers immediately after rice stubble burning. Moreover, the effect was primarily apparent in the upper 10 cm soil depth. As this surface layer was much more morphologically altered by burning temperature. Under this depth (10 cm) the soil seemed to be slightly affected by burning temperature.

It is expected that the pattern of burning inactivation is the same for all microorganisms. Whereas the three microbial groups were increasingly sensistive to rice stubble burning, accordingly, total counts of bacteria, *Azotobacter* and *Rhizobium* in the upper soil depth (1 cm) of the burnt treatment were permanently diminished after burning by > 70 %, > 90 % and > 90 %, respectively. Meanwhile, the reduction in the soil bacterial counts at the lower soil depth (10-15 cm) were - 31.6%, -53.20 % and -34.9%, respectively (mean values of the two studied seasons). The reduction in the numbers of soil microorganisms after burning may be due to the direct effect of heat. Burning directly affects their survival since cellular components such as proteins, membrane lipids and nucleic acids are unstable at elevated temperature. Heat may be also indirectly influence population by its harmful effects on genetic regulation and gene expression (Marx, 1983 and Dunn *et al.*, 1985). On the other hand, rice stubble burning reduced the numbers of soil microorganisms and inhibited their regeneration by reducing the quantity of organic matter.

The data show sharp decrease in bacterial numbers after burning rice straw (Table 2) particularly *Azotobacter* and *Rhizobium.* But after berseem cultivation the bacterial population recovered again due to root exudates of this legume plant (particularly *Rhizobium*).

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تأثير حرق مخلفات الأرز على كائنات التربة الدقيقة .١- درجة حرارة التربة والمحتوى الميكروبي.

رجاء عليوة أحمد صبره* ، يحيى عرفه نصر* ، شفيق إبراهيم عبد العال* ، محسن عبد الحميد البسيوني** وفاروق متولي حمودة***

* قسم الأراضي -كلية الزراعة - جامعة القاهرة -الجيزة،
**معهد بحوث الأراضي والمياه والبيئة - الجيزة ،
*** وقسم البكتريا - محطة البحوث الزراعية بسخا-كفر الشيخ - مصر .

أخذت دراسة التأثيرات البيئية لعملية حرق مخلفات المحاصيل كثيراً من الاهتمام في الأونة الأخيرة ، ورغم ذلك فإن تأثير عملية الحرق على كائنات التربة الدقيقة ليست معلومة تماما . من هذا المنطلق أجريت تجربة حقلية في موسمين زراعيين متتاليين لدراسة تأثير حرق مخلفات الأرز على كل من درجة حرارة التربة وبعض الأحياء الدقيقة بها ، وقد أجريت هذه التجربة بمحطة البحوث الزراعية بسخا بمنطقة شلني النطاف محافظة كفر الشيخ.

أظهرت النتائج الإحصائية لقياسات درجة حرارة التربة عقب حرق مخلفات الأرز مباشرة أن لعملية الحرق تأثير معنوي على زيادة درجة حرارة التربة حتى عمق ٧,٥سم . بعد هذا الحد لا يوجد لعملية الحرق تأثير معنوي على زيادة درجة حرارة التربة . كما أوضحت أن معدل تبريد (Cooling rate) الطبقة السطحية (٠ - ١سم) أعلى من الطبقة التي تليها فلقد استغرقت الطبقة الأولى ٤٠ دقيقة حتى تصل إلى درجة حرارتها الأولية (قبل الحرق) في حين استغرق تبريد الطبقة التي تليها (١ - ٢,٥سم) من ٢٥ - ٣٠ دقيقة.

أظهرت معاملة الحرق (NT + SB) انخفاضاً معنوياً في العدد الكلي للبكتريا وكل من اعداد الأزوتوباكتر والريزوبيوم وكان هذا الانخفاض واضحاً في الثلاثة طبقات الأولى حتى عمق ١٠ سم من سطح التربة . بلغ الانخفاض في أعداد هذه الأحياء الدقيقة في الطبقة السطحية (٠ - ١سم) > ٧٠٪ ، > ٩٠٪ ، ٩٠٪< على الترتيب ، في حين وصل الانخفاض في الطبقة السفلى (١٠ - ١٥سم) ٣١,٦٪ ، ٣,٢٪ ، ٣٤,٩٠٪ على الترتيب (متوسط موسمين) . من ناحية أخرى أظهرت الدراسة أن الكائنات الدقيقة المدروسة (العدد الكلي للبكتريا - الأزوتوباكتر - الريزوبيوم) قد استعادت كثافتها الأولية بعد زراعة البرسيم عند الحشة الأولى (شهرين بعد الزراعة) .