QUANTITATIVE EFFECTS OF INCORPORATING RICE RESIDUE ON POPULATIONS OF SOIL MICROFLORA

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SUMMARY

The populations of dominant members of the microflora in a rice field soil as detected on soil dilution plates are reported in relation to total populations of microorganisms. The relative populations of 13 fungi differed significantly either in different depths of rice soil or under different regimes of tillage and soil incorporation of rice straw. For example, *Penicillium* varied inversely with depth and had a lower relative population (RP) in the treatment where straw was burned prior to tillage. The RP of *Paecilomyces* was lower at the 5-cm soil level than at 10- or 20-cm level and the RP of *Phoma* was higher in soil with freshly incorporated straw than in soil with decomposed straw.

Changes in RP of other fungi are also reported. Total populations of bacteria or actinomycetes were generally unaffected by various residue management and tillage practices but were affected by soil depth.

Production of straw and grain of rice, *Oryzae sativa* L., in California is approximately 6,000 kg per ha (**25**) and when a rice crop is to be grown on the same soil in the following year, which is often the case, the straw must either be burned or incorporated. Burning of straw may not be permitted in California in the future, so the effects of incorporation are important to rice growers and are being studied from many aspects.

One such study pertains to stem rot disease of rice which is caused by *Sclerotium oryzae* Catt. Infection occurs in the spring at the waterline on rice seedlings from sclerotia which float to the surface of the paddy water. New sclerotia are formed on infected tissues toward the end of the rice-growing season and are scattered on the soil at harvest or remain in crop debris. These sclerotia represent the primary inoculum for rice grown on the same soil in the succeeding year, and they carry over in the soil for lengths of time which vary depending upon tillage methods (**16, 24**).

While sclerotia are in the soil they are subject to the activity of the soil microflora which should be high considering the amount of substrate provided by the incorporation of straw from a rice crop. In-

corporation of various organic materials into soil has been shown to reduce the severity of other soil-borne diseases by altering soil microbial populations (2, 6, 8, 15, 17). Therefore, it should be beneficial for future work on biological control of stem rot disease, as well as biologically interesting, to determine some of the effects of incorporating rice straw on the microflora of rice soil. This paper reports on the significant differences in populations of the dominant taxa of microorganisms found in rice soils after three consecutive years of different rice residue management practices.

MATERIALS AND METHODS

The site selected for the study is located in Butte County, California, where rice has been grown continuously for several years and stem rot disease is endemic. The soil type is Stockton clay adobe. The residue from the rice crop grown on the site in 1969 was burned immediately after harvest. The following treatments were begun in the fall of 1970 and were continued through 1973: 1) straw and stubble burned after harvest, soil disked to a depth of 15 cm in the fall; 2) crop residue not burned, but residue and soil disked together to a depth of 15 cm in the spring; 3) residue not burned, residue and soil plowed to a depth of 20–25 cm in the spring; 4) not burned, residue and soil disked to a depth of 15 cm in the fall after harvest; 5) not burned, residue and soil plowed in the fall to a depth of 20–25 cm after harvest; and 6) not burned, residue and soil rotovated in the fall after harvest. The rotovator simultaneously chops straw and blends it quite uniformly in the top 10–15 cm of soil. The disk used is a stubble disk which opens the soil with a slicing action and distributes the crop residue vertically through the soil. The plow is a mold-board plow which essentially inverts 20–25-cm-deep strips of soil and residue. Each treatment was represented by four replicated plots and each plot was 14.5×155 m separated by levees and provided with individual water systems to preclude the exchange of soil and water between plots. All other practices were those for normal production of a rice crop in California (14) including final tillage in the spring to prepare the soil for seeding.

Samples of ca. 30 g of soil for isolations of microflora were collected in the spring of 1973 following spring treatments and seed bed preparations but before flooding. Each plot was sampled at three different soil depths: 5 cm, 10 cm, and 20 cm. Six subsamples of ca. 5 g each were taken at random within areas of 40 m^2 in the same relative location of each plot. The samples were taken with a standard soil corer and placed in autoclaved paper bags and held at 1 C until use. Identical soil

samples were taken for determinations of soil moisture content so that all data could be based on the oven-dry weight of soil.

The soil dilution pate method of Waksman (21) modified by Tuite (20) and Johnson and Curl (11) was used to isolate colonies of fungi, actinomycetes, and bacteria for identification and counting. Each 30-g sample of soil was placed in a Waring Blendor with 600 ml of distilled water and blended for 1 min. Final dilutions of 1/10,000 were prepared in 0.2% water agar from samples of 5- and 10-cm soil depths and 1/1,000 from samples of 20-cm soil depth for isolations of fungi and actinomycetes, while dilutions of 1/100,000 and 1/10,000, respectively, were used for isolations of bacteria. For fungal isolations, 1 ml of each final soil dilution was placed in each of four replicated sterile petri dishes for each medium to which was added ca. 12 ml of cooled (48 C) medium and swirled for propagule dispersion. For isolations of bacteria and actinomycetes, 0.5 ml of each final soil dilution was spread on the surface of each selective medium which had been allowed to dry 48 hr.

Three selective media were used for fungi: O.A.E.S. (Ohio medium), V-8 juice (modified) agar, and PDTAS, all described by Tuite (20). Medium 523 (12) was used for bacteria, and glucose-asparagine agar with sodium propionate (3) was used for actinomycetes. Four replicated plates were prepared with each medium from each sample.

All plates were incubated at 23 ± 2 C under continuous fluorescent light of ca. 64 ft-c, fungi for 20 da, bacteria for 24–48 hr, and actinomycetes for 6–7 da. Thereafter, plates were stored at 1 C until colonies could be identified and counted.

RESULTS

The objective of this study was to determine the nature and extent of differences in populations of soil microorganisms in relation to others under different systems of rice residue management and not simply to determine changes in numbers of individual organisms per g of soil. This objective, which applied primarily to fungi, was based on (a) the viewpoint of Jackson (10) and Baker (1) that fungistasis of each fungus must at least in part be caused by one or more of the wide range of microbial metabolites excreted into the soil environment by all microorganisms in each microhabitat; (b) the observations of Watson and Ford (23) that fungistasis is a result of a delicate balance of stimulatory and inhibitory metabolites; and (c) the observations of Huber and Watson (9) that pathogen suppression in cultivated soil can be of microbial origin. Therefore, it seems likely that not the total number of propagules

of any one organism but instead the number of propagules of an organism in relation to the numbers of propagules of other organisms would be of greatest value in helping to understand microbial differences due to different stages of decomposition and different amounts of soil incorporated organic matter.

To reflect this viewpoint the colony count of each fungus is expressed as a percentage of the total number of fungal colonies or relative population (RP). The six treatments of residue management and three

TABLE I

POPULATIONS OF PENICILLIUM SPP. (NONSCLEROTIAL, NONPERITHECIAL) IN RELATION TO TOTAL FUNGAL POPULATIONS IN A RICE FIELD SOIL BEFORE SPRING FLOODING

Depth	Residue treatment						Average for all residue treatments
	Burn	No burn					
	Fall disk	Spring disk	Spring plow	Fall disk	Fall plow	Rotovate	
(cm)	(Percent *Penicillium* of total fungal colonies*)						
5	77.5^{a}	21.9^{t}	36.9^{t}	31.1^{t}	32.2^{t}	31.0^{t}	38.4^{x}
10	24.0^{e}	17.8^{e}	31.1	29.0	40.7^{d}	34.7	29.7^{y}
20	24.1	25.4	19.4	21.0	29.4	15.9	22.5^{z}
Average for all soil depths	41.9^{a}	21.7^{c}	29.5^{bc}	27.0^{bc}	34.1^{ab}	27.2^{bc}	

* Values with letters of the same group (abc, de, st, xyz) which are not in common differ significantly at 5% level. Least significant differences at 5% level are: Depth interacting with residue 15.3; average effect of depth 6.2; average effect of residue treatment 8.8.

subtreatments of depth were analyzed statistically as a factorial experiment to determine significant differences between (a) the averages of all treatments for each depth, (b) the averages of all depths for each treatment and (c) each combination of depth and treatment. Except for representatives of *Aspergillus* only those fungi which showed significant differences in at least one of the above comparisons are included in the tables.

There was an average for all residue treatments of 16.5×10^4 total fungal colonies per g of dry soil at the 5-cm depth of soil, 8×10^4 at the 10-cm depth and 9.5×10^3 at the 20-cm depth. The following fungi were identified: *Pencillium* spp., including one with yellow perithecia; *Paecilomyces* spp. (monophialidic and nonmonophialidic); *Phoma* spp.; *Cladosporium* spp.; representatives of 6 *Aspergillus* groups [sensu

Raper and Fennell (18)]; *Cephalosporium* spp.; *Fusarium oxysporum* Schlect. ex Fr.; *Chaetomium* sp.; *Trichoderma* spp.; *Stachybotrys atra* Corda; *Fusarium episphaeria* (Tode) Snyder et Hansen; *Humicola* spp.; *Alternaria alternata* (Fr.) Kreissler; *Walemia* sp.; *Cylindrocarpon* spp.; *Mucor* sp.; *Mortierella* sp.; *Coniothyrium* sp.; *Gliomastix* sp.; *Acremoniella verrucosa* Togn.; *Rhodotorula* sp.; *Epicoccum* spp.; *Verticillium* spp.; *Periconia macrospinosa* Lefebre et A. G. Johnson; *Nigrospora* spp.; *Helminthosporium pedicellatum* Henry and *Helminthosporium* sp.; *Alternaria* sp.; *Stemphylium botryosum* Wallr.; and *Candida* spp.

TABLE II

POPULATIONS OF PAECILOMYCES SPP. (NONMONOPHIALIDIC) IN RELATION TO TOTAL FUNGAL POPULATIONS IN A RICE FIELD SOIL BEFORE SPRING FLOODING

Depth	Residue treatment						Average for all residue treatments
	Burn	No burn					
	Fall disk	Spring disk	Spring plow	Fall disk	Fall plow	Rotovate	
(cm)	(Percent *Paecilomyces* of total fungal colonies*)						
5	2.3	0.7	4.6	2.8	5.1	1.7	2.9[z]
10	37.2[s]	35.0[s]	8.4[t]	28.2[s]	13.4[t]	29.5[s]	25.3[y]
20	29.1	24.9	13.7	15.5	15.3	32.7	21.9[y]
Average for all soil depths	22.9[a]	20.2[a]	8.9[b]	15.5[ab]	11.3[b]	21.3[a]	

* Values with letters of the same group (ab, st, yz) which are not in common differ significantly at 5% level. Least significant differences at 5% level are: Depth interacting with residue treatment 14.3; average effect of depth 5.8; average effect of residue treatment 8.3.

The relative populations (RP) of *Penicillium* spp. (without perithecia or sclerotia) in different depths of soil and in soils with different residue management treatments are shown in TABLE I. The data indicate that the RP of *Penicillium* varied inversely with depth and averaged higher for all depths in the burn treatment than in the other treatments except the fall plow treatment and it was higher here than in the spring disk treatment. At the 5-cm depth, the RP of *Penicillium* in the fall burn treatment was higher than in the other treatments but not at the 10- and 20-cm depths.

The RP of *Paecilomyces* spp. (TABLE II) averaged higher at 10 cm or 20 cm than at 5 cm. The RP in either of the plow treatments, fall

or spring, averaged lower than in the other residue management treatments. The burn treatment had no effect on the RP of *Paecilomyces* compared to the other treatments at any depth.

The RP of *Phoma* spp. (TABLE III) were higher at 5 cm than at either 10 cm or 20 cm, except in the burn treatment where they did not differ significantly with depth. RP of *Phoma* averaged lower in the burn treatment than in any of the other residue treatments. In the spring treatments, the RP of *Phoma* was lower in the plow than in the disk treatment at the 5-cm soil level.

TABLE III

POPULATIONS OF PHOMA SPP. IN RELATION TO TOTAL FUNGAL POPULATIONS IN A RICE FIELD SOIL BEFORE SPRING FLOODING

Depth	Residue treatment						Average for all residue treatments
	Burn	No burn					
	Fall disk	Spring disk	Spring plow	Fall disk	Fall plow	Rotovate	
(cm)	(Percent *Phoma* of total fungal colonies*)						
5	3.8^{u}	32.3^{s}	22.3^{t}	28.1st	30.9st	24.6st	23.7^{y}
10	4.7^{u}	3.9	10.7	10.2	5.8	6.7	7.0^{z}
20	6.6^{u}	11.6	10.5	11.3	2.2	5.8	8.0^{z}
Average for all soil depths	5.0^{b}	15.9^{a}	14.5^{a}	16.5^{a}	13.0^{a}	12.3^{a}	

* Values with letters of the same group (ab, stu, yz) which are not in common different significantly at 5% level. Least significant differences at 5% level are: Depth interacting with residue treatment 9.6; average effect of depth 3.9; average effect of residue treatment 5.5.

A species of *Mucor* and a species of *Mortierella* which occurred in small but consistent numbers were statistically analyzed together because of their similar characteristics (TABLE IV). Their combined RP averaged higher in the 5- and 10-cm depths than at 20 cm; however, in the fall disk treatment their RP was higher in the 10-cm depth than in either the 5-cm or 20-cm depths and averaged higher in the fall disk than other residue treatments.

Aspergillus groups isolated, which included *A. glaucus, A. wentii, A. niger, A. versicolor, A. terreus,* and *A. flavipes,* in the sensu of Raper and Fennell (**18**), were combined for statistical analysis (TABLE V). Their average RP for each of the residue treatments were not significantly different; however, their RP were higher at 10 cm and 20 cm

TABLE IV

COMBINED POPULATIONS OF MUCOR AND MORTIERELLA IN RELATION TO TOTAL FUNGAL POPULATIONS IN A RICE FIELD SOIL BEFORE SPRING FLOODING

Depth	Residue treatment						Average for all residue treatments
	Burn	No burn					
	Fall disk	Spring disk	Spring plow	Fall disk	Fall plow	Rotovate	
(cm)	(Percent *Mucor* and *Mortierella* in total fungal colonies*)						
5	1.7	1.4	0.8	1.8^{t}	0.8	1.4	1.3^{y}
10	0.0	0.0	1.7	5.5^{s}	0.0	0.0	1.2^{y}
20	0.0	0.0	0.3	0.0^{t}	0.0	0.4	0.1^{z}
Average for all soil depths	0.6^{b}	0.5^{b}	0.9^{b}	2.4^{a}	0.3^{b}	0.6^{b}	

* Values with letters of the same group (ab, st, yz) which are not in common differ significantly at 5% level. Least significant differences at 5% level are: Depth interacting with residue treatment 2.5; average effect of depth 1.0; average effect of residue treatment 1.5.

than at 5 cm except in the spring and fall disk treatments where the RP were highest at the 10-cm level.

All fungi whose RP differed significantly among the residue treatments were averaged for all depths (including those in TABLES I–IV,

TABLE V

POPULATIONS OF ASPERGILLUS SPP. IN RELATION TO TOTAL FUNGAL POPULATIONS IN A RICE FIELD SOIL BEFORE SPRING FLOODING

Depth	Residue treatment						Average for all residue treatments
	Burn	No burn					
	Fall disk	Spring disk	Spring plow	Fall disk	Fall plow	Rotovate	
(cm)	(Percent *Aspergillus* in total fungal colonies*)						
5	0.4	0.4	1.2	0.0	1.1	1.3	0.7^{b}
10	11.3^{tu}	26.8^{s}	4.1^{tu}	14.7^{t}	1.6^{u}	9.9^{tu}	11.4^{a}
20	4.5	6.0^{t}	6.1	3.4	8.2	14.5	7.1^{a}
Average for all soil depths	5.4	11.1	3.8	6.0	3.6	8.5	

* Values with letters of the same group (ab, stu) which are not in common differ significantly at 5% level. Least significant differences at 5% level are: Depth interacting with residue treatment 11.4; average effect of depth 4.7.

TABLE VI

POPULATIONS OF VARIOUS FUNGI IN RELATION TO TOTAL FUNGAL POPULATIONS IN RICE FIELD SOILS WITH DIFFERENT RESIDUE TREATMENTS AVERAGED FROM THREE SOIL DEPTHS (5, 10, AND 20 CM)

Fungi	Burn	Residue treatment				
		No burn				
	Fall disk	Spring disk	Spring plow	Fall disk	Fall plow	Roto-vate
	(Percent of total fungal colonies*)					
Penicillium spp.	41.9[a]	21.7[c]	29.5[bc]	27.0[bc]	34.1[ab]	27.2[bc]
Paecilomyces spp.	22.9[a]	20.2[a]	8.9[b]	15.5[ab]	11.3[b]	21.3[a]
Phoma spp.	5.0[b]	15.9[a]	14.5[a]	16.5[a]	13.0[a]	12.3[a]
Mucor sp. and *Mortierella* sp.	0.6[b]	0.5[b]	0.9[b]	2.4[a]	0.3[b]	0.6[b]
Chaetomium sp.	0.8[b]	0.0[b]	0.3[b]	0.5[b]	6.1[a]	0.1[b]
Unidentified fungus, W26	0.1[b]	0.1[b]	1.0[a]	0.1[b]	0.6[ab]	0.5[ab]
Cephalosporium spp.	2.2[b]	2.0[b]	7.5[a]	5.7[a]	5.5[a]	8.2[a]
Cladosporium spp.	1.9[c]	12.0[ab]	15.5[a]	8.7[b]	3.7[c]	3.4[c]

* Values for each separate fungus without common letters differ significantly at 5% level. No statistical comparisons were made between values of different fungi.

and V) and are grouped for comparison in TABLE VI. Of those fungi not already discussed, the RP of the *Chaetomium* sp. and an unidentified fungus, W-26, were highest in the fall plowed treatment.

TABLE VII

POPULATIONS OF VARIOUS FUNGI IN RELATION TO TOTAL FUNGAL POPULATIONS IN RICE FIELD SOILS AT DIFFERENT DEPTHS AVERAGED FROM SIX DIFFERENT RESIDUE TREATMENTS

Fungi	Depth of soil (cm)		
	5	10	20
	(Percent of total fungal colonies*)		
Penicillium spp.	38.4[x]	29.7[y]	22.5[z]
Paecilomyces spp.	2.9[z]	25.3[y]	21.9[y]
Aspergillus spp.	0.7[z]	11.4[y]	7.1[y]
Mucor sp. and *Mortierella* sp.	1.3[y]	1.2[y]	0.1[z]
Phoma spp.	23.7[y]	7.0[z]	8.0[z]
Penicillium sp. with yellow perithecia	0.0[z]	2.5[z]	5.6[y]
Stachbotrys atra Corda	0.0[z]	0.5[yz]	1.5[y]
Unidentified fungus W40	0.7[z]	0.9[z]	2.8[y]
Cephalosporium spp.	7.3[y]	4.6[z]	2.5[z]
Cladosporium spp.	12.4[y]	3.7[z]	6.4[z]

* Values for each separate fungus without common letters differ significantly at 5% level. No statistical comparisons were made between values of different fungi.

The RP of *Cephalosporium* spp. were highest in all but the fall burn and spring disk treatments while those of *Cladosporium* spp. were highest in the two spring incorporation treatments.

All fungi which showed significant differences in RP at different soil depths were averaged for all residue treatments and are grouped together for comparison in TABLE VII). The data in TABLE VII indicate that the RP of *Penicillium* spp., the *Mucor* and *Mortierella* spp., *Phoma* spp., *Cephalopsorium* spp., and *Cladosporium* spp. were higher in the upper soil levels while those of *Paecilomyces* spp., *Aspergillus* spp., *Penicillium* sp. with yellow perithecia, *Stachybotrys atra,* and an unidentified fungus, W40, were higher at the lower soil levels.

Bacteria and actinomycetes were not separated by genus or species, and their populations are expressed in TABLES VIII and IX as total number of colonies per g of over-dry soil. The results indicate that both groups were unaffected by the different residue management practices but differed significantly at the various soil depths sampled. The numbers of bacteria detected were inversely related to soil depth while actinomycetes were higher in the 10-cm depth than either the 5- or 20-cm depths.

Sclerotium oryzae was consistently isolated from the soil in all the various tillage treatments included in the study by use of the method described by Krause and Webster (13). Viability tests of sclerotia obtained from the various depths sampled revealed that the majority of viable sclerotia occurred in the top 1–10 cm. Extensive studies are underway to determine which if any of the fungi reported in the present study influence the differences in viable sclerotia at the various depths

TABLE VIII

POPULATIONS OF BACTERIA AND ACTINOMYCETES IN A RICE FIELD SOIL WITH DIFFERENT RESIDUE TREATMENTS AVERAGED FOR THREE SOIL DEPTHS (5, 10, AND 20 CM)

Organisms	Burn	Residue treatment				
		No burn				
	Fall disk	Spring disk	Spring plow	Fall disk	Fall plow	Rotovate
		($\times 10^6$ colonies per g of dry soil*)				
Bacteria	5.5	4.9	3.5	4.3	4.2	5.9
Actinomycetes	0.10	0.15	0.17	0.13	0.12	0.20

* Neither group of organisms differed significantly among the different treatments.

TABLE IX

POPULATIONS OF BACTERIA AND ACTINOMYCETES IN A RICE FIELD SOIL AT DIFFERENT DEPTHS AVERAGED FOR SIX DIFFERENT RESIDUE TREATMENTS

Organisms	Depth of soil (cm)		
	5	10	20
	($\times 10^6$ colonies per g of dry soil*)		
Bacteria	8.0[x]	5.2[y]	0.9[z]
Actinomycetes	0.09[b]	0.33[a]	0.02[b]

* Values with letters of the same group (abc, xyz) which are not the same differ significantly at 5% level.

observed. If so the information reported here on effects of tillage methods on RP of rice soil microflora might be exploited in minimizing *S. oryzae* inoculum levels.

DISCUSSION

The soil dilution plate method permits detection of primarily the dominant fungi. Those with fewer propagules than 10,000 per g of dry soil sampled at 5-cm depth were found only occasionally. Nevertheless, there were many such fungi detected and it would seem likely that they would show significant relationships to each other in low soil dilutions on media which selected against such dominant fungi as were found at high soil dilutions.

Penicillium spp. were generally the most numerous of any of the fungi found on the soil dilution plates. Some authors (4, 22) consider that colony numbers detected with this method reflect sporulation ability instead of relative activity in the soil. However, the evidence reported here shows that a highly significant quantitative relationship exists between *Penicillium* and the soil environment and therefore the method of detection must indeed be sensitive to differences in the levels of activity of *Penicillium* resulting from differences in the environment. Both *Cladosporium* and *Cephalosporium* spp. are also prolific sporulators but their numbers are not as high on the soil dilution plates as *Penicillium*.

Generally, the *Penicillium* spp. seemed to make up a smaller proportion of the fungal flora in soil when high amounts of undecomposed straw were present and when soil aeration was low. For example, their RP was highest in the 5-cm horizon where the straw was burned

and lower in the 20-cm horizon where the straw was plowed down in the spring and the 10-cm horizon where the straw was disked down in the spring, but only a few weeks before sampling. According to the principles postulated by Watson and Ford (23), Jackson (10) and Baker (1), the stimulatory factors of fresh organic matter or decomposition products resulting from primary colonizing fungi (5) caused increased activity of other fungi whose metabolites acted sufficiently fungistatic on *Penicillium* spp. to reduce their activity or to prevent them from increasing proportionately to those stimulated. It also appeared that quality of the soil atmosphere affected *Penicillium* either by being increasingly unfavorable when further from the influence of the ambient air or by being more favorable to other fungi whose metabolites adversely affected *Penicillium,* hence the balance of stimulatory and inhibitory factors described by Watson and Ford (23).

Among those fungi that were stimulated by the influence of the organic matter were *Phoma* spp. that showed nearly a tenfold increase in all nonburn treatments over the treatment where the straw was burned. Mucorales were stimulated by only the fresh, unweathered straw which was disked down in the fall. *Cladosporium* spp. were also much higher in the nonburn than in the burn plots.

Some fungi appeared less influenced by the presence of organic matter than by the depth of the soil and by the tillage methods. Populations of nonmonophialidic *Paecilomyces* were generally ca. tenfold higher at the 10- and 20-cm depths than at 5 cm but were significantly lower at the 10-cm level in each plow treatment, which left the soil rough and open, than in any of the other treatments at that level. The responses of *Paecilomyces* spp. to these conditions of depth and tillage suggest that they thrive in a soil atmosphere with a higher ratio of CO_2 to O_2 than usually found in shallower soil depths, or they are less inhibited in deeper soils due to lower levels of activity of *Penicillium* or other microorganisms. On the other hand, *Aspergillus* spp. seemed to react oppositely to *Penicillium* spp. in regard to both soil atmosphere and organic matter levels. Generally, *Asperigillus* spp. were tenfold or more higher in the two deeper soil levels; however, in the spring disk treatment where aeration should be less than in surface soil and with fresh organic matter present their numbers accounted for better than one fourth of the total fungal population.

From various reports in the literature (7, 8, 19) we expected to find close correlations between organic matter content and populations of bacteria and actinomycetes, but this was not the case. Their numbers were statistically very similar in all treatments but significantly affected

by soil depth. Perhaps, the presence of large quantities of monosaccharides in the green crop residues reported in the cited literature provide a substrate which these organisms preferred. Also, the lack of nitrogen in straw could have been a limiting factor to microbial development.

The evidence presented here indicates that populations of fungi in rice field soils can be changed in relation to each other by rice straw incorporation and by the time and method of postharvest tillage. Should further study reveal that the activity of certain microorganisms are antagonistic to sclerotia of *Sclerotium oryzae,* this information should provide guide lines for developing cultural practices which could reduce the incidence of stem rot disease of rice.

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