Published January, 1977

Decomposition of Rice Straw in Soils as Affected by Some Management Factors[1]

Pritam Sain and F. E. Broadbent[2]

ABSTRACT

Decomposition of rice straw contained in nylon bags was measured in field experiments at two different locations during winter and spring months. Incorporated straw decomposed more rapidly than did straw on the soil surface, and least decomposition occurred in straw samples suspended above the soil surface as in a windrow. Decomposition rates were not affected by chopping straw.

Laboratory decomposition experiments conducted at 8 and 25C and at 60 and 150% water holding capacity showed more effect of low temperature in retarding straw decomposition than excess water. Additional nitrogen stimulated straw decomposition in Stockton adobe clay during the first few weeks but had little effect in Sacramento clay. After 2 months' initial decomposition the soil samples treated with straw were dried and rewetted to 60% water holding capacity (WHC), then incubated another 2 months. During this period straw decomposition in Sacramento clay samples which had received additional N was significantly depressed. Additional P and S had no effect on rice straw decomposition.

Additional Index Words: nitrogen, phosphorus, sulfur, particle size.

The practice of open burning of agricultural wastes is becoming unpopular due to air pollution considerations. As a result, there is a need to turn to alternative means of disposal. The choice of method will vary from place to place, depending upon soil, climate, and management factors. Decomposition of crop residues in soil always occurs to some degree, whether by intent or otherwise. Particularly in the case of very bulky residues which are difficult to incorporate, some of the material will remain at or above the soil surface even after attempts at incorporation by use of tillage implements, and in this situation will be subject to wide variations in temperature and moisture. The relationship between relative humidity and straw moisture required for decomposition has been given in a previous publication (12). Incorporated materials, on the other hand, are much less subject to such fluctuations and are likely to sustain environmental conditions favorable to microbial activity on a more continuous basis. Greater decomposition of incorporated residues as compared to those left on the soil surface has been reported by various investigators (2, 11, 13) under field conditions. However, under laboratory conditions Gooding and McCalla (5) and Epstein (4) reported little difference in decomposition rates of various crop residues whether mixed with soil or placed on the soil surface.

One way of facilitating incorporation of bulky residues and improving the degree of contact between residues and soil where materials are left on the surface is to chop or shred the residues. Little work has been reported regarding the effect of particle size on decomposition of crop residues. Maas and Adamson (9) reported that particle size was not an important factor in the rate of decomposition of bark, sawdusts, and saphagnum peats.

Since mature crop residues typically have low N contents, the rate of their decomposition may be limited by a deficiency of this element. The role of N in straw decomposition has been extensively investigated. The reviews of Harmsen and Van Schreven (7) and of Allison (1) present the classical concepts relating carbon-nitrogen ratios to plant material decomposition. Smith and Douglas (14) found that addition of N did not accelerate decomposition when soil N was high, but when a large amount of straw remained from a crop low in residual N, additional N increased the rate of decomposition. Lueken et al. (8) found that addition of mineral N increased the initial rate of decomposition of straw, but in the more advanced stage of decomposition the reverse was true. Greb et al. (6) observed no effect of N applications during the crop season on straw accumulation.

Less work has been done showing the effects of other nutrient elements on straw decomposition. Stotzky and Norman (17) concluded that microbial activity would not be inhibited by S deficiency at C/S ratios < 900. However, Stewart and Whitfield (16) observed a yield depression in winter wheat (*Triticum aestivum* L.) grown in a greenhouse as a result of incorporation of straw with a C/S ratio of 350. Stewart et al. (15) found that the S content of straws should exceed 0.15% in order to achieve a maximum rate of decomposition. Increases in the rate of decomposition resulting from P addition have been reported by Chang (3), Stotzky and Norman (17), and Zayed et al. (18). However, McCalla (10) found a reduction in decomposition of *Carex filifolia* by the addition of phosphate.

This paper reports the results relating placement and particle size of rice straw to decomposition in the field. Also described are laboratory studies designed to measure effects of additions of N, P, and S to soils at two moisture contents on decomposition rates of added rice straw.

EXPERIMENTAL PROCEDURE

Field Experiment

Rice (*Oryza sativa*) straw was collected just after harvest of the grain, dried immediately, and chopped in two sizes: (i) coarse (15-20 cm) and (ii) fine (1-4 cm). About 25-g samples of the straw were placed in coarse weave 15 by 23 cm nylon bags and weighed. The nylon bags were labelled, closed at the ends with nylon thread, and placed inside cheesecloth bags of similar size to prevent soil from adhering to the nylon bags. The bags were placed in the field at two sites, one on Myers clay at the UCD (University of California, Davis) Experimental Rice Facility near Davis, California, and the other on Sacramento clay in a commercial rice grower's field designated as Landing Farms near Knight's Landing. Some physicochemical properties of the soils are listed in Table 1. The straw samples were put in place 20-21 Nov. 1972. One-third of the bags were supported 15 cm above the soil surface using thin galvanized wires to simulate the condition of straw left in windrows or of stubble above the soil surface, one-third were placed on the soil

---

[1] Contribution from the Dep. of Land, Air, and Water Resour., Univ. of California, Davis, CA 95616. Received 25 May 1976.

[2] Former Research Assistant and Professor of Soil Microbiology, respectively.

surface, and the remaining one-third were burried about 15 cm below the surface. Four bags of the straw sample placed under each method of placement at the two sites were removed nearly once a month until the last sampling on 18 Apr. 1973. The samples were dried and weighed. In spite of the double bagging procedure the surface and buried samples were contaminated with soil and had to be gently washed before drying. At each site hygrothermographs were installed 30 cm above the soil surface and records of temperature and relative humidity obtained throughout the experiment.

Two parts of a straw sample, one chopped and the other as shredded, 15-20 cm in length were taken in nylon bags as described above. The straw samples were buried at 15 cm below the soil surface in Myers clay at UCD site. The samples were taken out after 148 days on 18 Apr. 1973 and were gently washed, dried, and weighed again.

Laboratory Decomposition Experiments

Triplicate 50-g samples of Stockton adobe clay and Sacramento clay soils were placed in 250-ml glass jars and 0.5 g of ground rice straw was mixed with the soil. Treatments were as follows:

1) Soil alone.	Both soils
2) Soil + 5 mg N as urea.	
3) Soil + 1% rice straw (0.5 g).	
4) Soil + 1% rice straw + 5 mg N.	
5) Soil + 1% rice straw + 1.5 mg P as $CaHPO_4$.	Sacramento clay
6) Soil + 1% rice straw + 1.5 mg S as K_2SO_4.	
7) Soil + 1% rice straw + 1.5 mg P + 1.5 mg S.	

Additional water was added to provide 60% and 150% of the water holding capacity (WHC) as two moisture treatments for both soils. Each bottle contained a small beaker suspended from the stopper which contained 3 ml of 1*N* NaOH solution and a filter paper wick. At frequent intervals of time based on the rate of carbon loss, the NaOH was changed so as to avoid excessive depletion of the oxygen in the closed flasks, and the collected CO_2 determined by precipitation of the carbonate with $BaCl_2$ and titration of the unused alkali with standard acid. The experiment was carried simultaneously for 2 months at 8 and 25C. The effect of altered environmental conditions of increased temperature and decreased moisture level in soils commonly observed after winter on the decomposition of rice straw was observed. The samples were freeze dried so as to have a minimum effect on its biochemical properties and then rewetted to 60% WHC and incubated at 25C for an additional 2 months.

RESULTS

Field Experiment

Precipitation and relative humidity data at UCD and Landing Farms during the period of straw decomposition are presented in Table 2 and mean weekly air temperatures are given in Fig. 1. Precipitation was 4.1 cm greater at Landing Farms than at UCD. Relative humidities were above 90% about 46% of the time at UCD and 50% of the time at Landing Farms, and were between 80 and 90% about 14% of the time at both locations. The significance of these values is that straw exposed to the air would absorb moisture from the atmosphere at humidities above 80%, but it must be remembered that prolonged exposure to high humidity is required in order for the straw to reach a moisture content permitting microbial decomposition. Mean air temperatures were similar at both locations (Fig. 1).

Table 1—Physico-chemical characteristics of soils used in laboratory experiments

Soil	Carbon	Nitrogen	C-N ratio	Available P	SO_4 -S	Water holding capacity at saturation	Clay	Silt	Sand
	—— % ——			— ppm ——		—————— % ——————			
Sacramento clay	1.73	0.16	11.0	63.0	23	68	65	30	5
Stockton adobe clay	1.05	0.08	12.5	15.4	46	53	35	44	21

Table 2—Moisture data in the field during the period of rice straw decomposition (1972-73)

	Duration					
	20 Nov.- 4 Dec.	4 Dec.- 4 Jan.	4 Jan.- 8 Feb.	8 Feb.- 12 Mar.	12 Mar.- 18 Apr.	
	Sampling no.					
	I	II	II	IV	V	Total
			UCD Site			
Precipitation, cm	0.20	5.33	26.57	12.47	3.76	48.34
Hours of relative humidity						
80-90%	61	48	127	161	97	494
>90%	197	362	493	343	240	1,635
			Landing Farms			
Duration	21 Nov.- 5 Dec.	5 Dec.- 5 Jan.	5 Jan.- 9 Feb.	9 Feb.- 13 Mar.	13 Mar.- 18 Apr.	Total
Precipitation, cm	0.30	5.66	29.34	12.75	4.42	52.48
Hours of relative humidity						
80-90%	90	89	139	103	89	510
>90%	124	367	523	470	297	1,781

EFFECT OF METHOD OF PLACEMENT

The decomposition rates of rice straw samples in nylon bags as affected by method of placement are presented in Fig. 2 and 3 for the two locations. Decomposition rates followed the order: incorporated > on the surface > above the surface. Each treatment was found to be significantly different from the others using Duncan's multiple range test. A sharp increase in the rate of the straw decomposition was found after 12 Mar. 1973 at both the locations especially when the straw was placed below the surface of the soil, probably as a result of rapidly increasing temperature.

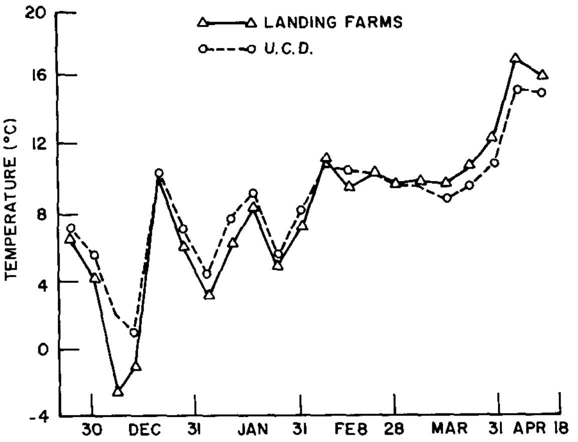

Fig. 1—Mean weekly air temperatures during the period of measurement of straw decomposition at two sites.

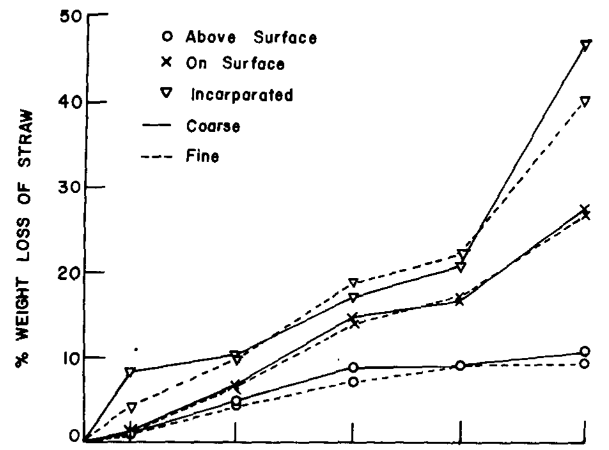

Fig. 2—Weight loss of rice straw at UCD site, Myers clay soil.

EFFECT OF PARTICLE SIZE

In Myers clay (Fig. 2), straw segmented into 15-20 cm lengths decomposed more rapidly after 12 Mar. 1973 than shorter pieces of 1-4 cm in length in samples incorporated 15 cm under the soil surface, probably due to better aeration of the coarser material. However, the results were not consistent for the entire period of straw decomposition. No difference was observed due to particle size in samples placed on or above the soil surface.

In Sacramento clay (Fig. 3), particle size of the straw showed little effect on decomposition as observed at the end of 148 days on 18 Apr. 1973, although higher decomposition was observed earlier with straw 15-20 cm in length compared to 1-4 cm size, again probably due to better aeration of the coarser material.

The results from a field experiment conducted in Myers clay at UCD to compare chopping vs. shredding rice straw on its decomposition showed 32.1% loss with chopped straw and 28.3% when it was shredded. The difference was statistically significant ($P \leqslant 0.05$).

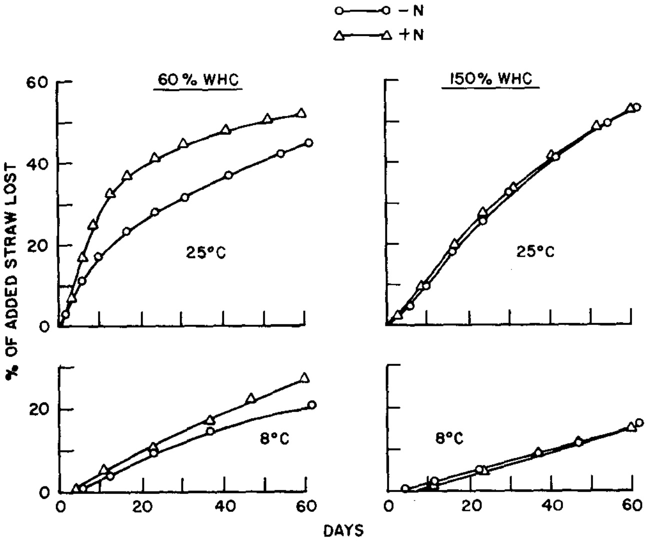

Fig. 4—Decomposition of rice straw in Stockton adobe clay as affected by temperature, moisture content, and added N.

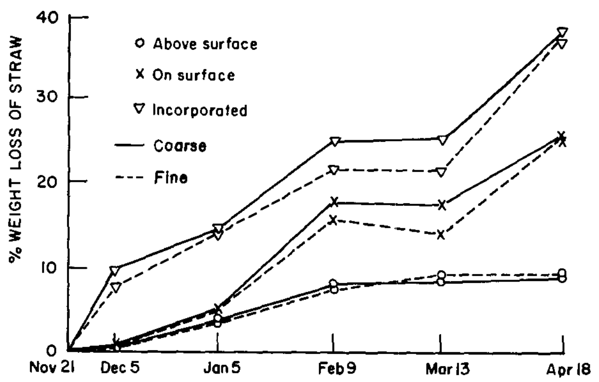

Fig. 3—Weight loss of rice straw at Landing Farms site, Sacramento clay soil.

EFFECT OF LOCATION

The difference in the decomposition of the rice straw between the two locations can be clearly observed by comparing Fig. 2 and 3. The data show a significant difference between locations when the straw was placed 15 cm below the soil surface. The decomposition of the straw up to 31 Mar. 1973 in Sacramento clay at Landing Farms was more rapid than in Myers clay at UCD, but on 18 Apr. 1973 the reverse was true. In Myers clay, 46.9% of the incorporated rice straw was lost after 149 days compared to 38.2% after 148 days in Sacramento clay. Smaller differences were observed with the finer particle size straw: 40.3% loss in Myers clay vs. 37.5% in Sacramento clay. Average rates of percent decomposition after 12 Mar. 1973 were 0.87 and 0.44 per day in Myers clay at UCD and in Sacramento clay at Landing Farms, respectively, accounting for 55.6 and 33.5% of the total decomposition. On the other hand, the rate of straw decomposition was lowest during the period between 8 February and 12 March at both locations, although this was not the period of minimum air temperature.

Laboratory Decomposition Experiments

Application of N significantly increased the rate and extent of C loss during the first 62 days when the Stockton adobe clay samples with added straw were incubated

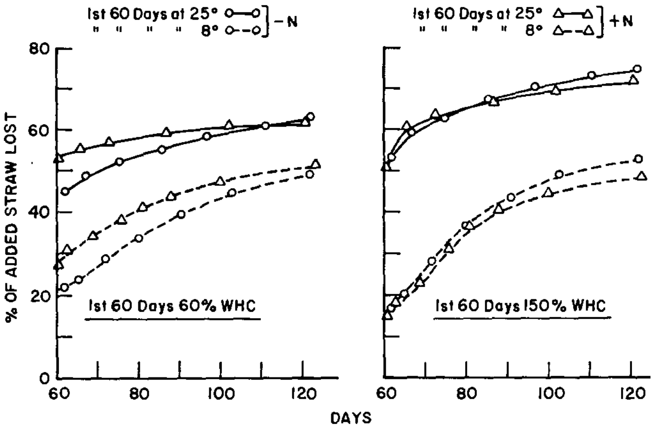

Fig. 5—Decomposition of rice straw in Stockton adobe clay after preincubation for 60 days under various conditions.

Table 3—Effect of P and S on rice straw decomposition in Sacramento clay at 25C

Moisture level	Treatment	4	10	20	34	51	62
		carbon loss, mg					
60% WHC	Soil alone	12.2	22.4	32.4	45.2	56.7	62.5
	Soil + P	12.5	23.3	33.9	46.0	58.0	64.1
	Soil + S	12.4	22.7	32.8	44.4	55.3	61.0
	Soil + P + S	12.5	23.1	34.0	46.0	57.5	63.4
150% WHC	Soil alone	3.4	12.8	25.4	38.4	49.7	55.2
	Soil + P	3.5	13.3	26.0	39.2	50.4	56.1
	Soil + S	3.4	13.4	25.9	39.2	51.2	57.1
	Soil + P + S	3.5	13.3	26.0	39.3	51.4	57.1

(Column headers 4–62: Time in days)

at 60% WHC (Fig. 4), probably due to greater multiplication and growth of the various microorganisms. However, little response was observed at 150% WHC. After drying and incubating at 60% WHC, the rate of C loss presented in Fig. 5 was lower with added N than without. At the end of the total incubation period (120 days), C loss was the same with and without added N. In Stockton adobe clay samples, total C loss at the end of 60 days of the second period was slightly lower with added N (Fig. 5). In Sacramento clay (Fig. 6) no differences due to N were observed at 60% WHC up to about 3 weeks; thereafter losses were slightly lower with added N than without. The effect of excess water on decomposition was more pronounced in this soil than in the Stockton soil. After drying and rewetting to 60% WHC C loss from Sacramento clay during the following 2 months was lower in all samples where N was added (Fig. 7).

Results of the P and S treatments are presented in Table 3. No significant differences in CO_2 production resulted from addition of these elements. The soil used in the experiment contained adequate P and S for crop growth, so it is not surprising that microbial requirements for these nutrients were also sufficient.

DISCUSSION

Some of the difficulties attending rice residue management are associated with the bulky nature of the residues and possible slow rates of decomposition in soils which are often both cold and wet in the interval between harvest and planting of the next crop. The slow rate of decomposition of residues above the soil surface as in stubble or windrow is due primarily to the fact that it is dry much of the time. Periods of high relative humidity in the California climate are not of sufficiently long duration to attain moisture levels required for active microbial activity. Contact with the soil surface makes residues more amenable to decomposition, but incorporation is better yet, even though oxygen may be excluded part of the time.

Rice straw decomposition may be accelerated by addition of N, but as a management practice this cannot be recommended unless another crop is planted soon after residue incorporation, since the degree of decomposition which occurred over a 4-month time period was in these experiments unaffected by addition of N, even in cases where a stimulatory effect was observed during the first few weeks. Sufficient decomposition occurred during a few weeks of relative favorable conditions to compensate for several weeks of low temperature and high moisture content. In this connection it may be noted that low temperature influenced decomposition rate more than did excessive moisture.

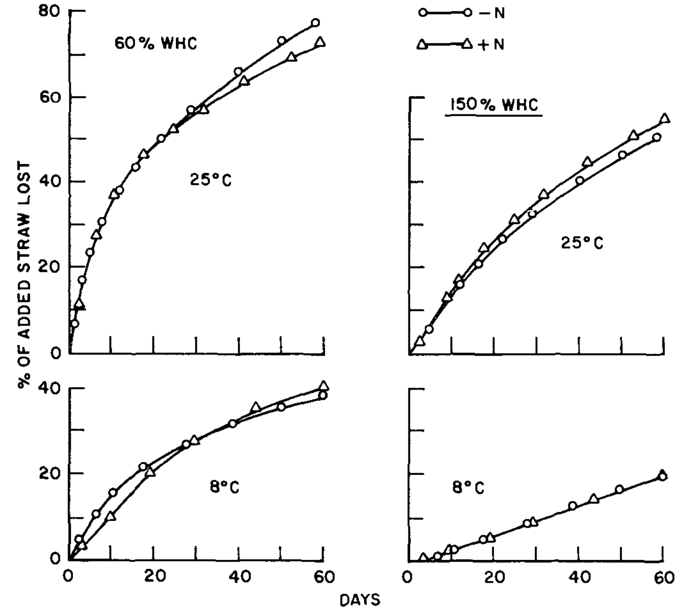

Fig. 6—Decomposition of rice straw in Sacramento clay as affected by temperature, moisture content, and added N.

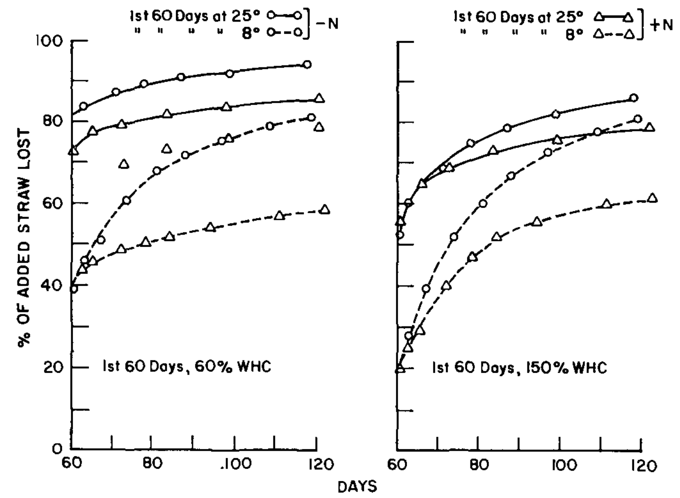

Fig. 7—Decomposition of rice straw in Sacramento clay after preincubation for 60 days under various conditions.

Chopping straw was not found to exert a beneficial effect on decomposition rates in these controlled experiments, but it should be pointed out that in field practice chopping or shredding straw permits better contact between residues and the soil surface, which would permit more rapid decomposition to occur.

LITERATURE CITED

1. Allison, F. E. 1966. The fate of nitrogen applied to soil. Adv. Agron. 18:219-258.
2. Brown, P. L., and D. D. Dickey. 1970. Losses of wheat straw residues under simulated field conditions. Soil Sci. Soc. Am.

Proc. 34:118-121.

3. Chang, S. C. 1940. Assimilation of phosphorus by mixed soil populations and by pure cultures of soil fungi. Soil Sci. 49: 197-202.
4. Epstein, E. 1956. The effect of organic matter on soil aeration with particular reference to nutrient uptake by plants. Ph.D. Thesis. Purdue Univ., West Lafayette, Ind. Diss. Abstr. 16:841.
5. Gooding, T. H., and T. M. McCalla. 1945. Loss of carbon dioxide and ammonia from crop residues during decomposition. Soil Sci. Soc. Am. Proc. 10:185-190.
6. Greb, B. W., A. L. Black, and D. E. Smika. 1974. Straw build up in soil stubble mulch fallow in the semiarid Great Plains. Soil Sci. Soc. Am. Proc. 38:141-166.
7. Harmsen, G. W., and D. A. Van Schreven. 1965. Mineralization of organic nitrogen in soil. Adv. Agron. 7:299-398.
8. Lueken, H., W. L. Hutcheon, and E. A. Paul. 1962. The influence of nitrogen on the decomposition of crop residues in the soil. Can. J. Soil Sci. 42:276-288.
9. Maas, F. E., and R. M. Adamson. 1972. Resistance of sawdusts, peats, and bark to decomposition in the presence of soil and nutrient solution. Soil Sci. Soc. Am. Proc. 36:769-772.
10. McCalla, T. M. 1948. The decomposition of *Carex filifolia.* Soil Sci. Soc. Am. Proc. 13:284-286.
11. Parker, D. T. 1962. Decomposition in the field of buried and surface applied cornstalk residue. Soil Sci. Soc. Am. Proc. 26:559-562.
12. Sain, P., and F. E. Broadbent. 1975. Moisture absorption, mold growth, and decomposition of rice straw at different relative humidities. Agron. J. 67:759-762.
13. Shields, J. A., and E. A. Paul. 1973. Decomposition of ^{14}C-labelled plant material under field conditions. Can. J. Soil Sci. 53:297-306.
14. Smith, J. H., and C. L. Douglas. 1971. Wheat straw decomposition in the field. Soil Sci. Soc. Am. Proc. 109:341-344.
15. Stewart, B. A., L. K. Porter, and F. G. Viets, Jr. 1966. Effect of sulfur content of straws on rates of decomposition and plant growth. Soil Sci. Soc. Am. Proc. 30:355-358.
16. Stewart, B. A., and C. J. Whitfield. 1965. Effect of crop residue, soil temperature, and sulfur on the growth of winter wheat. Soil Sci. Soc. Am. Proc. 29:752-755.
17. Stotzky, G., and A. G. Norman. 1961. Factors limiting microbial activities in soil. II. The effect of sulfur. Arch. Mikrobiol. 40:370-382.
18. Zayed, M. N., S. M. Taha, and M. A. Azazy. 1971. Bacteriological and chemical studies in rice straw compost. V. Effect of phosphorus. Zentralbl. Bakteriol. Parastenkd. Abt. 2. 126:678-686.