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Green Manuring and Crop Residue Management in Rice Production[1]

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ABSTRACT

A series of field experiments were conducted to determine the nature of the effects of green manures and rice crop residue management on lowland rice production. Winter leguminous green manure was determined to be an inexpensive, efficient source of nitrogen which fits in well with continuous rice culture in the Mediterranean type climate of California. The marked response of rice to leguminous green manure was duplicated, for the most part, by inorganic nitrogen applications when properly placed in the reducing zone of the rice soil.

Leguminous green manure served to add nitrogen to the highly carbonaceous rice crop residues. This permits decomposition to proceed without tying-up nitrogen needed by the subsequent crop, and provides a satisfactory alternative to the deleterious practice of burning the residues.

The utilization of inorganic sources of nitrogen by the rice plant, *Oryza sativa* L., has been investigated by numerous workers, and the efficient use of ammonia forms has been repeatedly demonstrated (see (4) for a recent review). Although the use of organic nitrogen is common in other parts of the world (3, 4, 7, 9) relatively few references to the utilization of green manure as a source of nitrogen appear in the literature on rice culture in the western hemisphere (1, 2, 6). In California rice culture, the use of organic nitrogen in the form of a leguminous green manure has become a common commercial practice during the past decade. It is reliably estimated[3] that 21% of the 336,000 acres planted to rice in 1955 in California followed a green manure crop of purple vetch, *Vicia atropurpurea* Desf., or common vetch, *V. sativa* L. A series of field experiments were initiated in 1952 to determine the nature of the effects of green manures on rice production in comparison with inorganic nitrogen applications.

Another factor which has merited attention in rice culture is the method of handling rice straw and stubble as it affects long-term soil productivity. The common practice of burning rice residues has resulted from the difficulty of spreading the abundant wet straw uniformly at harvest time, the difficulty of incorporating large quantities in seedbed preparation, the slowness of decomposition of the highly carbonaceous residue, and the resulting yield depression in instances of incorporation without enough supplemental nitrogen to prevent nitrogen tie-up. Studies of this problem have been under way since 1940. Progress in these two lines of investigation of soil management in rice culture are reported here.

EXPERIMENTAL PROCEDURE

These experiments were performed at the Rice Experiment Station in the Sacramento Valley, California, on Stockton clay. This soil is dark gray color with an exchange capacity of 28.7 me. per 100 g. and pH 5.3. It is representative of the clay soils in a large part of the rice-growing area of California.

Green manure experiments.—The first experiment was initiated by drilling 10 strips of purple vetch 20 by 150 feet at the rate of 44 pounds of seed per acre on September

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[3]A composite of estimates by Agricultural Extension Service personnel in the rice-growing counties of California.

25, 1952. The plots were irrigated once to germinate the vetch. Paired strips remained unplanted as controls. This field had been cropped to rice in the preceding odd years and was idle in the even years. The vetch was turned under in mid-April and Calrose rice planted at the rate of 150 pounds per acre in early May. A uniform application of 30 pounds of nitrogen per acre as ammonium sulfate was made on all plots at planting time. A 12 by 112 foot strip was harvested with a combine from each plot for rice yield on November 3, 1953. Rice was again planted on these plots in 1954, but no green manure crop was planted for the winter season of 1953-54. On September 24, 1954 purple vetch was broadcast at the rate of 40 pounds per acre on the same plots as in 1952, as the water was being drained from the standing rice prior to harvest. A random 4 by 4 foot quadrat was harvested from each plot on May 5, 1955 for the determination of dry matter production and nitrogen content of the green manure. Rice was broadcast seeded on May 12, 1955. Ammonium sulfate fertilizer was applied to five of the replications in a split-plot design with green manure treatments as subplots. The application consisted of 30 pounds of nitrogen per acre broadcast on the soil surface. The rice was harvested on September 30, 1955 by the method previously indicated.

In the second experiment strips 20 by 200 feet of purple vetch and Pacific Bluestem 37 wheat, *Triticum vulgare* L., were broadcast in 6 replications in a field of Colusa rice as the water was being drained on September 25, 1953. Unplanted strips were left as controls. The green manure strips were sampled for dry matter yield and nitrogen content on April 23, 1954 by harvesting a 2.83 by 30 foot strip in each plot. Rice was planted on May 31, 1954. On the same day 30 pounds of nitrogen per acre was broadcast in blocks over half of each replication of green manure treatments, the latter being sub-unit treatments in strips in a split plot design. The rice was harvested on November 11, 1954 from strips 12 by 81 feet in each subplot. The green manure strips were planted again on September 24, 1954 as the water was being drained. Quadrats were harvested from the green manure plots on May 5, 1955. Rice was planted and fertilized on May 12 and 13, 1955 following incorporation of the green manure crops as in the previous year. The rice was harvested on September 30, 1955.

Green manure and fertilizer placement experiment.—In this experiment a randomized block design was used with 6 replications of 5 treatments on plots 10 by 30 feet. The treatments consisted of 30 pounds of nitrogen per acre applied as follows: (*a*) broadcast on the soil surface as ammonium sulfate, (*b*) drilled 4 inches deep as ammonium sulfate, (*c*) as purple vetch tops containing 4.24% nitrogen on a dry basis disked once, and (*d*) same as (*c*) except disked twice. Unfertilized plots served as controls. The vetch was cut from an adjacent ranch and applied fresh on April 9, 1955, but inclement weather interfered with the application of the fertilizer and broadcasting of Caloro rice until May 10 and 13, 1955, respectively. The plots were harvested for yield on September 28, 1955.

Rice residue management experiment.[4]—In this experiment Caloro rice was planted on odd numbered years and the land lay idle on the alternate years. The rice crops were cut with a binder at the usual binder height and the straw returned to the plots at the rate of 3,000 pounds per acre immediately after the harvest. The treatments consisted of straw applied alone, the use of ammonium sulfate and superphosphate separately and together, with the straw. Another treatment was straw applied and burned prior to plowing. Plots which received no straw served as controls. These treatments were established in triplicate on plots 33 by 132 feet. The treatments were repeated 5 times during the years 1940 and 1949. The ammonium sulfate was applied at the rate of 100 pounds per acre in 1941 and 150 pounds per acre for each succeeding crop. Single superphosphate was applied at the rate of 300 pounds per acre in 1941 and treble superphosphate was applied at the rate of 120 pounds in 1943 and 1945, and 400 pounds in 1947 and 1949.

All rice yields are paddy rice corrected to 14% moisture. All green manure data are reported on a dry basis.

[4]The aid of Mr. A. H. Williams in conducting this experiment from 1947 to 1949 is gratefully acknowledged.

Table 1.—Effect of purple vetch winter green manure on the production of Calrose rice.

Treatment	1953 Rice yield	1955 Green manure crop Yield	1955 Green manure crop Nitrogen		1955 Rice yield
	lbs./A.	lbs./A.	%	lbs./A.	lbs./A.
No fertilizer					
Fallow	—	—	—	—	2170
Vetch	—	830	2.94	24	2680
30 lbs. N/A.					
Fallow	2600	—	—	—	2540
Vetch	3700	830	2.94	24	3030
LSD 5%					
Fertilizer	—				450
Green manure	220				320

RESULTS

Green Manure Experiments

The October 1953 rice harvest of the first experiment showed that the vetch green manure had increased yield of paddy rice by 1,100 pounds per acre (table 1). This increase in yield was in addition to that resulting from the application of 30 pounds of nitrogen per acre as ammonium sulfate.

During the growing season the rice plants on the vetch plots were taller and a darker green color than those on the fallow plots. Just prior to heading, tissue samples were collected consisting of the leaf immediately below the flag leaf from approximately 50 plants per plot for chemical analysis. Phosphorus was high in the leaves from the fallow plots and low following vetch, but nitrogen was significantly higher in the leaves from the vetch plots than from the control plots. This evidence indicates that the rice plants were benefited by the improved nitrogen nutrition resulting from the vetch green manure. Apparently the ammonium sulfate application was far below the amount required for optimum nutrition or else it was inefficiently utilized.

Rice was grown on the same plots in 1954 without green manuring, and there were no residual effects evident from the vetch turned under during the spring of 1953.

Soon after draining the field prior to the rice harvest in September 1954, purple vetch was broadcast into the mud on the same plots where vetch was planted 2 years previously. The vetch produced a fair green manure crop without irrigation, the residual moisture from the rice flood water tiding it over until late fall rains arrived. The top growth, 830 pounds of dry matter per acre, turned under the following spring contained 24 pounds of nitrogen per acre (table 1). The green manure improved rice yields by an average of 500 pounds. Thirty pounds of nitrogen per acre as ammonium sulfate, applied just prior to flooding the planted rice, improved rice production an average of 370 pounds per acre. There was no interaction between the fertilizer and the green manure treatments.

In 1953 the second experiment was initiated. Leguminous and non-leguminous green manures were compared with and without inorganic nitrogen being applied to the subsequent rice crop. Pacific Bluestem 37 wheat and purple vetch were sown in the mud prior to the harvest of a uniform crop of Colusa rice in September 1953. A fair crop of green manure was turned under the following spring containing 9 and 26 pounds of nitrogen per acre in the wheat and vetch, respectively (table 2). The vetch green manure improved rice yields by 1,000 pounds per

Table 2.—Effect of wheat and purple vetch as winter green manure on the production of Colusa rice.

Treatment	1954				1955			
	Green manure crop			Rice	Green manure crop			Rice
	Yield	Nitrogen		yield	Yield	Nitrogen		yield
	lbs./A.	%	lbs./A.	lbs./A.	lbs./A.	%	lbs./A.	lbs./A.
No fertilizer								
Fallow	—	—	—	2340	—	—	—	2060
Wheat	900	1.00	9	2710	530	1.65	9	2100
Vetch	910	2.82	26	3340	1250	3.50	44	3040
30 lbs. N/A.								
Fallow	—	—	—	2640	—	—	—	2370
Wheat	900	1.00	9	2890	350	1.54	5	2320
Vetch	910	2.82	26	3670	1260	3.42	43	3350
LSD 5%								
Fertilizer				310				380
Green manure				430				360

Table 3.—Effect of vetch green manure and the placement of inorganic nitrogen on Caloro rice production.

Nitrogen source and placement lbs./A.	Rice yield lbs./A.
Check	3050
30 N as ammonium sulfate broadcast on surface	3440
30 N as ammonium sulfate drilled 4 inches deep	4050
30 N in vetch tops (4.24% N) disked once	4320
30 N in vetch tops (4.24% N) disked twice	4030
LSD 5%	850

acre without inorganic nitrogen and 1,030 pounds with inorganic nitrogen. Wheat improved rice yield an average of 310 pounds per acre. Thirty pounds of nitrogen per acre as ammonium sulfate broadcast on the fertilizer plots just prior to flooding the planted rice improved the rice yield an average of 270 pounds per acre. There was no interaction.

The treatments were repeated in the 1954-55 season. The wheat green manure crop was poorer and the vetch better than the preceding year (table 2). Rice yields followed closely the trend of the previous year except for the wheat green manure treatment, which did not benefit the rice crop in 1955.

Green Manure and Fertilizer Placement Experiment

As a result of these trials, it became evident by the end of the 1954 crop season that leguminous green manure was behaving differently as a source of nitrogen than the inorganic nitrogen fertilizer as the latter has been customarily applied in California. As a result of the work on the placement of nitrogen fertilizer in rice production by Mikkelsen and Finfrock (5) it was postulated that the greater benefit of the organic nitrogen was the result of its incorporation in the zone of reduction in the rice soil. Their studies show that surface-applied ammonia-form fertilizer is low in efficiency because nitrification occurs in the surface zone of oxidation, a thin layer extending 0.5 cm. deep measured from the soil-water interface in a flooded soil. Then the nitrates are leached into the zone of reduction underneath, and subsequently denitrified to gaseous nitrogen, which escapes into the atmosphere. Whereas, ammonia-form fertilizer drilled into the soil prior to flooding is not altered chemically subsequently.

The hypothesis was tested by comparing inorganic nitrogen broadcast on the surface and drilled to a depth of 4 inches with an equivalent amount of nitrogen applied as vetch tops disked in. The rice harvest results in table 3 show that the surface broadcast fertilizer and the green manure treatments performed as in the previous experiments. That is, the efficiency of the surface applied inorganic nitrogen was much lower than that of the nitrogen in the leguminous green manure. However, the yield resulting from the drilled fertilizer closely approached that resulting from the green manure. This shows that the response to vetch green manure in these experiments is mainly a fertility response, and that it can be duplicated, for the most part, by properly placed inorganic nitrogen fertilizer.

Rice Residue Management Experiment

In 1940 an experiment was established to evaluate various methods of handling rice crop residues in alternate-year rice culture in which the land lies idle every other year. These were: burning; three fertilizer treatments including nitrogen, phosphorus, and a combination of the two; and straw left unburned and unfertilized. A sixth treatment was a control to which no straw was returned. These treatments were repeated in the same plots for a total of five rice crops from 1940 to 1949. During the first three crop years no clear trends in yield were apparent except that nitrogen and phosphorus fertilzers improved yield. In 1947 and even more so in 1949 the yield of the burned straw treatment fell below the control (figure 1). The straw alone treatment remained at about par with the no straw control. Apparently the carbonaceous nature of the residue balanced off the benefits of the addition of organic matter. However, when nitrogen and phosphorus fertilizer were added to the straw, yields were increased appreciably. Treatment effects were significant at the 5% level in 1947 and at the 0.1% level in 1949 when definite trends in yield could be ascertained as the experiment was terminated. A better measure of the value of the returned residues would have been obtained had fertilizer treatments been included with no straw and with straw burned.

DISCUSSION

During the past few years under the pressure of rising land values and costs of production, California rice farmers have increasingly switched from alternate rice culture to rice in rotation with other crops and continuous rice. In order to meet this increased draft on the soil, interest in green manure crops and fertilization has heightened. The information obtained in these studies

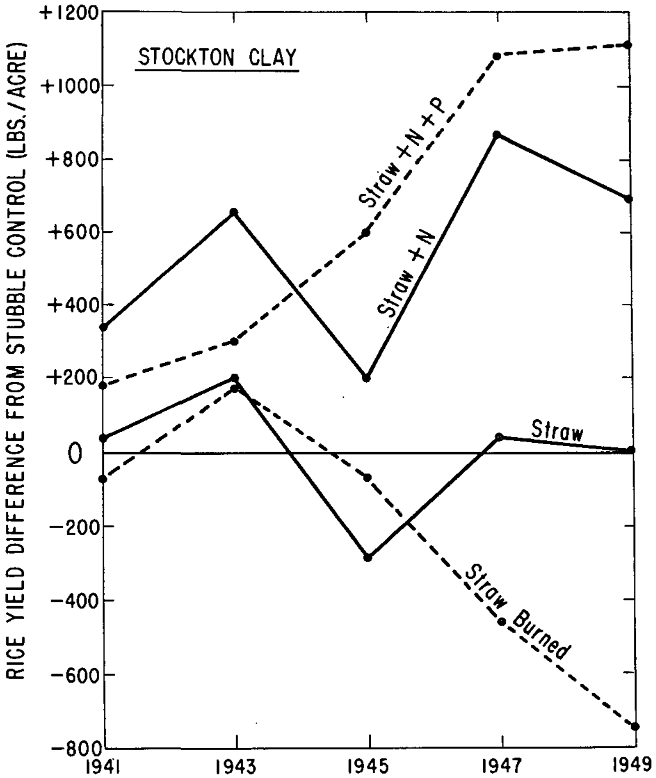

Figure 1.—Effect of rice residue treatment on rice yields.

justifies the increasingly popular practice of growing a vetch crop during the winter between successive annual crops of rice. The economics of this practice are favorable because the costs of the green manure operation are low. They consist of the cost of about 40 pounds per acre of purple or common vetch seed, the cost of airplane seeding into standing rice just after draining for harvest, and the cost of the slight additional power required to turn under the green manure crop during seedbed preparation. The vetch seed normally germinates on the residual moisture from the rice flood water making irrigation unnecessary. Winter rains then sustain the growth of the green manure crop until it is time for incorporation. An added advantage is the earlier drying of soils under a vetch cover permitting timely preparation of the soil for the rice crop. The returns in yield from the leguminuous green manure nitrogen as a result of its placement through incorporation into the reducing zone of the soil are high.

The incorporation of vetch green manure serves to add nitrogen to the highly carbonaceous rice crop residues because of the high nitrogen content of the vetch tops.

Table 4.—Effect of a winter legume on the nitrogen content of the associated rice stubble at the time of green manure incorporation, April 23, 1954.

Green manure treatment	% Nitrogen (dry basis)	
	Green manure crop	Associated rice stubble
Wheat	1.31	0.50
Vetch	3.31	1.72
LSD 5%	0.85	0.38

Furthermore, separation and analysis of vetch and rice stubble mixtures showed that rice residue increased from a value of 0.50% nitrogen to 1.71% from association with vetch (table 4). Apparently rice stubble can remain physiologically active following harvest and accumulate available nitrogen during a mild winter. Thus, growing a leguminous green manure places the conservation of organic matter contained in the rice residue on a more feasible basis. It obviates the often presumed necessity of burning the rice crop residue to prevent the tieup of nitrogen needed by the subsequent crop.

Since amounts of organic matter incorporated in these green manure experiments were fairly small, and the experiments were of short duration, no attempt was made to evaluate their effect on soil structure. However, Reed and Sturgis (8) have shown that large applications of soybean hay to a Louisiana rice soil improved soil structure and rice yields in lysimeter tests. As the current green manure tests are continued, the accumulative effect of successive green manure crops will be assayed in terms of soil physical conditions.

LITERATURE CITED

1. Chambliss, C. E., and Jenkins, J. M. Experiments in rice production in southeastern Louisiana. U.S.D.A. Bul. 1356. 1925.
2. Davis, L. L., and Jones, J. W. Fertilizer experiments with rice in California. U.S.D.A. Tech. Bul. 718. 1940.
3. DeGeus, J. G. Means of increasing rice production. Leiter-Nykels, Maastricht. Netherlands. pp. 143. 1954.
4. Grist, G. H. Rice. Longmans, Green. New York. pp. 331. 1953.
5. Mikkelsen, D. S., and Finfrock, D. C. Availability of ammoniacal nitrogen to lowland rice as influenced by fertilizer placement. Agron. Jour. 49:296-300. 1957.
6. Nelson, M. Effect of the use of winter legumes on yields of cotton, corn, and rice. Arkansas Agr. Exp. Sta. Bul. 451. 1944.
7. Pieters, A. J. Green manuring principles and practice. John Wiley & Sons, Inc., New York. pp. *xiv* + 356. 1927
8. Reed, J. F., and Sturgis, M. B. Chemical characteristics of the soils of the rice area of Louisiana. Louisiana Agr. Exp. Sta. Bul. 307. 1939.
9. Sethi, R. L. Manuring of rice in India. The India Counc. Agr. Res. Bul. 38. 1952.