Vetch Green Manure Increases Rice Yields

. . . proper depth and timing of incorporation allows maximum results

W. A. WILLIAMS · D. C. FINFROCK

Purple vetch produces greater rice yields when turned under 4 to 6 inches than when placed at shallower depths. Shortening the time interval between turning under the vetch and flooding and sowing the rice, also increases yields—when conditions are favorable to nitrification during the preflooding period. When properly incorporated, vetch green manure is equal to mineral sources of ammonium nitrogen in increasing rice yields.

THE USE OF VETCH as a green manure crop prior to the planting of rice is a common practice in California. The vetch, usually purple vetch, *Vicia benghalensis* L. syn. *V. atropurpurea* Desf., is produced during the winter growing season utilizing rainfall moisture, and the rice is grown during the summer season under irrigation with the fields kept flooded continuously. The practice has been highly effective and provides an inexpensive source of nitrogen needed by the rice crop. Similar results have been reported by workers in Asia for many other species, but especially the legumes, used for green manure.

The oxidation status of a rice soil soon after flooding varies in depth from an oxidizing condition at the soil-water interface to a strongly reducing state at a depth of one or more inches. It is likely that this variability affects the green manure decomposition. The oxidative pathway leading to nitrate production causes nitrogen loss because of subsequent denitrification to molecular nitrogen and nitrous oxide in the reducing zone of the flooded soil. The depth of incorporation of leguminous organic matter thus may influence the subsequent path of chemical change of the nitrogen that it contains.

Prior to flooding a field for rice culture, conditions may be favorable for the oxidative processes of organic matter decomposition, aminization, ammonification and nitrification—if soil temperature, moisture, aeration, and other factors are appropriate. Loss of effectiveness of the green-manure nitrogen then becomes a possibility, if the crop is plowed in too far ahead of flooding. Two aspects of vetch crop management, depth and time of incorporation, were studied in field experiments from 1956 to 1959 at the Rice Experiment Station in the Sacramento Valley.

Depth of incorporation

Vetch containing about 4% nitrogen was buried at depths of 1, 2, 4, and 6 inches in plots excavated following seedbed preparation. Thirty pounds of nitrogen were applied this way in 1956 and 40 pounds in 1957 and 1958 in separate experiments. An equal amount of nitrogen in the form of ammonium sulfate was applied as a chemical source for comparison with the organic source of nitrogen. The effectiveness of the vetch applications increased with greater depth of placement in all three years of testing. The 6-inch placement gave an additional yield of 14 cwt per acre in 1956 and 16 cwt per acre in 1957 over the 1-inch placements. In 1958 the 6-inch placement gave a 6 cwt per acre greater yield than the 2-inch placement as shown in Table 1. The net effect of the best vetch treatment was a yield increase of 23 cwt per acre in 1956, 22 cwt per acre in 1957 and 18 cwt per acre in 1958.

When ammonium sulfate was placed at the 2-inch depth, it produced a yield response significantly less than vetch at the best depth in 1957 and slightly (but not significantly) less in 1956. When ammonium sulfate was applied at the 4-inch depth (1958) it duplicated the response from the best green manure treatment depth. Ammonium chloride was also ap-

TABLE 1. EFFECT OF DEPTH OF PLACEMENT OF VETCH ON RICE YIELD

Material and depth*	Rice yield cwt/A.		
	1956	1957	1958
Check	13	34	42
Vetch 1 in.	22	40	..
Vetch 2 in.	32	48	54
Vetch 4 in.	36	52	56
Vetch 6 in.	36	56	60
Am. sulfate 2 in. (4 in. 1958)	34	43	61
Am. chloride 4 in.	..	..	62
LSD 5%	5	9	5

* All treatments except check contained 30 lb./A. nitrogen in 1956 and 40 lb./A. nitrogen in 1957 and 1958. Dates of flooding and sowing were April 8, 1956, May 16, 1957, and May 22, 1958.

plied in 1958 to test the possibility that the sulfate source might be causing near toxic levels of hydrogen sulfide (incipient Akiochi disease) as sometimes occurs on degraded paddy soils in Japan. This appeared not to be the case, because the ammonium chloride application produced about the same rice yield increase as ammonium sulfate or as much as the best vetch treatment that year (1958).

Because previous work has shown that the short-term benefit of a leguminous green manure is largely confined to its nitrogen contribution, the possibility of nitrogen loss under various management practices was considered in this study. It is known that organic matter proceeds by microbiological decomposition through the processes of aminization and ammonification, but not nitrification, under anaerobic conditions obtained after flooding the soil. The ammonium ions thus produced in the reducing zone of a rice soil are a readily usable source of nitrogen to the rice plant. However, the surface of a flooded soil is in an oxidative state, and organic matter decomposition proceeds there with the formation of nitrates. Upon movement down into the reducing zone, the nitrates are microbiologically reduced to molecular nitrogen and nitrous oxide, which escape from the soil. A few days after flooding (4 to 6 days in Stockton clay) the oxidative layer attains an equilibrium depth within ½ inch of the soil surface.

In the present experiments, rice yields indicated that significant nitrogen losses from the vetch applications occurred down to the 4-inch placement depth, although the losses became less with increasing depth of placement. It would appear that appreciable mineralization of vetch occurred at the shallower depths during these experiments in the few days before the reducing zone was established in the plow layer—most markedly at the 1-inch depth. It is inferred that oxidative conditions were maintained there for a longer period than at any of the greater depths of placement.

It is possible that an effect of placement of green manure relative to the feeding zone of the rice root system might be a contributing factor to the lower efficiency of materials placed at shallow depths. However, this is not considered likely to be important, because rice roots are known to feed heavily close to the soil surface. Vetch green manure is most beneficial when well covered during seedbed preparation. Other benefits of good coverage include reduction of scum-forming algae and mosquitoes.

Timing incorporation

Vetch was turned under 4 inches deep every 10 days prior to flooding and sowing in 1957 and 1959, and every seven days in 1958. For comparison, ammonium sulfate was distributed uniformly at the same depth on the day of flooding and sowing. All treatments except the check treatment contained 40 pounds of nitrogen per acre. The experiments were located at a different site each year.

Vetch turned under 30 days prior to flooding and sowing rice in 1957 yielded 19 cwt per acre less than the same treatment applied the same day as flooding and sowing as shown in Table 2. Vetch applied 20 days prior to flooding and sowing yielded 9 cwt per acre less, and vetch applied 10 days prior yielded 4 cwt per acre less (not considered a significant difference). The net gain in rice yield for the vetch applied the day of flooding and planting was 30 cwt per acre. However, there were no response differences due to time of vetch incorporation up to 21 days prior in 1958 and 30 days in 1959, although there was a net response of 15 cwt per acre to the vetch green manure in each of those years.

The moisture condition of the soil and rainfall data help to explain the year-to-year variation in response to different time intervals between incorporation and time of flooding and sowing. In 1957, when decreasing the interval increased the yield response to the vetch so strikingly, the soil was moist throughout the period. Rain fell in nearly equally spaced storms averaging 0.3 inch each and totaling 1.5 inches. In 1958, 0.3 inch fell and in 1959 no rain fell during the treatment interval. In both years, the soil remained dry to the 4-inch depth.

Soil temperature data were not available, but mean air temperatures were 62° in 1957, 68° in 1958 and 64° in 1959 during time intervals from the earliest incorporation treatment to flooding and sowing. Based on correlations of air and soil temperatures obtained at Davis, the mean soil temperatures at the 4-inch depth under a bare surface might be expected to average about 10 degrees above the mean air temperature in that season of the year. Such temperatures would be in the optimum zone for the various microbiological transformations of nitrogen—indicating that temperature was probably not a variable influencing the results.

TABLE 2. EFFECT OF LENGTH OF INTERVAL BETWEEN APPLICATION OF VETCH AND FLOODING ON RICE YIELD

Material and interval to flooding*	Rice yield cwt/A. 1957	1958	1959
Check	22	32	49
Vetch 30 days (21 days 1958)	33	49	62
Vetch 20 days (14 days 1958)	43	44	54
Vetch 10 days (7 days 1958)	48	48	64
Vetch 0 days	52	47	64
Am. sulfate 0 days	41	47	63
LSD 5%	6	5	7
Rain (in.) in longest interval	1.5	0.3	0
Mean air temp. (°F.)	62	68	64

* All treatments contained 40 lb./A. nitrogen and were applied at a depth of 4 in. Dates of flooding-and-sowing were May 16, 1957, May 22, 1958, and May 13, 1959.

In these time-of-incorporation experiments, the vetch was subjected to varying periods of well-aerated conditions resulting from excavation and replacement of the soil during the burying of the material, as well as the subsequent period of reducing conditions after flooding. In both 1958 and 1959, the evidence indicated that inadequate soil moisture limited decomposition and nitrification of the vetch prior to flooding, and its efficiency for rice production was not impaired. In 1957, moisture and temperature were favorable to decomposition and nitrification during the preflooding period, and the longer the materials were exposed to these conditions, the less effective they were in rice production. It is very probable that the nitrates produced at that time were denitrified after flooding as a result of the reducing conditions attained, and were lost from use by the rice plants. Thus the time interval between incorporation of either organic or inorganic sources of nitrogen and flooding should be as short as possible when soils are moist enough for microbiological activity.

Efficiency of nitrogen utilization

Nitrogen contained in leguminous green manures has been considered less efficient than inorganic nitrogen, according to tests on upland crops and soils. However, these experiments show that when a precisely measured amount of nitrogen from green manure is applied well into the reducing zone of a flooded soil, the efficiency of utilization is equal to that of the best mineral source of nitrogen. Other experiments have shown that the response in rice to green manure nitrogen can greatly exceed that of mineral nitrogen that has been placed improperly on the soil surface or into the flood water.

W. A. Williams is Associate Professor of Agronomy, University of California, Davis; and D. C. Finfrock, formerly Specialist in Agronomy, is now Crop Production Advisor, Ford Foundation, New Delhi, India.