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duced a 5-year average of 7.65 tons of green forage and 3.29 tons of dry hay. These yields exceeded the averages for all entries by about 20%. Ballard is one of the tallest growing and latest heading of all entries included.

Yields of green and dry forage of Lee and Arlington, two locally grown, grain-producing oats, differed considerably. In yield of green forage Lee averaged somewhat above the mean of all entries, whereas Arlington's yields were below average. Yields of dry forage from Lee approximated the average of all entries, but Arlington's dry-forage yield was some 8% below the average of all entries. As a result, Arlington, for over 10 years the leading oat for grain production in the area, appears to be inferior to most of the other entries grown as far as forage yields are concerned. The comparatively poor showing made by Arlington resulted in part from the fact that it was severely winterkilled in 1958–59.

Seed of Ballard is not available in quantity; hence, it appears that Lee is definitely the best variety available at this time for growing for forage purposes in the Beltsville area of Maryland.—FRANKLIN A. COFFMAN, *Research Agronomist, Crops Research Division, ARS, USDA, Beltsville, Md.*

RESPONSES OF FOUR CROPS TO VERY HIGH RATES OF SUPERPHOSPHATE

AT THE Storrs, Connecticut, Station alfalfa had grown much more rapidly during the seedling stage when superphosphate (46% P_2O_5) was banded 1.5″ below the seed than when it was mixed with the soil. In one greenhouse experiment the rate of growth was still increasing at rates between 1600 and 3200 pounds per acre of superphosphate, with either banded or mixed-in placements. In view of those results it was deemed advisable to measure the responses of several crops to even larger applications.

In February 1959, alfalfa, cabbage, ryegrass, and tomato were planted in 1-gallon cans of Paxton very fine sandy loam with a pH of 5.5 and "medium" amounts of Ca, Mg, and K, but "low" in P. It contained approximately 50% sand, 30% silt, and 20% clay and had an exchange capacity of 20 me. per 100 grams.

Banded and mixed-in placements of superphosphate (46% P_2O_5) were applied at 0, 400, 1600, 6400, 25,600, and 102,400 pounds per acre to soil treated with either 4000 or 8000 pounds of dolomitic hydrated lime. The standard fertilization was 200 pounds each of urea (45% N) and muriate of potash (50% K), plus 40 pounds of borax (10% B). Each treatment was triplicated for alfalfa and ryegrass, quadruplicated for cabbage and tomato. Thus, a total of 336 cultures were established.

The banded superphosphate was toxic at the 25,600 and 102,400 rates. Nevertheless, ryegrass produced the largest yields at the second cutting on the 102,400-pound mixed-in treatment and on the 25,600-pound banded placement. The 6400-pound rate stimulated the greatest early growth and largest yields in most of the other comparisons. In a few cultures the 1600-pound rate was nearly as effective as 6400 pounds but 400 pounds seldom equalled any of the higher, nontoxic applications.

These exploratory tests indicate that some very interesting results might be obtained from experiments with different species, soils and rates of superphosphate.—B. A. BROWN, *Emeritus Professor of Agronomy, Connecticut Agr. Exp. Sta., Storrs, Conn.*

EFFECT OF PLACEMENT AND TIME OF INCORPORATION OF VETCH ON 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 shown to be a highly effective and inexpensive source of the nitrogen needed by the rice crop.[1]

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.[2] It is likely that the redox status affects the decompositional pathways of organic matter. 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. Hence, the depth of incorporation of leguminous organic matter 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 aminization, ammonification and nitrification, if soil temperature, moisture, aeration, etc., are appropriate. Hence, loss of effectiveness of the green manure nitrogen is a possibility, if incorporation (plowing-in the crop) precedes flooding of the field for long.

With these concepts of rice-soil behavior in mind, 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, California.

Experimental Procedure

The experiments were conducted on Stockton clay, described previously,[1] which is representative of the clay soils in the major rice-growing area of California. Fresh purple vetch top growth used as the source of organic nitrogen was obtained away from the plot area, dried, and analyzed for nitrogen. The nitrogen content (dry basis) was 3.2 ± .1% in 1956, 4.0 ± .3% in 1957, 4.4 ± .2% in 1958, and 4.6 ± .2% in 1959. All vetch was applied after being oven dried except in the 1956 experiment when fresh wilted vetch was used. Plots 8 × 8 feet were used and the center 4 × 4 feet harvested for yield. The treatments were replicated six times in a randomized block design. The rice variety, Caloro, was used and the yields of rough rice (paddy) were calculated to 14% moisture content.

In the depth of incorporation experiments vetch was buried at depths of 1, 2, 4, and 6 inches in plots excavated following seedbed preparation. The experiment was repeated in different locations in three succeeding years. In 1956, 30 pounds and in 1957 and 1958, 40 pounds nitrogen per acre were applied in this fashion. An equal amount of nitrogen in the form of ammonium sulfate was applied as a separate treatment. In 1956 and 1957 the ammonium

[1] Williams, W. A., Finfrock, D. C., Davis, L. L., and Mikkelsen, D. S. Green manuring and crop residue management in rice production. Soil Sci. Soc. Am. Proc. 21:412–415. 1957.

[2] Mikkelsen, D. S., and Finfrock, D. C. Availability of ammoniacal nitrogen to lowland rice as influenced by fertilizer placement. Agron. J. 49:296–300. 1957.

Table 1—Effect of depth of placement of vetch on rice yield.

Nitrogen source and depth of placement*	Rice yield, cwt./A.		
	1956	1957	1958
Check	13	34	42
Vetch, 1 in.	22	40	-
2 in.	32	48	54
4 in.	36	52	56
6 in.	36	56	60
$(NH_4)_2SO_4$, 2 in. (4 in.,1958)	34	43	61
NH_4Cl, 4 in.	-	-	62
LSD 5%	5	9	5

* Nitrogen treatments were 30 lb./A. in 1956 and 40 lb./A. in 1957 and 1958. Dates of flooding and sowing were Apr. 8, 1956, May 16, 1957, and May 22, 1958.

Table 2—Effect of length of interval between application of vetch and flooding on rice yield.

Nitrogen source and interval to flooding*	Rice yield, cwt./A.		
	1957	1958	1959
Check	22	32	49
Vetch, 30 days (21 days, 1958)	33	49	62
20 days (14 days, 1958)	43	44	54
10 days (7 days, 1958)	48	48	64
0 days	52	47	64
$(NH_4)_2SO_4$, 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

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

sulfate was buried after uniform distribution at the 2-inch depth and in 1958 at the 4-inch depth.

In the time of incorporation experiments vetch was buried similarly at a depth of 4 inches at varying intervals prior to flooding and sowing. The intervals were multiples of 10 days in 1957 and 1959 and 7 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 nitrogen. Each year the experiments were located at a different site.

Previous work at the Station has indicated that yield responses in rice result from the addition of only one element, nitrogen, in the locale of these experiments.

Results and Discussion

Depth of incorporation experiments—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./A. in 1956 and 16 cwt./A. in 1957 over the 1-inch placements. In 1958 the 6-inch placement gave a 6 cwt./A. greater yield than the 2-inch placement (Table 1). The net effect of the best organic treatment was an increase in yield of 23 cwt./A. in 1956, 22 cwt./A. in 1957, and 18 cwt./A. 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 in. depth (1958) it duplicated the response from the best green manure treatment depth. Ammonium chloride was also applied in 1958 to test the possibility that the sulfate source might be causing incipient Akiochi disease, i.e. near toxic levels of hydrogen sulfide as sometimes occurs on degraded paddy soils in Japan.[3] This appeared not to be the case as the ammonium chloride application produced about the same rice yield increase as the ammonium sulfate, which in turn produced as much as the vetch treatment in that year (1958).

[3] Mitsui, S. Inorganic nutrition, fertilization and soil amelioration for lowland rice. Yokendo Ltd. Tokyo. 107 pp. 1954.

Previous work at the site of these experiments and elsewhere has shown that the short-term benefit of a leguminous organic matter is largely confined to its nitrogen contribution. Hence, the possibility of nitrogen loss from a green manure crop under various management practices is worthy of consideration. 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 of a few millimeters to 1 centimeter[2]. The experimental evidence from 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 under the circumstances of these experiments appreciable decomposition of vetch occurred at the shallower depths in the few days before the reducing zone was established in the plow layer, most markedly at the 1 in. depth where it is inferred that oxidative conditions were maintained for a longer period than at any of the greater depths of placement.

Time of incorporation experiments—Vetch applied 30 days prior to flooding and sowing rice in 1957 gave 19 cwt./A. less yield than the same treatment applied the same day as flooding and sowing (Table 2). Vetch applied 20 days prior gave 9 cwt./A. less yield, and vetch applied 10 days prior gave 4 cwt./A. less, the last difference not being a significant one. The net gain in rice yield for the vetch applied the day of flooding and planting was 30 cwt./A. However, in 1958 and 1959 there were no response differences due to time of incorporation of vetch of up to 21 days and 30 days, respectively, although there was a net response of 15 cwt./A. to the vetch application 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 application so strikingly, the soil was moist throughout the period. Rain fell in roughly equally spaced storms averaging 0.3 in. each totaling 1.5 in. In 1958 0.3 in. and in 1959 no rain fell during the treatment interval and in both instances the soil was dry at the 4-inch depth.

In the time-of-incorporation experiments the organic source of nitrogen applied was subjected to varying periods of well-aerated conditions resulting from excavation and replacement of the soil during the burying of the materials, as well as the subsequent period of reducing conditions after flooding. In two seasons (1958 and 1959) the evidence indicates that inadequate soil moisture was a limiting factor to decomposition and nitrification of the materials before flooding, and their 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 hence lost from use by the rice plants.

Precisely measured amounts of nitrogen in the form of purple vetch tops were placed at various depths in the plow layer and the efficiency of utilization determined for lowland rice production. Placement at 4- to 6-inch depths was observed to produce higher rice yields than placement at shallower depths. It is concluded that for maximum effectiveness in rice production leguminous material should be well turned under. Similarly vetch was incorporated at varying intervals prior to flooding and sowing rice. Under conditions favorable to nitrification during the preflooding period, the shorter the period the greater was the effectiveness of the organic nitrogen source. Under dry soil conditions no loss of effectiveness occurred. Properly applied vetch as a source of nitrogen was equally as effective in increasing rice yield as mineral sources of ammonium nitrogen applied at optimum depth.—W. A. WILLIAMS, *Associate Professor of Agronomy, University of California, Davis, and* D. C. FINFROCK, *formerly Specialist in Agronomy, UCD, now Crop Production Advisor, Ford Foundation, New Delhi, India.*

A CONTINUOUS ELECTRIC SOIL MOISTURE RECORDER[1]

THE purpose of this brief communication is to present an electric recorder which makes a continuous record of the moisture in the soil, using the new sensitive plaster of paris block.[2] The recorder is battery operated.

The recorder may have considerable use in soil moisture-plant research. It can give valuable data on the rate of moisture exhaustion at the root zone under various conditions.

The Recorder

The recorder is housed in a convenient carrying case (Figure 1) and possesses the following parts and features:

1. A clockwork mechanism which drives the chart and operates for one month without rewinding.
2. Two 6-volt batteries which power the transistor circuitry. The transistors lengthen the life of the batteries for 3 or 4 weeks of continuous service.
3. An A.C. wheatstone bridge which operates at a frequency of 40 cycles per second.
4. A temperature compensator which automatically corrects instrument readings for temperature variations.
5. Plug-in type connections.

Experimental Results

For soil moisture, the recorder can be set for measuring resistances over the ranges 0 to 10,000 or 0 to 100,000 ohms. Naturally, the smaller the range the more sensitive are the readings.

The recorder illustrated covers the range of 0 to 10,000 ohms. This is equivalent to an available moisture range from 100% to about 25%. This range was purposely chosen so it will give a sensitive measurement of soil moisture in the wet portion of the moisture scale. For plant growth and irrigation control this is the most important range.

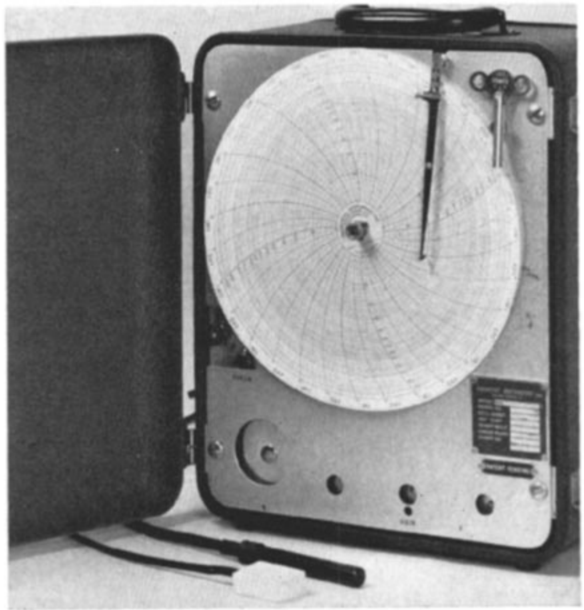

Figure 1—Electric soil moisture recorder with temperature compensator and plaster of paris block.

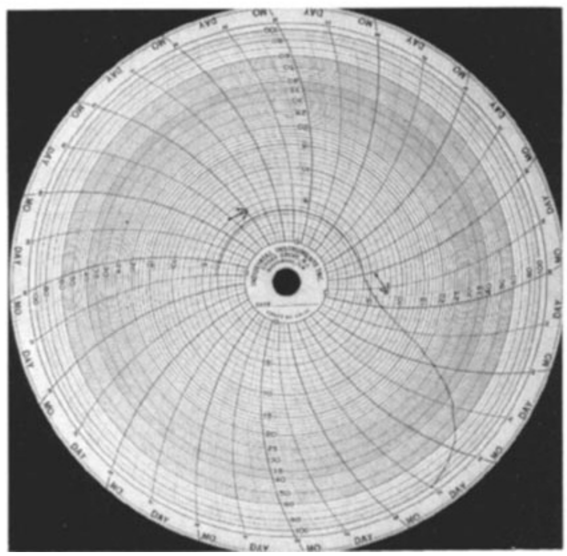

Figure 2—The electrical resistance remains unchanged during soil saturation but rises as the water is removed.

The figures on the chart are multiplied by 100 to convert them directly into ohms resistance.

A great number of experiments were conducted to test the recorder under a large variety of conditions. Figure 2 indicates that when the soil is saturated, the electrical resistance stays unchanged for a long time, but when the excess water is exhausted and field capacity is reached, the electrical resistance begins to rise at a rapid rate.

The recorder can also be used to indicate the need for irrigation; however, due to the differences in water release and in reserve available water in soils of different textures, water should be applied according to the irrigation chart.[2] —GEORGE JOHN BOUYOUCOS, *Professor Emeritus of Soil Science, Michigan State University.*

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[1] Authorized for publication by the Director as Journal Article No. 2925 of the Michigan Agr. Exp. Sta., East Lansing, Michigan. Received Jan. 31, 1962.

[2] Bouyoucos, G. J. Soil moisture improved. Agr. Eng. 42:136–138. 1961.