ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE: Interaction of Rice Straw Incorporation and Green Manuring: Effects on Rice Straw Decomposition, Soil Tilth, Nitrogen Nutrition, and Stem Rot

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OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

A special grant of $55,000 obtained from the Rice Research Board in mid-1988 was used to establish a multi-year field study of green manure-straw disposal method interactions and to develop a nitrogen soil test for rice. Two sites were chosen in commercial rice fields, one in Butte County (Emmett and Bill Skinner farm) covering 2.3 acres, the second in Sutter County (Sills Farms) covering aabout 15 acres. Legume cover crops were grown on large plots at both sites in 1988-89 and at the Sutter County site in 1989-90. Nitrogen rate trials were conducted at each site in the 1989 and 1990 rice crop. At the Sutter County site following the 1989 and 1990 rice harvests, one-acre straw treatment main plots were established on top of the winter cover crop subplots. Rice straw treatments consisted of fall burning, fall discing, or fall rolling, with all plots disced in the spring. The following report covers work done during 1990, referring to earlier work only where required for the sake of clarity.

Objective 1: Determine effect of winter green manure cropping on rice straw decomposition. In the spring of 1990 following discing, we measured the amount of straw remaining in soil samples collected from the rice straw-purple vetch plots at the Sutter Co. site. In a greenhouse pot study we followed disappearance of rice straw from soil in pots with and without purple vetch.

Objective 2: Determine effects on soil tilth of straw incorporation and green manuring. Force required for chiseling, cone penetrometer resistance, and soil bulk density were measured at the Sutter Co. site during the spring and fall of 1990.

Objective 3: Determine effects on nitrogen nutrition of straw incorporation and green manuring; develop a soil test for estimating potentially available nitrogen. A bank of N fertilizer rate plots in 30 lb N/acre increments was established in each main plot at both sites in 1989 and 1990. To evaluate nitrogen effects of the main plot treatments, the following measurements are being made: Cover crop nitrogen and dry matter yield, rice Y-leaf nitrogen content at mid-tillering, maximum tillering, and panicle initiation, rice grain and straw yield and nitrogen content, soil mineralizable nitrogen and organic carbon content. Soils data from both sites is being used to develop a soil nitrogen test for rice.

Objective 4: Determine the effect of green manuring on stem rot disease of rice where rice straw has been incorporated. Stem rot disease and other diseases appeared in the 1990 crop at the Sutter County experiment. Plant disease ratings were made in September.

Objective 5: Determine the response of purple vetch to lime and phosphate applications when it is grown in an acid soil; investigate pelleting of these materials with seed. Phosphate and pelleting experiments with legume green manure seedings were established following the 1990 rice harvest at Sills Farms. Some pre-rice harvest plantings were also established.

SUMMARY OF 1990 RESEARCH BY OBJECTIVE:

Objective 1: Effect of green manuring on rice straw decomposition.

In one field and one greenhouse pot experiment, we have not observed any obvious effect of the presence of a winter cover crop on rice straw decomposition. Soil samples collected from the Sutter Co. field plots in the spring of 1990 just before seedbed preparation were air dried and rice straw was separated by hand using a coarse screen. The amount of straw in burned plots was about half of the amount found in plots that had been neither burned nor disced (Table 1). It appears possible that fall discing resulted in some reduction in straw but not to levels found on burned plots. High variability in data is a problem. Number of replicate samples will be increased in 1991.

In the greenhouse experiment, we observed large differences in rate of rice straw disappearance between pots with straw left on the surface and straw incorporated into soil (Table 2). This is consistent with previous reports (e.g., Sain and Broadbent, 1977). However, the size of the difference (10% remaining after 16 weeks where straw was mixed vs 49% with straw on soil surface) is surprising considering that the environment provided in the greenhouse was much warmer (25^{o} C) than a rice field in winter, pots were watered daily, and the straw was in contact with soil, which would not necessarily be the case in a rolled rice field. There was no apparent effect of the presence of purple vetch plants. We had difficulty keeping the soil moisture content the same in the vetch and non-vetch pots. Also, the vetch plants were quite small until late in the experiment. In 1991, we want to determine if straw that is in less intimate contact with soil--due either to burial in clumps or being held above the soil surface--breaks down faster in the presence of a cover crop. This could happen if the presence of the plant canopy were to result in an increase in relative humidity immediately above the soil surface thus improving conditions for saprophytic microorganisms, or if cover crop vetch roots were to exude organic compounds that enhance the rate of microbial degradation of straw below the soil surface.

Objective 2: Influences on soil physical properties.

There is no single measure of soil tilth. We are using resistance to a tractor-pulled chisel as a measurement of soil strength related to tilth. We also are monitoring soil organic carbon content, penetrometer resistance, and bulk density. Chisel draft measurements were made in the spring and fall of 1990, but data have been analyzed only through the spring of 1990, i.e., after two years of winter green manuring and after only a single (fall 1989) set of post-harvest straw handling treatments were carried out. Up through the spring of 1990, no treatment effects on chisel draft and penetrometer resistance were observed. Chisel draft requirement were found to be related to tractor speed and depth of chiseling without regard to the presence of purple vetch residues or rice straw disposal method. In the fall of 1990 after burning, soil bulk density was not significantly affected by the green manuring practice the preceding winter (Table 3). Organic carbon content has been measured using a wet oxidation procedure that has given us highly variable results. We are switching to a dry combustion procedure and will report the 1990 results when analyses are completed.

Objective 3: Nitrogen nutrition relationships to cover cropping and straw disposal methods.

Rice grain yields on a dry basis at the two field sites are shown in Figures 1 and 2. These data were collected from 10 ft x 30 ft N-rate plots in larger main plots. At the Sutter Co. site, main plots assigned to purple-vetch x rice straw handling combinations are 0.5 acre in size, replicated five times. At the Butte Co. experiment, green manure main plots were 0.1 acre in size and were replicated six times. In Butte Co., all plots were fallowed and spring-burned between the 1989 and 1990 rice crops. The small effect of purple vetch apparent in Figure 2 is the residual from 18 months earlier, i.e., green manuring during the 1988-89 winter.

Purple vetch growth at the Sutter Co. site during the winter preceding the 1990 rice crop was poor due to the November planting, in turn the result of the cool 1989 summer and late rice harvest. Purple vetch stands in fall-burned main plots were good, but in both fall-disced and fall-rolled plots, stands were very non-uniform. Above-ground nitrogen content of the vetch on both burned and rolled plots was between 30 and 40 lb N/acre about two weeks before spring discing but was only 16 lb N/acre on the fall-disced plots (Table 4).

1990 rice grain yields at the Sutter Co. site are shown in Figure 1 (burned plots only) and in Table 5. With no nitrogen fertilizer applied, purple vetch increased yield more than 3000 lb/acre in burned plots, 900 lbs/acre in fall-disced plots, and some 1500 lb/acre in undisced rolled plots. For all three straw treatments, where purple vetch was planted, the maximum rough rice yield (about 8300 lb/acre) was achieved with 30 lb N/acre preplant fertilizer. On the winter fallow plots, maximum rice yield was the same as (on non-burned) or somewhat lower than (on burned plots) the yields on green-manured plots. Rice on the winter fallow plots required a preplant fertilizer application of about 90 lb N/acre (on burned or fall-disced) or about 120 lb N/acre (on undisced, rolled). The fertilizer replacement value of a winter cover of purple vetch was between 60 and 75 lb N/acre, depending on the straw disposal method (Table 6). This is a rather striking illustration of the relatively greater efficiency of recovery by rice of N contained in green manure residues compared to N contained in fertilizer applied preplant. The greater fertilizer requirement on plots receiving the non-disced, rolled straw treatment was probably due to increased N tie-up (immobilization) in the presence of large amounts of low-N straw in the soil after the spring discing.

Leaf N content at three growth stages was related to final grain yield (Figure 3). Data plots of rice leaf N content against fertilizer N rate (Figure 4), show a fertilizer replacement value of the purple vetch of between 55 and 80 lb N/acre at Sutter County (Table 6). N content associated with maximum grain yield at both sites was similar to critical values published by Mikkelsen (Mikkelsen, D.S., 1984. Proceedings, California Plant and Soil Conference). On the winter fallowed plots, there was little difference in N content of leaves from the different straw treatment plots at equivalent N fertilizer rates. In contrast, in the green manured plots, leaf N content was higher in the burned plots than the fall-disced or rolled plots at a given N fertilizer rate. This is most likely due to denser and more uniform stands of vetch on the burned plots.

One well-known effect of burning of rice harvest residues is the loss of nitrogen to the air. In the fall of 1989, rice straw at the Sutter Co. site contained about 80 to 90 lb N/acre in the areas of the field used for the 1990 rice crop N rate plots (Figure 5). The burn was a relatively cool, incomplete burn, but still it seems likely that half or more of the straw nitrogen would have been lost by burning. But apparently, the improvement in vetch stand establishment achieved by burning more than made up for this loss of nutrient. We note that to the extent that straw in green-manured areas contained more nitrogen than straw in fallowed areas, burning would result in a greater N loss on green manured areas, thus reducing the value of green manure in retaining and increasing N in the soil. One counteracting factor at the Sutter Co. site is the increase in pH of the acid soil by about 0.3 pH units (Table 7). It is possible that burning will mobilize phosphorus, nitrogen, and improve rhizobial effectiveness by this pH effect.

Comparison of total rice crop N uptake in the various green manure-rice straw disposal treated plots will allow us to determine whether observed effects are due strictly to nitrogen effects or to other non-nitrogen rotation effects. 1990 rice straw yields and nitrogen content and grain nitrogen content were measured but data analysis is still in progress.

At the Butte Co. site, rice response to nitrogen shows only a very small effect of the purple vetch grown one and one-half years earlier (Figure 2), perhaps on the order of 5 lb N/acre fertilizer N replacement value.

Work is continuing on development of a nitrogen mineralization soil test. The most promising candidate is ammonium produced during a two-week, anaerobic incubation (NH4INC) at 25^{o} C. We found that air-drying or oven-drying of soil samples results in a large increase in anaerobic incubation ammonium. Experiments with samples collected from 19 fields shows that the ammonium produced during the two-seek incubation largely reflects the release of N contained in the soil's microbial biomass. This portion of the soil organic N pool has been shown by many researchers to be closely related to plant-available nitrogen. NH4INC was slightly lower in samples collected immediately after fall discing or where large amounts of low N-content straw was present. As shown in Table 8, NH4INC is considerably elevated in samples collected from green-manured plots (compared to samples from fallow plots) even when the samples are collected before the green manure crop is disced under. Data in Table 8 also show that NH4INC does not change much between the fall and spring. We are proceeding with the idea that a field could be sampled in the fall and the resulting value adjusted for the presence of rice straw or a winter green manure residues.

Objective 4: Disease Relations.

In August 1990, we observed the presence of stem rot disease, aggregate sheath blight, and possibly other diseases at the Sutter Co. site. The stem rot appeared to be present at a low to moderate level of severity. In September, immediately after water was drained from the fields, plant samples were collected from several of the main plots. Disease ratings were made and are being analyzed for possible effects of the rice straw handling and green manure treatments. We note that irrigation basins were designed for the 1990 season to prevent mixing of irrigation water from the different straw and cover crop treatments. However, during field preparation activities in April and May, 1990, it was not possible to avoid dragging some soil and residues across main plot boundaries in spite of large size (0.5 acre) of main plots.

Objective 5: Response of green manure crops to lime, phosphorus, and pelleting of seed.

In 1989, the Sutter Co. site was limed with 5 tons/acre sugarbeet lime. By fall, after rice harvest, this had raised the pH from 4.8 to between 5.5 and 6.0, with considerable spatial variability present. A small area was left unlimed. In November 1989, purple vetch and triple superphosphate (60 lb P_2O_5/acre) were broadcast in small plots across the unlimed area and adjacent unlimed areas. Purple vetch growth was improved by the superphosphate, but unfortunately even in the phosphate-fertilized areas, growth was considerably poorer than in the main plot areas of the field. This was probably due to the heavy straw levels that had not been reduced by discing or burning in that particular part of the field.

In the fall of 1990, small plots were established within the field at the Sutter Co. site to test the following practices:

1. Pre-harvest sowing of woollypod vetch, purple vetch, subclover (varieties 'Larissa', 'Trikalla', and 'Meteora'), berseem ('Multicut') with and without Pelgel inoculum. These plots were planted on September 26, 1990.

2. Use of rock phosphate seed coating vs. broadcast triple superphosphate.

3. Post-harvest sowing of purple vetch.

Immediately after planting, a sustained period of warm, dry, windy weather resulted in dessication of the germinated subclover. It appears that vetch survived the drought, but growth has been very slow. We do not know yet whether the pre-harvest sowing will result in better growth than post-harvest. Also it is too early to evaluate responses to pelleting, rock phosphate, and broadcast phosphate fertilizer treatments.

PUBLICATIONS AND REPORTS:

Pettygrove, G.S., D. Jiayou, J.F. Williams, C. Wick, A.A.B. Hafez, and G. DeBoer. 1990. Variability of several forms of soil nitrogen in two rice fields. Communic. Soil and Plant Anal. 21:13-16.

Pettygrove, G.S., J. Deng, C. Wick, J. Williams, and S. Roberts. 1990. <u>In Press</u>. Soil nitrogen availability indexes for a rice-winter legume rotation. Proceedings. Twenty-third Rice Technical Working Group. Texas A&M University System, College Station TX 77843.

Pettygrove, G.S., C. Liu, J. Deng, J. Williams, and G. DeBoer. 1990. Effect of soil sample drying on anaerobic incubation ammonium. Agronomy Abstracts, American Society of Agronomy, Madison WI

Pettygrove, G.S., R.O. Miller, J. Deng, J.F. Williams, and C.M. Wick. 1991. Using a portable chlorophyll meter to determine leaf N content of grain crops. Proceedings. 1991 California Plant and Soil Conference. California Chapter, American Society of Agronomy.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

A large (15-acre) multi-year field experiment involving a continuous rotation of rice and purple vetch was established at Sills Farms in Sutter County during the fall of 1988. Following rice harvest in 1989, rice straw treatments were established in replicated one-acre main plots: Fall stubble-discing, fall rolling, and fall burning. Within each main plot are two half-acre plots with and without winter purple vetch green manure. Rice straw treatments were again carried out in the fall of 1990. Funding permitting, one more cycle of rice and green manure will be repeated in 1991-92. A second site in Butte Co.involved a green manure-rice-winter fallow-rice sequence for investigation of the carry-over effects of green manure to a second rice crop and to provide additional data for the development of a nitrogen soil test for rice.

In field measurements and a greenhouse pot experiment, no evidence has been found that the presence of a green manure crop hastens straw decomposition, but further experimentation is needed.

Methods have been developed for monitoring changes in soil physical and related characteristics in large plots receiving different rice residue disposal and green manuring treatments. So far, little or no differences in chisel draft or bulk density of soil have been observed in the different plots. Data from fall 1990 are being analyzed. Measurements will be made in the spring and fall of 1991, and finally in the spring of 1992 after four green manure crops and three rice crops in a continuous rotation.

At both sites in both years, the fertilizer replacement value of green manure has exceeded the above-ground N content of the cover crop just before spring discing. At the Sutter Co. site in 1990, the purple vetch containing 16 to 38 lb N/acre provided a fertilizer N replacement value of 60 to 75 lb N/acre. The carry-over effect of green manure to a second rice crop at the Butte Co. site was very small, perhaps 5 lb N/acre fertilizer replacement value. In Sutter Co. in early 1990, vetch stand uniformity and growth was better on fall-burned plots than on fall-disced or fall-rolled plots. This apparently compensated for the loss of N that occurs due to burning of rice residues. Spring discing of rice straw resulted in an increased fertilizer N requirement, apparently due to immobilization of N by soil microorganisms. Purple vetch green manure apparently reduced immobilization, and the fertilizer N requirement of spring-disced plots was no higher than for burned or fall-disced plots that were green-manured. Preliminary work on development the anaerobic incubation ammonium soil test is nearly completed.

Stem rot disease and aggregate sheath blight appeared at the Sutter Co. site in 1990. Plant samples were collected for disease rating in September 1990. Data are being analyzed.

A number of small plots were established in the fall of 1990 at the Sutter Co. site to determine the best method for establishing cover crops in unburned rice residue. Factors being tested include species of cover crop, pre-harvest versus post-harvest planting, phosphate fertilizer requirement, and response to pelleting of rock phosphate with seed. The value of these experiments appears to have been diminished by the severe fall drought, but purple vetch stands are established on most plots.

Table 1. **Rice straw content of soil, Sills Farms, following spring seed-bed preparation as determined by hand picking.**

Rice Residue disposal after 1989 harvest	Winter purple vetch[a]	Winter fallow[a]
	---tons/acre---	
Burned, 11/89	2.67 (0.73)	2.00 (0.98)
Stubble disk, 11/89	2.81 (1.08)	3.17 (1.45)
Spring disk, 4/90	4.93 (1.77)	4.09 (1.44)

[a] Standard deviation in parenthesis

Table 2. **Effect of purple vetch and straw placement on rice straw rate of decomposition.**

Weeks	No vetch Straw mixed	Vetch Straw mixed	Vetch Straw on top
		% Straw remaining	
4	44.7	50.7	77.0
8	13.7	10.8	68.1
12	9.7	10.9	60.1
16	5.2	9.8	48.5

Table 3. **Soil bulk density immediately after fall burning, Sills Farms, November 1990.**

Depth	Winter fallow[a]	Winter purple vetch[a]
	----------------g/cm^3-------------	
0-3 inches	1.32 (0.07)	1.24 (0.04)
3-6 inches	1.47 (0.11)	1.46 (0.10)

[a] Standard deviations in parenthesis

Table 4. **Purple vetch above-ground dry matter and N content, April 17, 1990. Sills Farms, Sutter Co.**

Fall 1989 residue Treatments[a]	Dry Matter Yield (lb/acre)[b]	N (%)[b]	N Yield (lb/acre)[b]
Burn	1289 (242)	2.97 (.07)	38.3 (7.3)
Disk	530 (333)	3.04 (.05)	16.1 (10.2)
None	940 (182)	3.55 (.24)	33.2 (6.1)

[a] All plots rolled in fall and disked in spring.

[b] Standard deviations shown in parenthesis.

Table 5. **Green manure and rice straw handling effects on 1990 M-202 grain yield. Sills Farms, Sutter Co.**

Fall 1989 residue treatments[a]	Unfertilized Yield		Yield at Opt. N rate [b]	
	Fallow	Vetch	Fallow	Vetch
	----------------dry grain / acre ----------------			
Burn	5036	8050	7970 (90)	8290 (30)
Disk	6464	7360	8255 (90)	8283 (30)
None	5809	7367	8187 (120)	8280 (30)

[a] All plots rolled in fall and disked in spring.

[b] Optimal fertilizer N rate (lb/acre) shown in parenthesis.

Table 6. **Green manure and rice straw handling effects on 1990 M-202 response to N fertilizer. Sills Farms, Sutter Co.**

Fall 1989 residue treatments[a]	Apparent fertilizer N substitution value of vetch		Vetch above-ground N content April, 1990
	To yield	To leaf N	
	-- lb fertilizer N/acre --		lb N/acre
Burn	60	80	38
Disk	60	55	16
None	75	55	33

[a] All plots rolled in fall and disked in spring.

Table 7. Effect of burning on soil pH. Sills Farms, Sutter County, December 1989. In April 1989, 5 tons/acre of sugarbeet lime was applied to field.

Depth (inches)	November 1989 residue treatment [a]	
	Burned	Control
0-8	6.03 (.89)	5.77 (.71)
8-15	6.50 (.66)	6.22 (.36)

[a] Standard deviation in parenthesis.

Table 8. Anaerobic incubation ammonium levels in soil as influenced by green manuring, straw disposal method, and timing. Sills Farms, Sutter County.

	Fall 1989	Spring 1990	
		Pre-disc	Post-disc
Winter fallow	-----mg NH_4^+-N/kg soil-----		
Burned	17.9	16.1	18.5
Fall disked	12.9	15.9	19.4
Spring disked	16.2	15.4	16.0
Winter purple-vetch			
Burned	16.5	22.5	37.7
Fall disked	15.3	18.1	44.4
Spring disked	13.8	21.0	40.9

Figure 1 Rice Grain Yield vs Nitrogen Fertilizer Rate
(Sutter County, 1990)

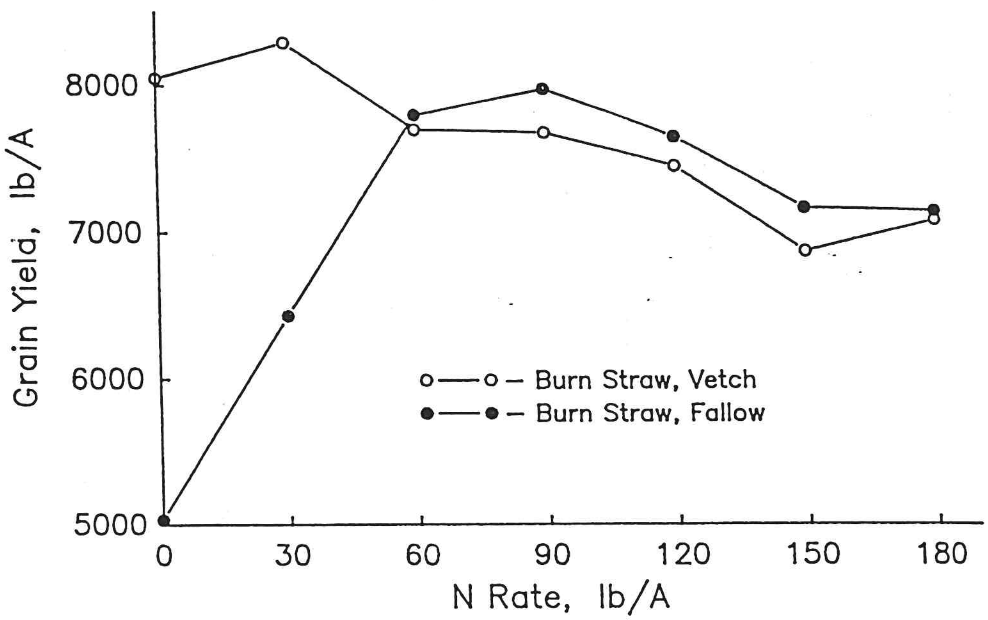
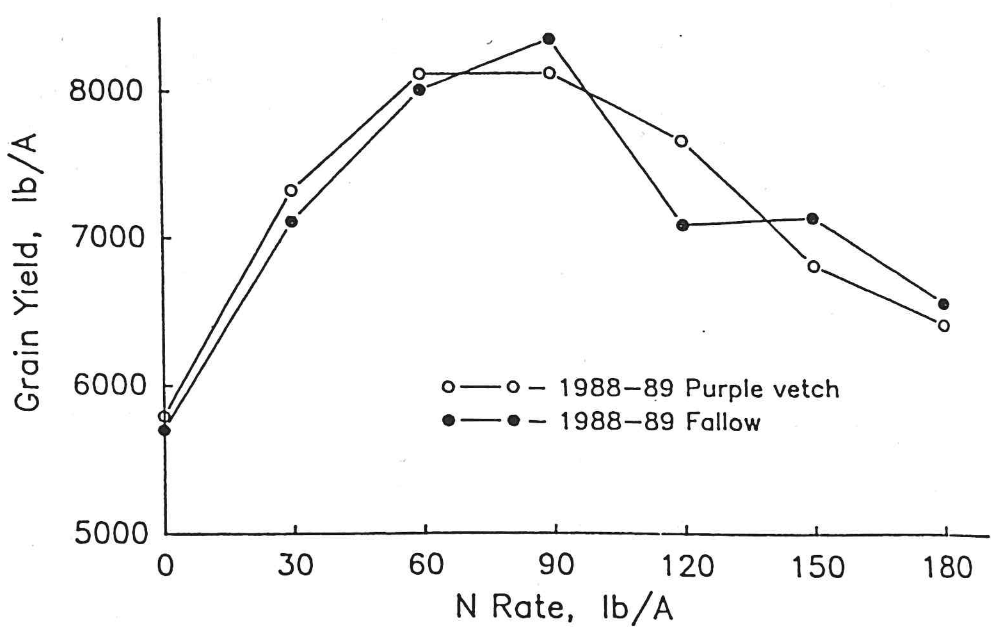


Figure 2 Rice Grain Yield vs Nitrogen Fertilizer Rate
(Butte County, 1990)



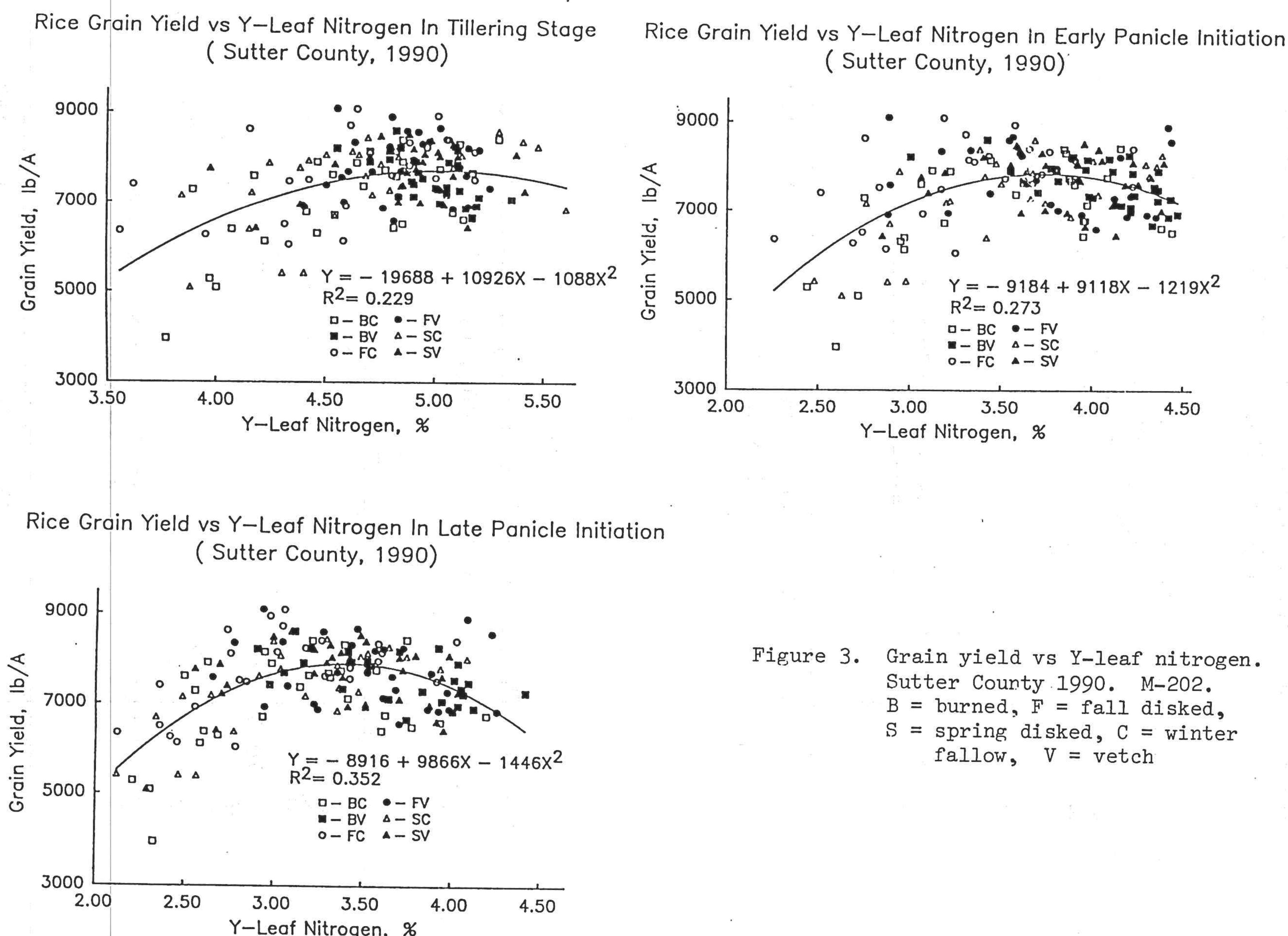
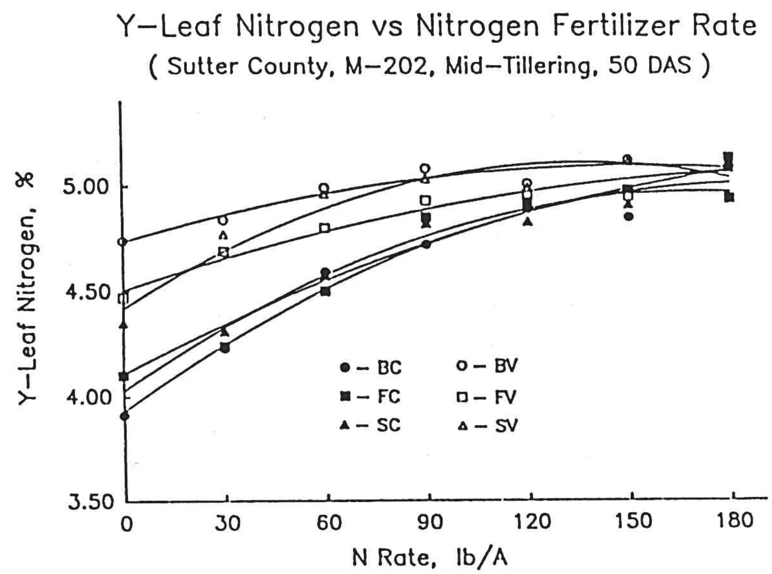
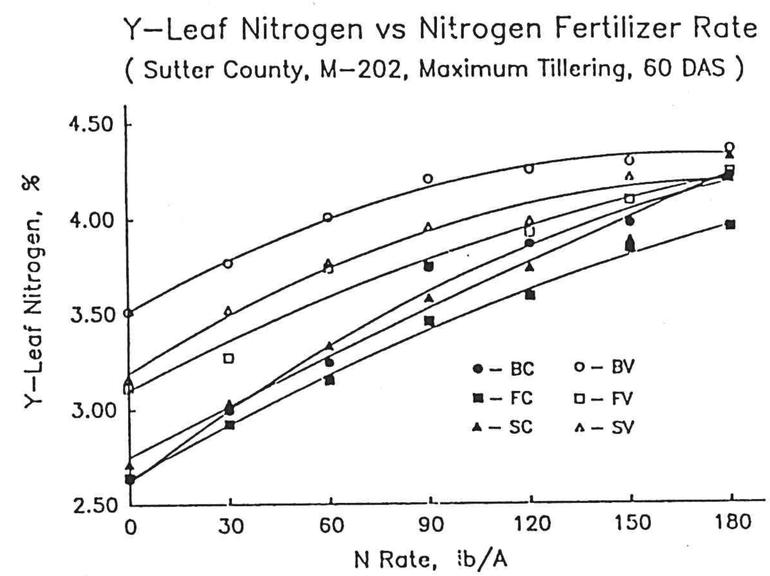


Figure 3. Grain yield vs Y-leaf nitrogen. Sutter County 1990. M-202. B = burned, F = fall disked, S = spring disked, C = winter fallow, V = vetch





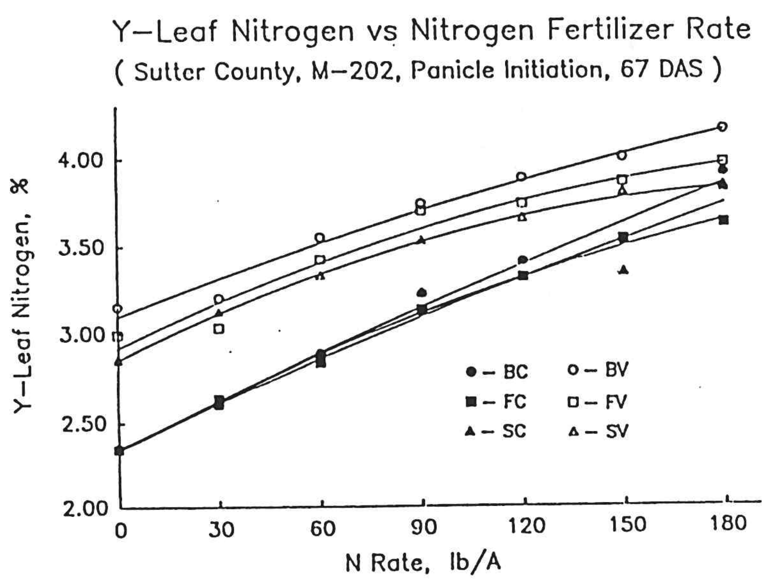


FIGURE 4. Y-leaf N vs N rate. Sutter Co. 1990.
B = burned, F = fall disked,
S = spring disked, C = winter fallow,
V = vetch

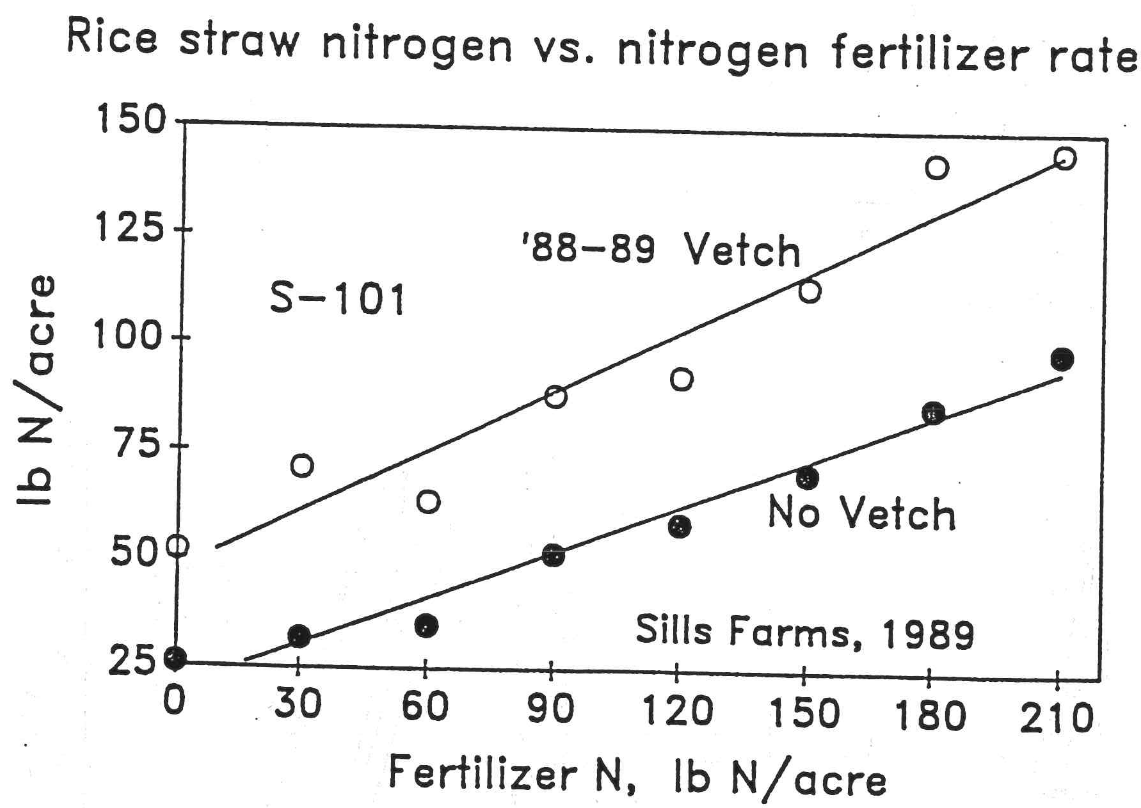

Rice straw nitrogen vs. nitrogen fertilizer rate
150
125
100
75
50
25
lb N/acre
'88-89 Vetch
S-101
No Vetch
Sills Farms, 1989
0
30
60
90
120
150
180
210
Fertilizer N, lb N/acre

FIGURE 5.