PROJECT No. RB-1

COMPREHENSIVE RESEARCH ON RICE
ANNUAL REPORT
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PROJECT TITLE: Nutritional and Environmental Factors Affecting High Yield Potential in California Rice

PROJECT LEADER AND PRINCIPAL UC INVESTIGATORS:

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LEVEL OF 1979 FUNDING: $16,423

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

OBJECTIVE I

Continuing studies to determine the nitrogen fertilizer requirements of new rice varieties in respect to rates of nitrogen, time and method of nitrogen application for optimum nitrogen utilization and grain yield under the various climatic regimes existing in California.

1. Evalution of the response of four very early, early and late California rice varieties and new releases to rates and time of nitrogen application. Six field experiments were conducted at 5 California locations.

2. Evaluation of the growth, yield and nutrient uptake patterns of seven California rice varieties, grown under 5 levels of nitrogen application. Two field experiments were conducted at the U.C. Rice Facility.

OBJECTIVE 2

To determine the plant utilization and fate of fertilizer nitrogen applied to rice. Experiments are designed to improve nitrogen fertilizer use and increase plant use efficiency for grain production.

1. One experiment conducted in 50 gallon cans was completed utilizing N^{15} labelled ammonium sulfate as a tracer.

OBJECTIVE 3

To develop and calibrate diagnostic tests to determine the fertilizer requirements of rice for optimum grain yield.

1. Plant tissue samples were collected from seven field experiments for calibrating methods of plant analysis in rice.

2. A procedure for rapid colorimetric determination of the nitrogen status of rice was developed in the laboratory. Infra-red reflectance techniques are being evaluated further.

OBJECTIVE 4

Soil and water quality constraints affecting rice production were examined in greenhouse experiments to determine the cause of poor growth and to develop ameleatory practices.

1. Greenhouse experiments were conducted with sub-soil limestone materials to determine how land levelling and sub-soiling affect rice growth.

2. Greenhouse experiments were conducted with irrigation water of varying quality to determine its effect on plant growth and nutrient uptake.

OBJECTIVE 5

Rice stand establishment problems were examined to determine causal factors and to develop remedial measures.

1. Field and greenhouse experiments were conducted with calcium peroxide as an oxygen extender for more satisfactory emergence of rice.

2. Field experiments were conducted to determine the feasibility of planting calcium peroxide coated rice seed by different cultural methods.

SUMMARY OF 1979 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVE

OBJECTIVE 1

Nitrogen fertilizer requirements of new rice varieties in respect to rates of nitrogen and time and method of nitrogen application.

Six field experiments were completed during 1979 as a continuing study of nitrogen requirements and adaptation of new rice varieties and material available for release. Experiments were conducted cooperatively with the Cooperative Extension at 6 locations in 5 countries. Four rice varieties comprising very early, early and late maturing material were evaluated with 13 nitrogen variables. A summary of the effects of nitrogen rates and time of application at the 6 locations are shown in Tables 1, 2, 3, 4, 5, and 6.

Among the experiments conducted with very early varieties increasing increments of nitrogen fertilizer increased yields from an average of 3639 pounds rice per acre without fertilization to maximum yields of 8,474, obtained with 120 N at the San Joaquin Co. site. At the Sacramento Co. site, yields increased from 4,794 without fertilizer nitrogen to the maximum average yield of 7,337 pounds rice per acre with 90 N. In both experiments there was no statistically significant difference in yield when 90 N was applied pre-plant or in split applications. Earlirose and 78-Y-38+41 were the highest yielding very early varieties grown in these experiments (Table 1 and 2).

The early rice varieties examined at the Colusa Co. and Butte Co. trials showed the variety 78-Y-38-41 to be the highest yielding rice at both locations (Table 3 and 4). At these locations the early rice varieties produced a maximum yield at 90 N, namely 8,275 pounds per acre at Colusa Co. and 8,977 pounds per acre at the Butte Co. site. At these locations pre-flood application of 90 N produced the same yield response as 2/3 of the N applied pre-flood with 1/3 applied at mid-tillering, panicle initiation or the flag-leaf stage.

Late varieties planted in the Butte Co. and Sutter Co. showed best yield performance from M7 and 78-Y-65 (Butte) and Calrose (Sutter). Maximum rice yields of all varieties was obtained with 150 N at the Butte location and with 180 N at the Sutter Co. trial. In these trials with late varieties, no significant differences were observed at the Butte location in comparisons of pre-plant and split nitrogen applications. In the Sutter Co. trial, pre-flood nitrogen was significantly better than split applications (Tables 5 and 6).

Utilizing information obtained from the Sutter Co. trial, it was observed that nitrogen top-dressing made at mid-tillering and panicle initiation were similar in effect to the pre-flood application on nitrogen uptake, plant growth and grain yield. The nitrogen top-dressed at the flag leaf stage did not affect the number of grain per panicle but tended to increase the percentage of ripened grain.

Nitrogen uptake by Calrose at successive growth stages is shown in Figure 1. Nitrogen uptake from the 7 rates of basal fertilizer continued beyond the flag leaf stage to grain maturity. Nitrogen use efficiency is high in increasing leaf length, panicle number, dry matter production and grain yield. The percentage of ripened grain decreased with nitrogen rates in excess of 60 N. The relationships between nitrogen rates at various growth stages to full grain maturity is shown in Figure 2.

The chemical composition of rice plants at four growth stages are shown for the Butte, San Joaquin and Sutter Co. trials in Tables 7, 8, and 9.

2. Seven current California rice varieties were grown at the

Table 1. Effect of rate and timing of nitrogen applications of yields at four rice varieties
Paulus - San Joaquin Co. - very early varieties.

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: Earlirose	M101	78-Y-38-41	L201	Average all varieties
1	0				0	4502	3830	3399	2828	3639 F*
2	30				30	6919	5456	5659	4936	5743 E
3	60				60	8074	7203	7188	6359	7206 D
4	90				90	8158	8800	8653	7664	8319 ABCD
5	120				120	8992	9542	8418	8211	8791 AB
6	150				150	8818	9100	8335	7640	8474 ABC
7	180				180	7807	9198	8762	7673	8361 ABCD
8	60	30			90	8855	7543	7736	6662	7699 BCD
9	60		30		90	8692	8067	7634	6738	7783 ABCD
10	60			30	90	7922	7605	7510	6326	7341 CD
11	100	50			150	9032	9284	9308	8125	8937 A
12	100		50		150	9100	9013	8998	8633	8936 A
13	100			50	150	9341	8902	9391	8262	8974 A
		Means				8171_A	7965_{AB}	7769_B	6928_C	

Variety Means (.05) = 300 pounds/acre
Treatments (.05) = 802

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 2. Effect of rate and time of nitrogen application on yield of four rice varieties
Bolen - Sacramento Co. - very early varieties.

Treatment No.	Nitrogen - Pounds Per Acre At Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O Earlirose	M101	78-Y-38+41	L201	Average all varieties
1	0				0	6314	3277	5586	3998	4794 E*
2	30				30	7031	4434	6550	5431	5862 D
3	60				60	6481	5248	8731	6711	6793 ABCD
4	90				90	6810	7304	8546	6687	7337 A
5	120				120	5093	7090	7969	5030	6296 BCD
6	150				150	5948	6420	7432	4845	6162 CD
7	180				180	4601	6492	7091	6468	6163 CD
8	60	30			90	7068	6856	8555	6816	7324 A
9	60		30		90	6723	5374	8185	4958	6310 A
10	60			30	90	6773	7305	8435	6518	7258 AB
11	100	50			150	5899	6889	8370	5385	6636 ABCD
12	100		50		150	6606	6730	7829	6373	6885 ABC
13	100			50	150	6441	7792	7771	5455	6865 ABC
		Means				6292_B	6247_B	7773_A	5744_B	

Variety Means (.05) = 563 pounds/acre
Treatments (.05) = 860

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 1. Effect of rate and time of nitrogen applications on yields of four rice varieties
Erdman - Colusa Co. - early varieties.

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: S6	M9	(S201) 78-Y-38+41	L201	Average all varieties
1	0				0	3673	3687	3554	3933	3711 F*
2	30				30	4494	5252	5186	5056	4997 E
3	60				60	6763	6975	7506	6832	7031 BCD
4	90				90	8511	8656	7924	8051	8285 A
5	120				120	7626	8463	8299	8714	8275 A
6	150				150	6779	7813	8615	7331	7635 AB
7	180				180	4916	7478	7320	5827	6385 CD
8	60	30			90	8409	8908	8695	7171	8295 A
9	60		30		90	7642	8063	8269	7550	7881 AB
10	60			30	90	8104	8558	8369	8080	8278 A
11	100	50			150	6045	7018	8081	7879	7260 BC
12	100		50		150	5193	5939	7231	6302	6166 D
13	100			50	150	6667	7192	8453	7723	7509 AB
		Means				6525_C	7231_{AB}	7500_A	6963_B	

Variety Means (.05) = 322 pounds/acre
Treatments (.05) = 896

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 4. Effect of rate and time of nitrogen applications on yields of four rice varieties McKnight - Butte Co. - early varieties.

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: S6	M9	78-Y-38+41	L201	Average all varieties
1	0				0	7596	8012	8000	8814	8105 A *
2	30				30	7541	8196	9667	8960	8591 A
3	60				60	7563	9362	9526	9498	8987 AB
4	90				90	7289	9216	9684	9717	8977 AB
5	120				120	6834	8674	9719	8550	8444 ABC
6	150				150	6113	8218	8868	7988	7797 ABCD
7	180				180	6478	7574	8449	6901	7351 ABCD
8	60	30			90	8626	8926	9033	9073	8915 ABCD
9	60		30		90	6820	8626	10445	7621	8378 BCD
10	60			30	90	8409	9309	9346	8757	8955 ABC
11	100	50			150	6351	8185	9152	8401	8023 CDE
12	100		50		150	7421	8119	8523	8863	8232 DE
13	100			50	150	7282	8711	9366	8322	8421 E
		Means				7256_C	8549_B	9214_A	8574_B	

Variety Means (.05) = 440 pounds/acre
Treatments (.05) = 640

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 5. Effect of rate and timing of nitrogen applications on yields of four rice varieties
Kelleher - Butte Co. - late varieties

Treatment No.	Nitrogen - Pounds Per Acre At					Rice Yields - 14% H_2O				
	Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Calrose	M7	M5	78-Y-65	Average all varieties
1	0				0	5275	4466	4547	4219	4627 D*
2	30				30	6449	6194	5274	5540	5865 C
3	60				60	7044	6962	7114	7233	7089 ABC
4	90				90	7527	8976	7444	7801	7938 AB
5	120				120	7869	9492	6476	8025	7966 AB
6	150				150	6688	9962	7017	8856	8131 AB
7	180				180	6549	9298	4222	7144	6803 BC
8	60	30			90	7477	8069	8125	8626	8075 AB
9	60		30		90	7558	6571	7573	8379	7521 AB
10	60			30	90	8428	8109	7673	8141	8088 AB
11	100	50			150	6853	9822	7435	8407	8130 AB
12	100		50		150	6985	9515	6145	7917	7641 AB
13	100			50	150	7875	8683	8208	8471	8310 A
		Means				7122_{BC}	8163_{A}	6712_{C}	7597_{AB}	

Variety Means (.05) = 801 pounds/acre
Treatments (.05) = 1185

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test: P = 0.05.

Table 6. Effect of rate and timing of nitrogen applications on yields of four rice varieties
Illerich - Sutter Co. - late varieties

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: Calrose	M7	M5	78-Y-65	Average all varieties
1	0				0	3218	3085	2570	2895	2942 I*
2	30				30	5000	4018	4112	4321	4215 H
3	60				60	6032	6016	5827	6424	6074 G
4	90				90	7901	6549	8008	7276	7434 DE
5	120				120	8350	8085	8403	7902	8185 BC
6	150				150	9373	8324	8557	8406	8665 AB
7	180				180	9249	8712	7913	9554	8857 A
8	60	30			90	7132	6328	7052	7322	6959 EF
9	60		30		90	6864	6106	7018	6847	6709 F
10	60			30	90	6144	5711	5897	5796	5887 G
11	100	50			150	10071	8276	8280	8578	8801 AB
12	100		50		150	8882	8306	8683	8792	8666 AB
13	100			50	150	8043	7860	8235	7695	7958 CD
		Means				7366_A	6722_C	6966_{BC}	7056_B	

Variety Means (.05) = 261 pounds/acre
Treatments (.05) = 571

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 1. Effect of rate and timing of nitrogen applications of yields at four rice varieties San Joaquin Co. - very early varieties.

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: Earlirose	M101	78-Y-38-41	L201	Average all varieties
1	0				0	4502	3830	3399	2828	3639 F*
2	30				30	6919	5456	5659	4936	5743 E
3	60				60	8074	7203	7188	6359	7206 D
4	90				90	8158	8800	8653	7664	8319 ABCD
5	120				120	8992	9542	8418	8211	8791 AB
6	150				150	8818	9100	8335	7640	8474 ABC
7	180				180	7807	9198	8762	7673	8361 ABCD
8	60	30			90	8855	7543	7736	6662	7699 BCD
9	60		30		90	8692	8067	7634	6738	7783 ABCD
10	60			30	90	7922	7605	7510	6326	7341 CD
11	100	50			150	9032	9284	9308	8125	8937 A
12	100		50		150	9100	9013	8998	8633	8936 A
13	100			50	150	9341	8902	9391	8262	8974 A
		Means				8171_A	7965_{AB}	7769_B	6928_C	

Variety Means (.05) = 300 pounds/acre
Treatments (.05) = 802

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 2. Effect of rate and timing of nitrogen applications of yields at four rice varieties Sacramento Co. - very early varieties.

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: Earlirose	M101	78-Y-38+41	L201	Average all varieties
1	0				0	6314	3277	5586	3998	4794 E*
2	30				30	7031	4434	6550	5431	5862 D
3	60				60	6481	5248	8731	6711	6793 ABCD
4	90				90	6810	7304	8546	6687	7337 A
5	120				120	5093**	7090	7969	5030	6296 BCD
6	150				150	5948**	6420	7432	4845	6162 CD
7	180				180	4601**	6492	7091	6468	6163 CD
8	60	30			90	7068	6856	8555	6816	7324 A
9	60		30		90	6723	5374	8185	6816	7324 A
10	60			30	90	6773	7305	8435	6518	7258 AB
11	100	50			150	5899	6889	8370	5385	6636 ABCD
12	100		50		150	6606	6730	7829	6373	6885 ABC
13	100			50	150	6441	7792	7771	5455	6865 ABC
		Means				6292_B	6247_B	7773_A	5744_B	

Variety Means (.05) = 563 pounds/acre
Treatments (.05) = 860

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

** RAT damage

Table 3. Effect of rate and timing of nitrogen applications of yields at four rice varieties Colusa Co. - very early varieties.

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: Earlirose	M101	78-Y-38+41	L201	Average all varieties
1	0				0	3683	3698	3554	3033	3711 F*
2	30				30	4494	5252	5186	5056	4997 E
3	60				60	6763	6975	7506	6882	7031 BCD
4	90				90	8511	8656	7924	8051	8285 A
5	120				120	7626	8463	8299	8714	8275 A
6	150				150	6779	7813	8615	7331	7635 AB
7	180				180	4916	7478	7320	5827	6385 CD
8	60	30			90	8409	8908	8695	7171	8295 A
9	60		30		90	7642	8063	8269	7550	7881 AB
10	60			30	90	8104	8558	8369	8080	8278 A
11	100	50			150	6045	7018	8081	7879	7260 BC
12	100		50		150	5193	5939	7231	6302	6166 D
13	100			50	150	6667	7192	8453	7723	7509 AB
		Means				6525_C	7231_{AB}	7500_A	6963_B	

Variety Means (.05) = 322 pounds/acre
Treatments (.05) = 896

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 4. Effect of rate and timing of nitrogen applications of yields at four rice varieties
Butte Co. - very early varieties.

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: Earlirose	M101	78-Y-38+41	L201	Average all varieties
1	0				0	7596	8012	8000	8814	8105 A *
2	30				30	7541	8196	9667	8960	8591 A
3	60				60	7563	9362	9526	9898	8987 AB
4	90				90	7289	9216	9684	9717	8977 AB
5	120				120	6834	8674	9719	8550	8444 ABC
6	150				150	6113	8218	8868	7988	7797 ABCD
7	180				180	6478	7574	8449	6901	7351 ABCD
8	60	30			90	8626	8926	19033	9073	8915 ABCD
9	60		30		90	6820	8626	10445	7621	8378 BCD
10	60			30	90	8409	9309	9346	8757	8955 ABC
11	100	50			150	6351	8185	9152	8401	8023 CDE
12	100		50		150	7421	8119	8523	8863	8232 DE
13	100			50	150	7282	8711	9366	8322	8421 E
		Means				7256_C	8549_B	9214_A	8574_B	

Variety Means (.05) = 440 pounds/acre
Treatments (.05) = 640

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 5. Effect of rate and timing of nitrogen applications of yields at four rice varieties
Butte Co. - late varieties

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: Earlirose	M101	78-Y-38+41	L201	Average all varieties
1	0				0	5275	4466	4547	4219	4627 D*
2	30				30	6449	6194	5274	5540	5865 C
3	60				60	7044	6962	7114	7233	7089 ABC
4	90				90	7527	8976	7444	7801	7938 AB
5	120				120	7869	9492	6476	8025	7966 AB
6	150				150	6688	9962	7017	8856	8131 AB
7	180				180	6549	9298	4222	7144	6803 BC
8	60	30			90	7477	8069	18125	8626	8075 AB
9	60		30		90	7558	6571	17573	8379	7521 AB
10	60			30	90	8428	8109	7673	8141	8088 AB
11	100	50			150	6853	9822	7435	8407	8130 AB
12	100		50		150	6985	9515	6145	7917	7641 AB
13	100			50	150	7875	8683	8208	8471	8310 A
		Means				7122_{BC}	8163_{A}	6712_{C}	7597_{AB}	

Variety Means (.05) = 801 pounds/acre
Treatments (.05) = 1185

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 6. Effect of rate and timing of nitrogen applications of yields at four rice varieties
Sutter Co. - late varieties

Treatment No.	Nitrogen - Pounds Per Acre At: Pre-plant	Mid-tillering	Panicle initiation	Flag leaf	Total	Rice Yields - 14% H_2O: Earlirose	M101	78-Y-38+41	L201	Average all varieties
1	0				0	3218	3085	2570	2895	2942 I*
2	30				30	5000	4018	4112	4321	4215 H
3	60				60	6032	6016	5827	6424	6074 G
4	90				90	7901	6549	8008	7276	7434 DE
5	120				120	8350	8085	8403	7902	8185 BC
6	150				150	9373	8324	8557	8406	8665 AB
7	180				180	9249	8712	7913	9554	8857 A
8	60	30			90	7132	6328	7052	7322	6959 EF
9	60		30		90	6864	6106	17018	6847	6709 F
10	60			30	90	6144	5711	5897	5796	5887 G
11	100	50			150	10071	8276	8280	8578	8801 AB
12	100		50		150	8882	8306	8683	8792	8666 AB
13	100			50	150	8043	7860	8235	7695	7958 CD
		Means				7366_A	6722_C	6966_{BC}	7056_B	

Variety Means (.05) = 261 pounds/acre
Treatments (.05) = 571

* Means followed by the same letter are not statistically significant - Duncan's Multiple Range Test P = 0.05.

Table 7. Chemical composition of leaves, culms and rice grain. Butte Co. - variety M-7.

Plant Part	Stage of Growth	Chemical Composition (%)						
		N	P	K	Ca	Mg	Zn	Fe
		-----------percent-----------					ppm	ppm
Leaves	Mid-till	5.16	0.33	1.94	0.26	0.21	48	263
	Panicle In	5.31	0.26	1.63	0.23	0.24	38	450
	Flag Leaf	3.89	0.28	1.75	0.28	0.25	31	213
	Mature	2.12	0.19	2.38	0.08	0.16	60	750
Culms	Mid-till	3.41	0.27	1.94	0.13	0.13	50	550
	Panicle In.	2.95	0.24	2.00	0.34	0.19	29	438
	Flag Leaf	2.13	0.29	2.38	0.08	0.15	60	613
	Mature	0.74	0.10	2.25	0.15	0.15	38	100
Grain	Mature	1.75	0.34	0.52	0.09	0.22	33	104

Table 8. Chemical composition of leaves, culms and rice grain. Sutter Co. - variety M-7.

Plant Part	Stage of Growth	Chemical Composition (%)						
		N	P	K	Ca	Mg	Zn	Fe
		-----------percent-----------					ppm	ppm
Leaves	Mid-till	3.79	0.26	1.75	0.30	0.16	39	513
	Panicle In	2.22	0.24	1.75	0.33	0.20	28	250
	Flag Leaf	1.83	0.23	1.44	0.36	0.24	25	263
	Mature	0.94	0.08	2.38	0.14	0.15	56	188
Culms	Mid-till	1.12	0.24	1.25	0.06	0.15	41	875
	Panicle In.	0.71	0.25	1.38	0.09	0.15	41	563
	Flag Leaf	0.66	0.23	1.38	0.09	0.15	46	213
	Mature	0.48	0.14	1.94	0.14	0.16	49	113
Grain	Mature	1.24	0.27	0.22	0.11	0.19	36	162

Table 9. Chemical composition of leaves, culms and rice grain. San Joaquin Co. - variety M101.

Plant Part	Stage of Growth	Chemical Composition (%)						
		N	P	K	Ca	Mg	Zn	Fe
		-----------percent-----------					ppm	ppm
Leaves	Mid-till	2.18	0.14	1.38	0.33	0.21	29	325
	Panicle In	2.69	0.19	1.63	0.38	0.31	29	350
	Flag Leaf	1.77	0.18	1.50	0.34	0.19	25	350
	Mature	0.71	0.10	1.13	0.33	0.20	25	690
Culms	Mid-till	0.66	0.19	1.19	0.13	0.16	31	513
	Panicle In.	1.01	0.31	1.81	0.11	0.19	29	713
	Flag Leaf	0.69	0.23	1.38	0.11	0.16	39	263
	Mature	0.35	0.15	1.00	0.30	0.15	23	375
Grain	Mature	1.14	0.26	0.36	0.15	0.18	29	294

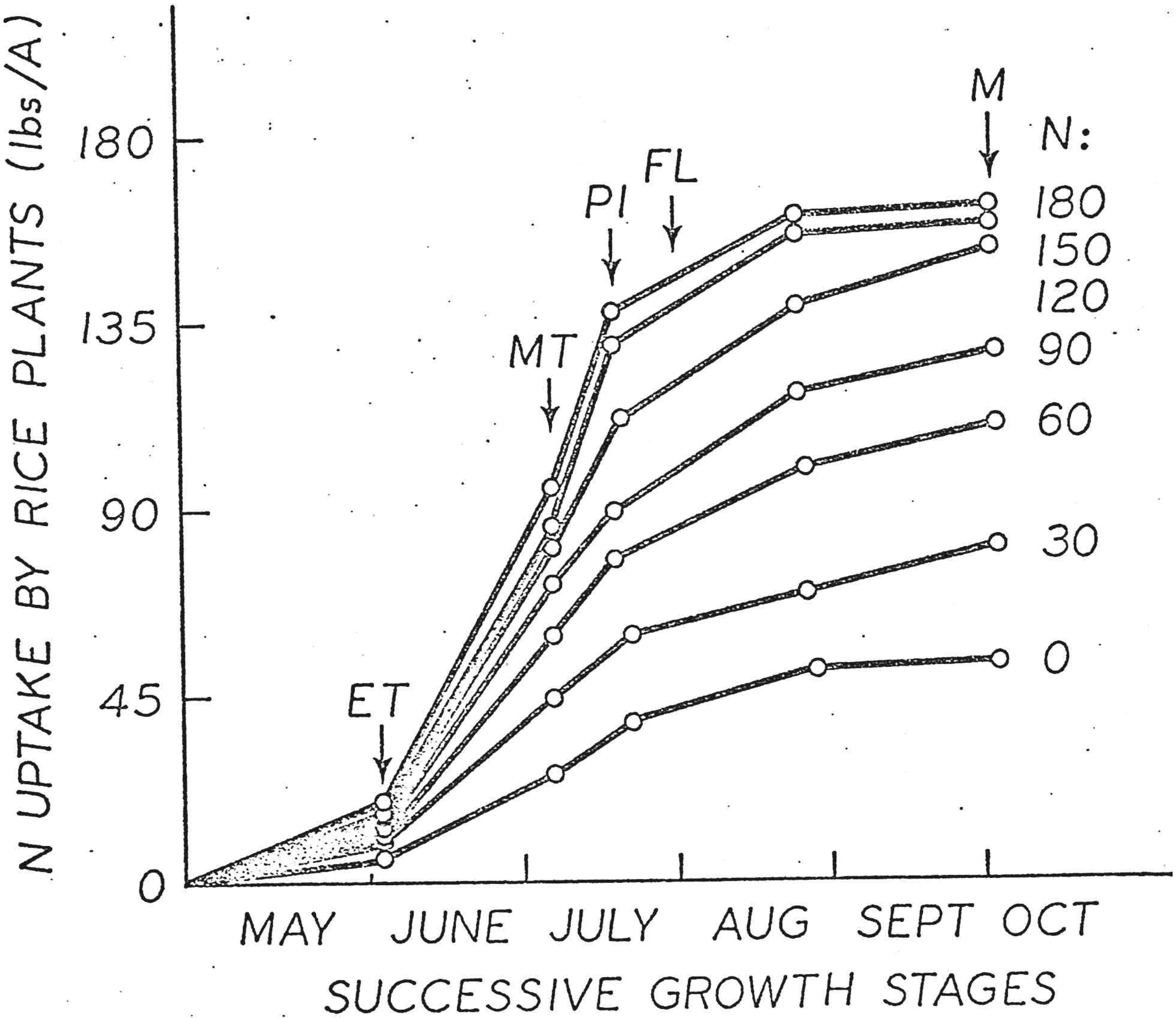

Fig. 1. Nitrogen uptake by rice at different growth stages from different levels of pre-flood nitrogen.

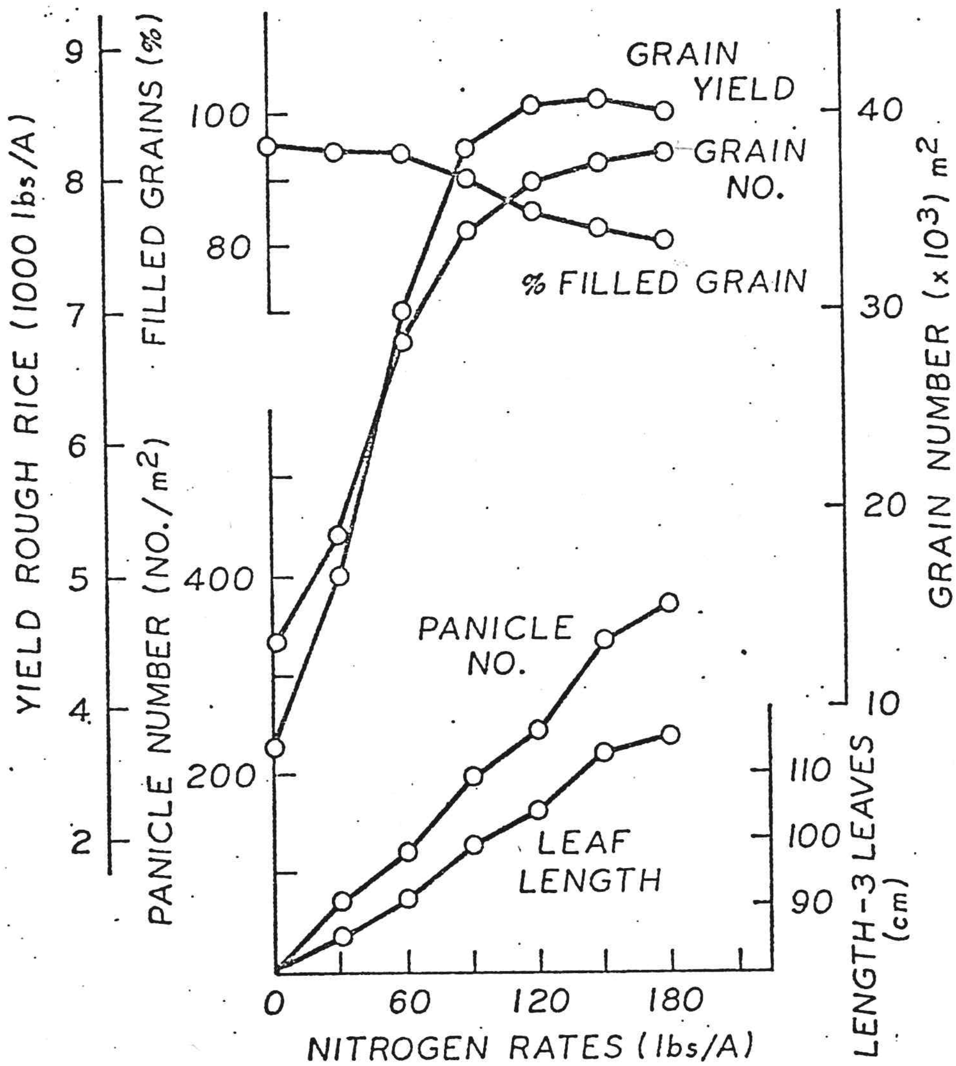

Fig. 2. Relationships between nitrogen applications and response of rice to fertilization.

U.C. Rice Facility to evaluate patterns of plant growth, nutrient uptake, and grain and straw yields as affected by nitrogen fertilization. Grain and straw yields of these varieties and grain/sraw ratios are reported in Table 10. Data on nutrient uptake patterns shown by the different varieties is not yet available.

OBJECTIVE II

To determine the plant utilization and fate of fertilizer nitrogen applied to rice.

1. Recovery of fertilizer N by rice is seldom greater than about 60 percent. Succeeding crops grown on the same soil usually recover some additional organic matter combined N, but it is usually less than 1 to 3 percent additional. Attempts to account for this low recovery have shown that a variety of factors may be involved either biologically or associated with chemical reactions in the water and soil. Losses may occur from gasification, volatilization, leaching, clay-fixation or immobilization in the soil organic matter fraction. Estimates of the amounts last from these sources vary widely depending on the reliability of the experimental procedures.

In recent studies, using N^{15} tracers in ammonium sulfate fertilizers a number of factors associated with the fate of fertilizer nitrogen have been identified. Figures 3 and 4 show the fate of fertilizer nitrogen applied to rice as ammonium sulfate by split-broadcast applications and basal applications applied pre-flood at 60 and 120 pound per acre rates. It is significant that basal applications of nitrogen increase nitrogen in the crop from 27% applied as a split top-dressing to 82% when aplied basally at 60 N per acre. The losses associated wth denitrification accounts for the largest single loss from the system (50%) followed by ammonia volatilization (6%).

At the 120 N rate, the nitrogen taken up by the crop amounted to 24% from a split nitrogen application, broadcast to 81% recovery when the fertilizer was applied as a pre-flood application. With proper pre-flood placement losses due to denitrification and ammonia volatilization were reduced to about 10% of the fertilizer application.

OBJECTIVE III

To develop and calibrate diagnostic tests to determine the fertilizer requirements of rice for optimum grain yields.

1. Plant tissue analyses provide a useful guide to determine if nutrient deficiencies are a significant constrant to rice yields. They can be useful in determining what plant nutrients to apply and whether top-dressings are likely to increase rice yields.

Previous research has shown that the most recently mature rice leaf is the most sensitive indicator of the nutrient status, especially for N, P and K. Probably the two most variables in the use of plant analysis are the stage of plant development and the critical level for each nutrient which appears to decrease with plant age.

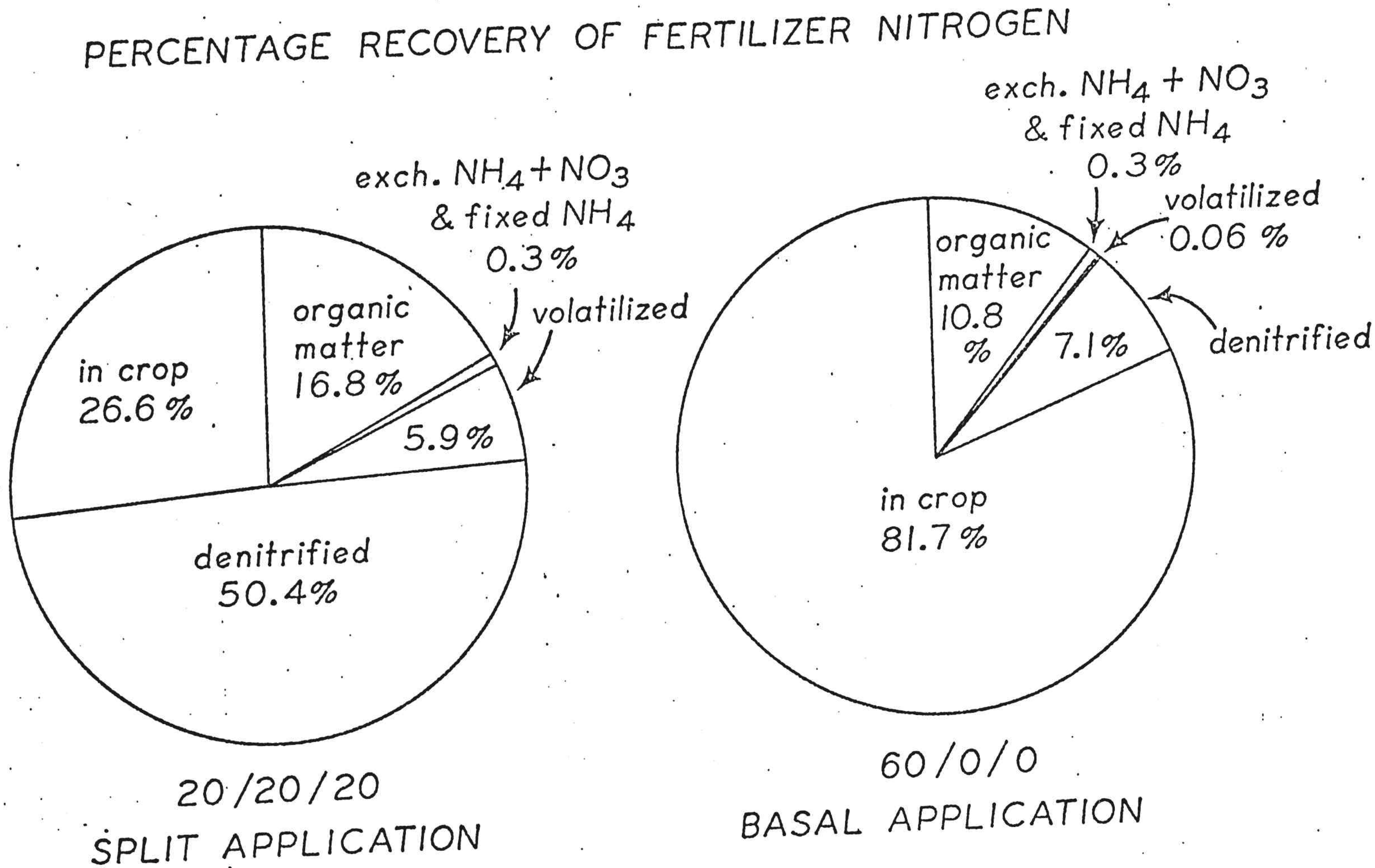

Fig. 3. Percentage recovery of fertilizer nitrogen with broadcast and pre-flood applications (60 N).

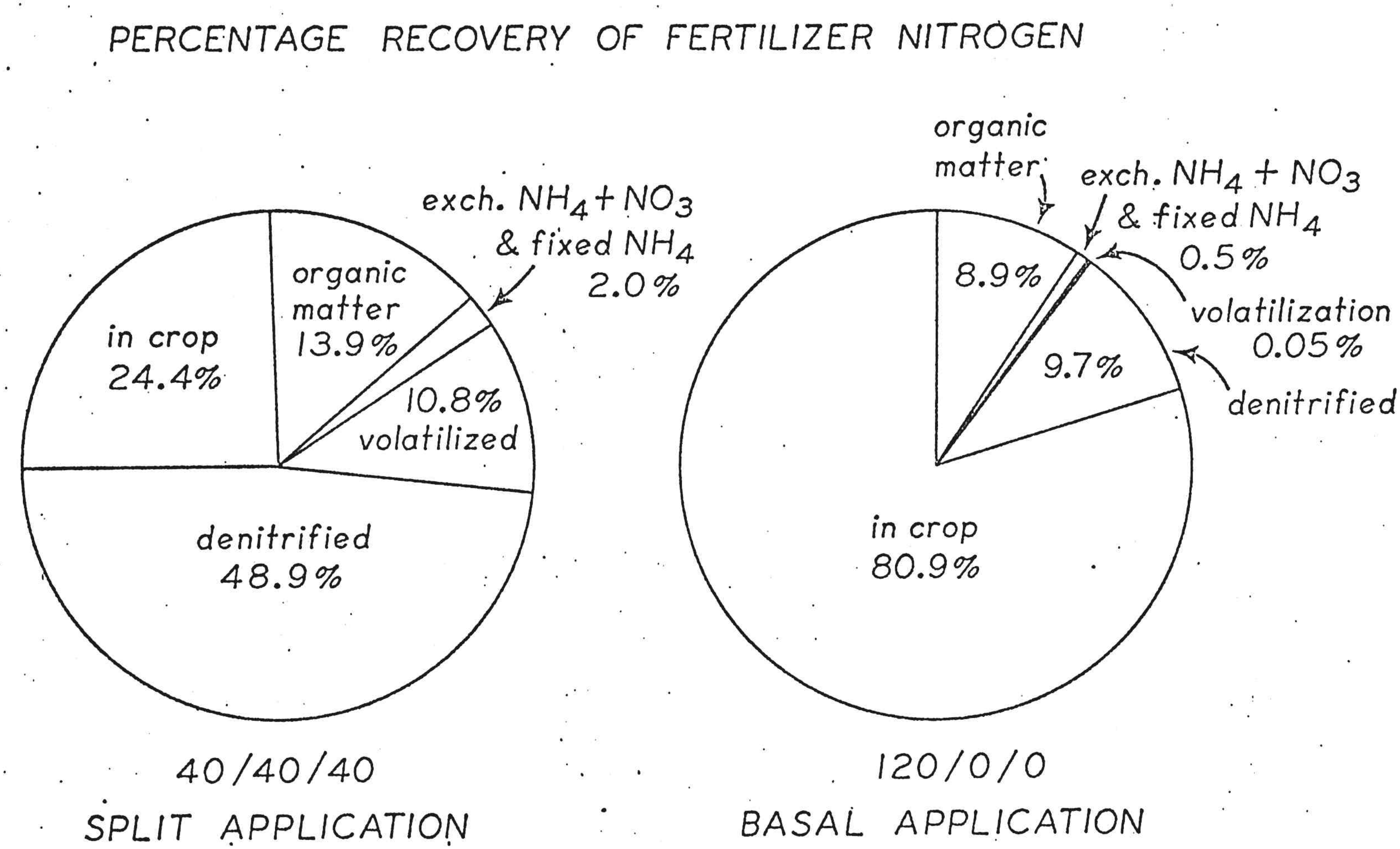

Fig. 4. Percentage recovery of fertilizer nitrogen with broadcast and pre-flood applications (120 N).

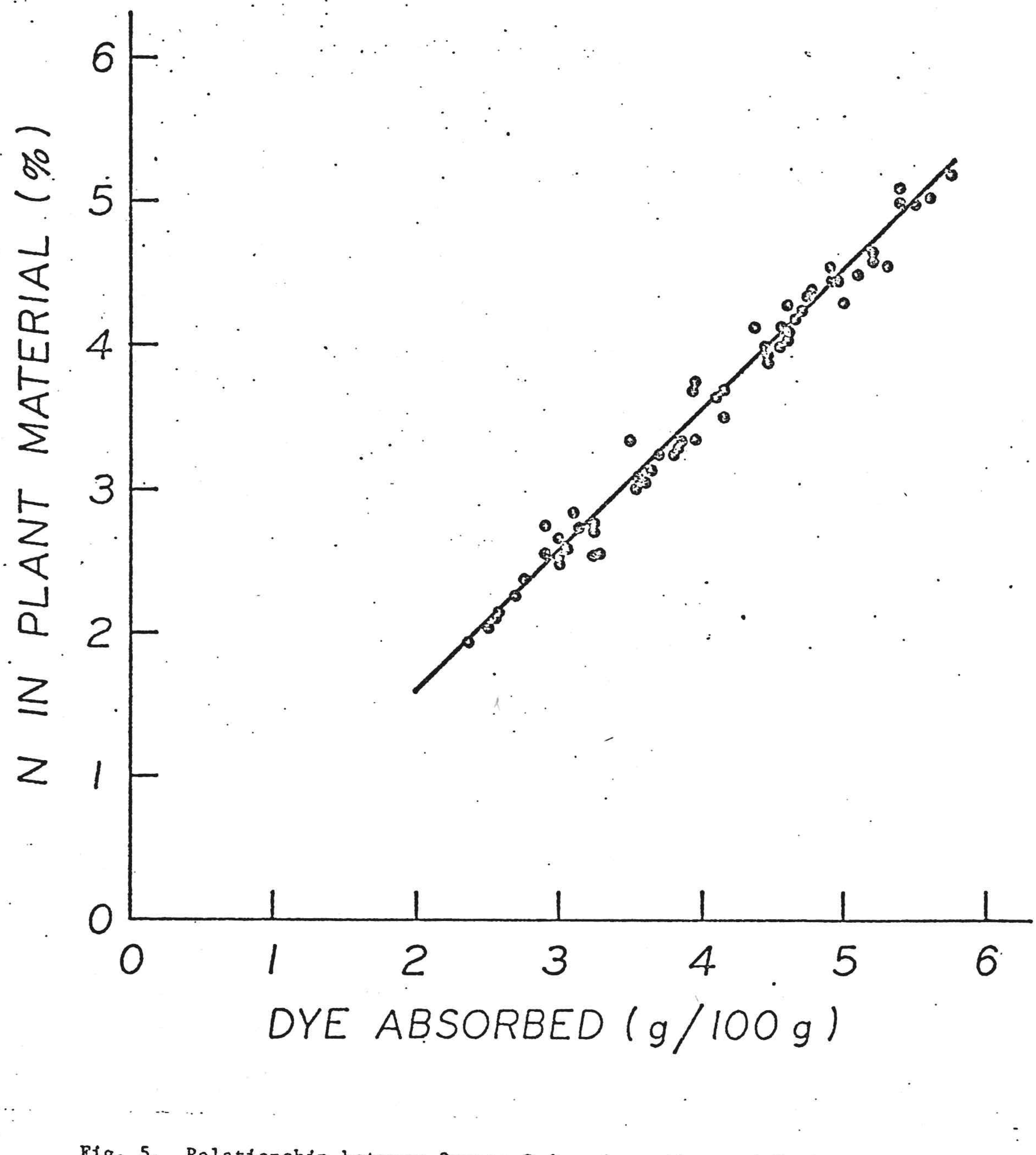

Fig. 5. Relationship between Orange G dye absorption and Kjeldahl nitrogen in rice leaf tissue.

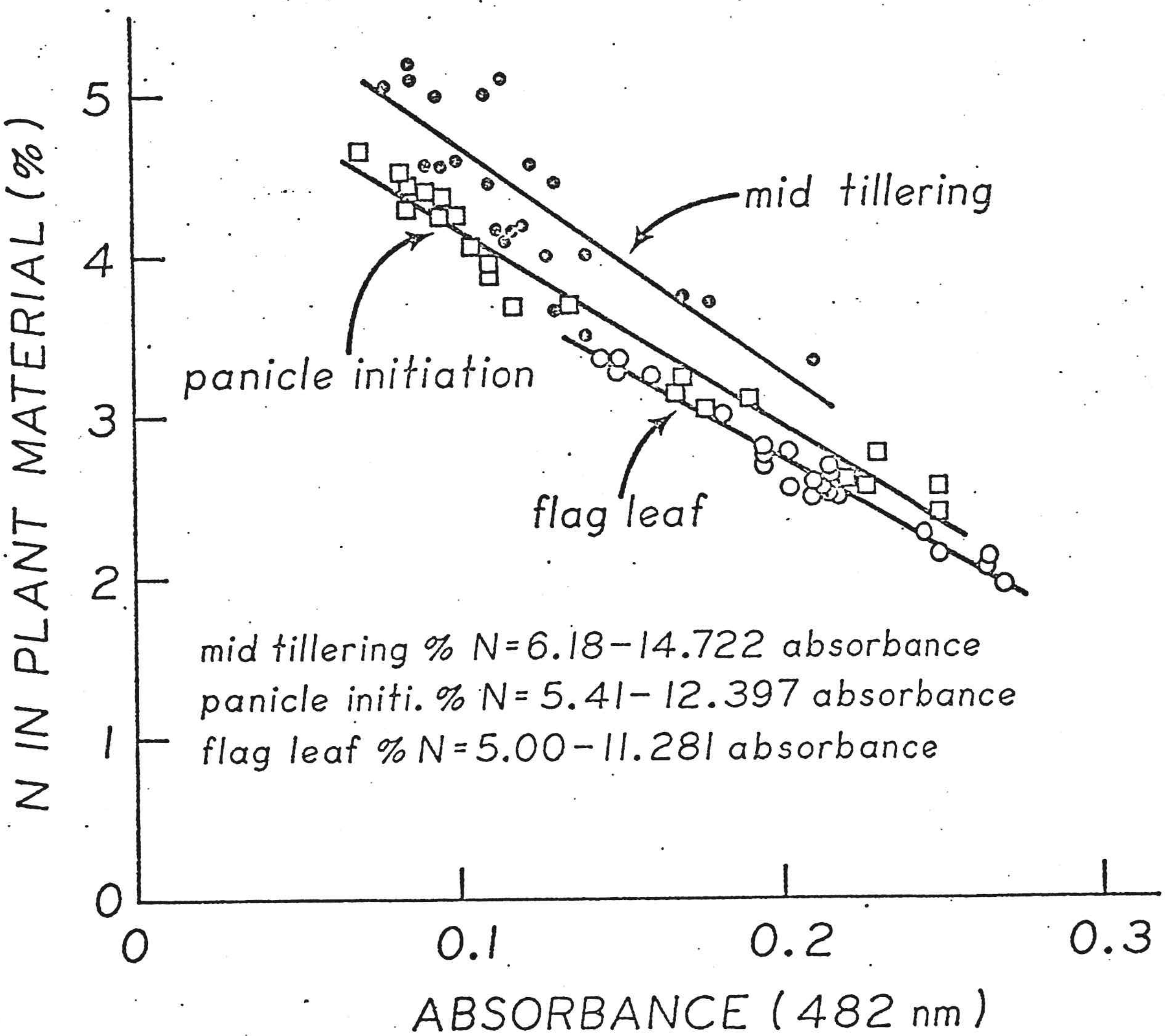

Fig. 6. Relationship between nitrogen content of rice leaves and dye absorbance at three growth stage.

In this research, an effort has been made to determine what the critical nutrient levels are for the short-statured, high yielding varieties now in use. A great deal of information has been collected during the past three years for nitrogen. At this time the complete data must be evaluated for varieties and the various stages of plant development. Critical research has not been conducted to determine if the critical nutrient values for P and K need to be changed.

On the basis of an incomplete evaluation of all the available data, it appears that the critical ntrogen values of the new varieties need to be adjusted to higher levels. This is reflected in part because of the greater nitrogen responsiveness of the short-statuted varieties to produce higher grain yields and also a lesser danger that lodging will adversely affect yields.

On the basis of new information the following tentative critical levels are suggested. Further refinement may be necessary as specific variety effects are examined.

Tentative Plant Analysis Guide for Rice

	Kjeldahl N values	
Growth Stage	Critical Value	Adequate Range
Mid-tillering	3.6%	4.0 - 4.8%
Panicle Initiation	3.0%	3.2 - 4.0%
Early Booting	2.4%	2.4 - 3.2%

2. The orange G-dye method for nitrogen determination was adapted as a rapid quantitative method for determining the nitrogen status of rice. The amount of dye absorbed by rice leaf tissue is highly correlated with N% determined by the Kjeldahl method Figure 5. The regression line, however, changes with each developmental stage in the growth of rice (Figure 6).

The ratio of plant material to aliquot of Orange G-dye, significantly affects the regression lines, especially at the mid-tillering stage.

The dye absorption method was tested on 60 tissue samples from three stages of rice development, mid-tillering, panicle initiation and the flag leaf stages. The regression lines derived from these comparisons are shown in Figure 7. There was no significant difference between the mean values of the Orange G dye and the standard Kjeldahl method ($p = .01$) and the standard deviation of the difference between the two methods was 0.2% N. The Orange G dye absorption to technique can provide an effective, rapid and low cost means of evaluating the nitrogen status of rice leaf samples from which fertilizer recommendations can be derived.

OBJECTIVE IV

Soil water quality constraints affecting rice production.

1. Effect of limestone hardpan material on the growth, grain yield and nutrient uptake patterns in rice: Subsoiling is often practiced on

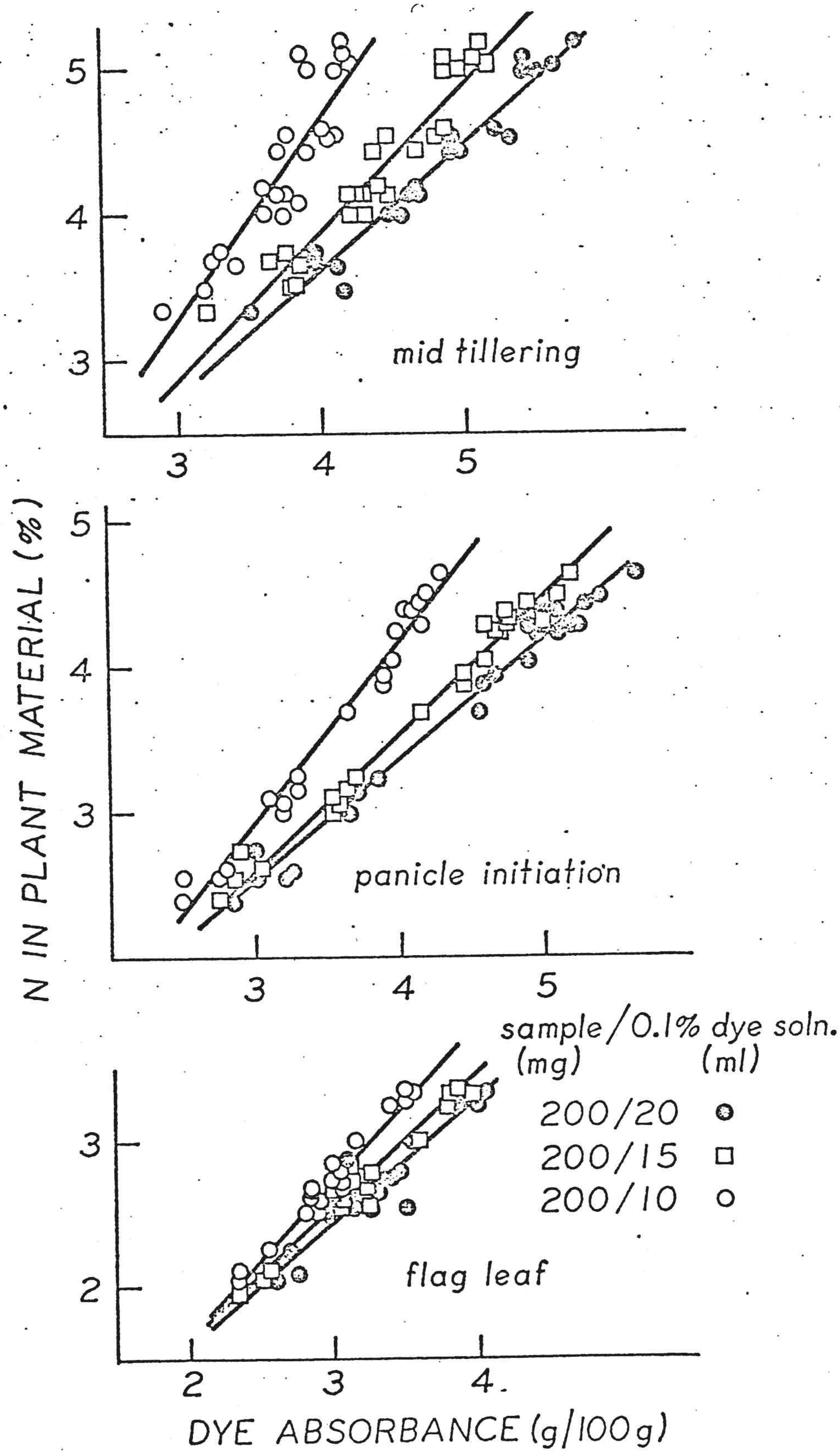

Fig. 7. Effect of ratio of plant material to dye solution on dye absorbance by rice tissue.

land where crops are rotated with rice. During subsoiling, hardpan and calcareous subsoil materials are often brought to the soil surface. When rice is planted on certain soils which have been deep-tilled poor growth of rice usually occurs, usually being severely stunted and chloratic directly in the subsoil channels.

A calcareous (limestone) hardpan material collected from a rice field where poor growth occurred after subsoiling, was brought into the greenhouse, with affected soil. The pulverized limestone was added to normal soil at the rates of 5 and 10 percent additions by weight. Zinc sulfate was applied to provide 5 and 10 pounds of Zn per acre equivalent and all treatments received 120 N nd 60 P_2O_5 equivalent per acre. Twelve rice seeds Variety M9 were planted in each pot and finaly thinned to 4 plants per pot. Treatments were harvested at the mid-tillering, flag leaf and mature growth stages for yield determinations and chemical analyses to determine the effect of the limestone subsoil material on the growth and nutritional status of rice grown on this soil.

The addition of pulverized limestone subsoil material to a soil in amounts ranging from 0 to 10 percent decreased the growth and grain yields of rice (Table 11). The plants were affected by a chlorosis resembling zinc deficiency. Increasing the limestone rate decreased the concentration and uptake of Zn. Increasing the zinc in the soil with zinc sulfate to suply 5 and 10 ounds per acre Zn increased plant zinc values and zinc uptake at the mid-tillering, flag leaf stage and at maturity (Table 11). Zinc applications helped alleviate the chlorosis and poor growth observed in the limestone treated soils.

The concentration of plant nitrogen and phsophorus in the plant material harvested at the mid-tillering and flag-leaf stage was decreased by the addition of limstone subsoil material (Table 12). The concentration and uptake of nitrogen increased and that of phosphorus decreased in mature rice plants (grain and straw) with increasing levels of applied zinc sulfate (Table 13).

Limestone hardpan brought to the surface by subsoiling increased the pH of the soil from 7.2 to about 7.6 with 5% limestone and to 8.3 with 10% additions. Limestone induced a deficiency of zinc which was corrected with 5 and 10 pounds actual zinc equivalent per acre as zinc sulfate.

OBJECTIVE V

Rice stand establishment problems, with emphasis on dissolved oxygen deficiency and its amelioration.

1. It has long been known that rice seed will germinate and seedlings will emerge when sown in water or when planted in a well-drained soil, but not when covered by both. When the dissolved oxygen levels surrounding rice seed fall below 0.3%, failure of germination and seedling establishment occurs. The development of water-sown rice culture in California takes advantage of the adequate oxygen levels occurring in irrigation water for satisfactory stand establishment. In the Southern States rice seed is often drilled into soil and then germinated by flush irrigation and complete

Table 11. Effect of limestone and $ZnSO_4$ on dry matter production and grain yields - variety M9.

	Dry matter and Grain yield (g/pot)					
	Straw			Grain		
Treatment	0Zn	5Zn	10Zn	0Zn	5Zn	10Zn
Control	18.5	19.8	21.5	12.4	14.4	15.8
Limestone 5%	17.4	19.1	20.8	9.8	11.2	14.5
Limestone 10%	14.0	17.4	19.8	8.0	10.1	11.9

LSD (.05) = 0 .42 LSD (.05) = 1.7

Table 12. Effect of limestone and $ZnSO_4$ levels on plant Zn concentration and total Zn uptake at different stages of development.

Treatment	Zinc concentration (ppm)				Zinc uptake (g/pot)			
	Mid-Tiller	Flag Leaf	Straw	Grain	Mid-Tiller	Flag Leaf	Straw	Grain
Control	58.6	25.6	23.2	16.1	63.7	420.1	450.1	219.3
Limsestone 5%	57.1	25.7	23.0	16.0	54.7	401.3	436.3	174.0
Limestone 10%	55.6	25.7	23.0	13.8	42.9	342.6	392.1	148.2
Zn 5 lbs/A	59.3	27.1	24.3	16.1	55.6	403.2	433.1	185.3
Zn 10 lbs/A	67.4	32.3	29.4	17.8	76.0	527.1	587.3	241.3
LSD (05)	1.05	1.04	1.16	1.10	1.05	15.8	21.6	12.5

drainage to aerate the soil for emergence. Whenever rice ssed is covered by both soil and water, sometimes with only a thin layer of silt, the supply of dissolved oxygen to the seed is cut off and seedling emergence is stopped.

Under stand establishment conditions where oxygen deficiency exists the coleoptile (sheath covering the first leaf) will emerge but until adequate oxygen is available emergence of the primary root and plumule (shoot) is restricted. Evidence obtained shows that coleoptile emergence precedes primary root emergence under water and that the rice coloptile is the morphological portion for the entry of oxygen to the developing seedling. If oxygen is limiting, elongation of the shoot is stimulated and root development is suppressed. It is suggested that the reduction of root-shoot rates under these circumstances may be caused by destribution of mitochondria in roots when they are subjected to anoxia.

Under California conditions low dissolved oxygen values in water-sown rice cause poor root development and consequently poor plant anchorge during stand establishment. Poorly attached seedlings often float and are blown to the levees by wind action. Another serious problem occurs when rice seed becomes covered with silt or soil after water sowing. Under these conditions, covered seed will fail to germinate and emerge, resulting in a low plant population.

Research conducted on this project has shown that many of the stand establishment problems encountered in water-sown rice can be prevented by coating rice seed with calcium peroxide (CaO_2). Seed coated with CaO_2 (60% active) at the rate of twnety to forth percent will provide adequate oxygen for emergence under all conditions and even when covered by 1 inch of soil and up to 6 inches of water. The use of CaO_2 as a seed coating material will allow rice seed to emerge under most conditions encountered in the field and enables rice seed to be drill planted or broadcast on a dry seed bed and covered lightly with soil. This alternative method of rice seeding opens many opportunities to reduce seeding rates, insure uniform emergence, enhance nitrogen use efficiency and to utilize new methods of weed control.

Calcium peroxide reacts in soil and water to liberate oxygen which rice seed can readily utilize. This chemical is first hydrolyzed to hydrogen peroxide (H_2O_2), an effective fungicide and calcium hydroxide ($Ca(OH)_2$), the H_2O_2 decomposing further to produce dissolved oxygen (O_2) and water. The rate of calcium peroxide degradation in flooded soils depends to a large extend upon soil pH, but remains efective as an oxygen provides for about 8-10 days after soil flooding. The rates of degradation in 3 California rice soils, with different soil pH values are shown in Figure 8. It is observed that calcium peroxide degradation is accelerated by acid soil conditions, but without alteration, it provides adequate oxygen for rice seedling emergence.

The effect of calcium peroxide seed coating on the percent emergence of rice seed (variety S-6) from water and water + 2.5 cm soil, together with seeding grwoth characteristics is shown in TAble 14. Calcium peroxide increase emergence percentage with each increasing rate in both water-sown and soil-sown seed. The calcium peroxide effect was significantly more

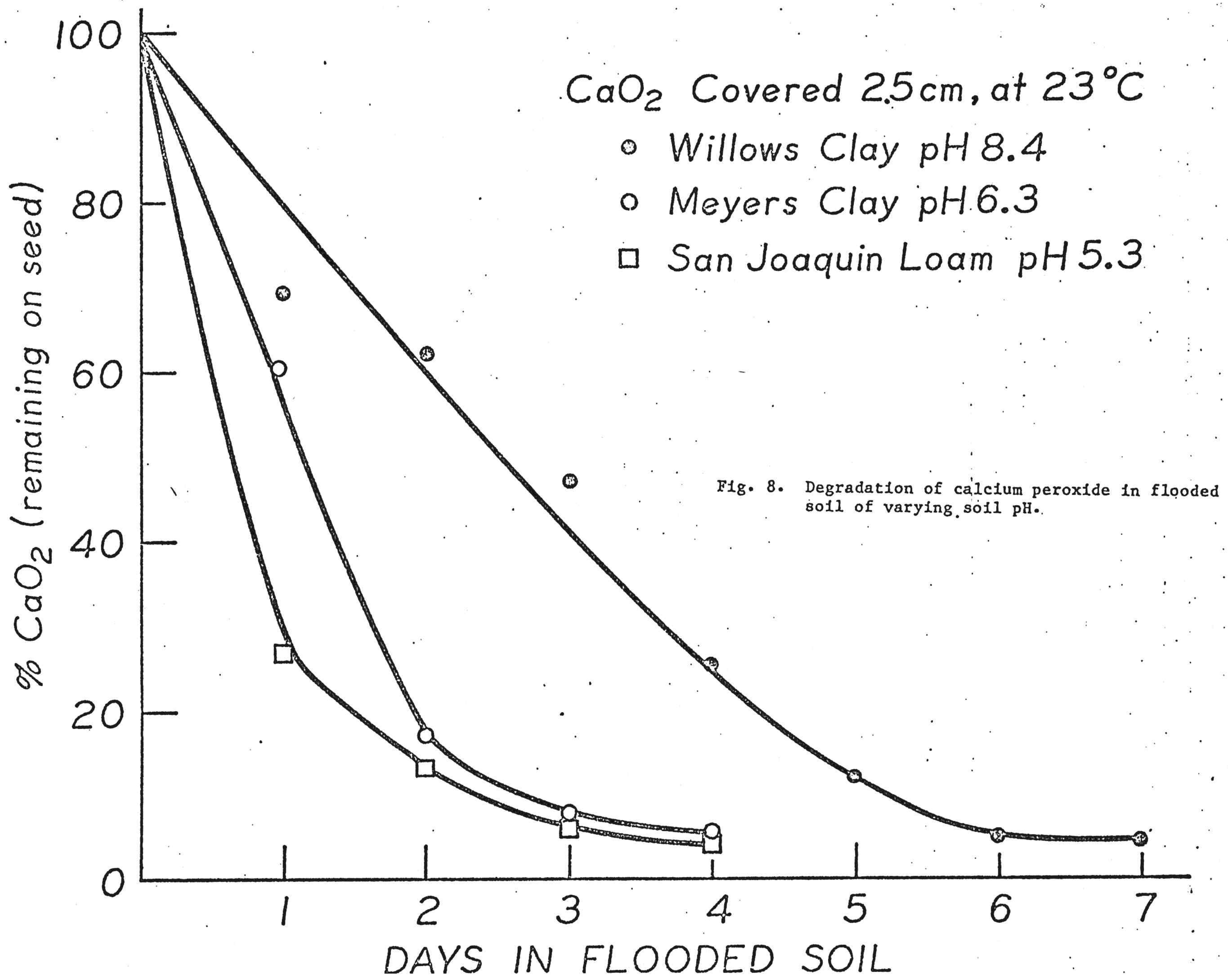

Fig. 8. Degradation of calcium peroxide in flooded soil of varying soil pH.

Table 14. Effect of CaO_2 coating on % emergence and rice seedling development.

	In Flood Water				Covered with 2.5 cm Soil + Water			
CaO_2	Emerg.	Plumule length	Root length	Root No.	Emerg.	Plumule length	Root length	Root No.
	%	mm	mm		%	mm	mm	
0	62	26	5	1	12	10	0	0
10	78	32	28	3	28	39	19	1
20	82	37	31	5	76	44	37	5
30	89	36	32	5	91	57	41	6
40	91	38	32	6	91	67	42	6

* Measurements 12 days after planting.

** CaO_2 was 60% material

Germination (%) 93%

Soil pH 6.2
Temp 30 C
Water 5 cm deep
Variety S6

Table 15. Effect of peroxide source on rice germination and seedling growth.

		CaO_2				MgO_2				ZnO_2			
	Control	10%	20%	30%	40%	10%	15%	18%	22%	10%	20%	30%	40%
% germination of rice seeds after 2 weeks--	69	72	76	76	81	73	81	74	80	80	81	76	86
Average seedling length (cm) after 2 weeks--	14	15	14	16	16	15	17	15	16	15	15	14	13
Average seedling dry wt. (mg) after 3 weeks--	9	13	12	14	16	10	13	9	11	9	10	11	18

* Rice seeds were broadcasted on soil flooded with 2" water. Variety S-6 - 92% germination.

Table 16. Effect of coating rice seed with CaO_2 on rice yields and stand establishment.

Seed Coating Treatment	Seedling rate (lbs/acre) 75# (1974)	150# (1974)	75# (1979)	150# (1979)	Stand Establishment 75# seedlings	150# seedlings	75# mature plants	150# mature plants
CaO_2 10%*	2070	3420	6570	7380	50	33	79	54
CaO_2 20%	6260	6885	6450	6940	54	33	90	58
CaO_2 30%	7330	7565	7730	7520	78	52	103	68
CaO_2 40%	7860	7920	6820	7730	77	55	94	72
California practice**	5275	5820	5180	6860	32	23	55	47

* Seed coated with CaO_2 (60%) and covered with 2.5 cm soil.

** Pre-germinated and broadcast into water.

effective in the soil-planted seed than where broadcast into water. Plumule length, root length were increased in all treatments with calcium peroxide, and the greatest seedling development occurred in 30 and 40% (wgt. basis) of calcium peroxide coated on seed.

Various peroxide chemicals release oxygen when placed in water or soil. In order to determine if one source was more effective than another, three of the most economical materials were evaluated as seed coating materials on seed broadcast into 2 inches of water. The comparison of peroxides of calcium, magnesium and zinc were made at different levels of seed coating. Calcium and zinc peroxides were loaded on rice seed at similar rates, but it was not possible to coat seed with MgO_2 at similar rates. The active oxygen content of calcium, magnesium and zinc peroxides were 13.3, 14.2 and 9.0 percent, respectively. Peroxide coatings significantly increased the germination percentage of water sown rice, slightly enhanced seedling length and increased dry matter production on seedling growth by values ranging up to 100 percent with 40% MgO (Table 15).

Field experiments have been conducted in recent years to determine the quantity of calcium peroxide required for satisfactory stand establishment under conditions where the seed is placed 1 inch deep in the soil. Table reports the effects of 0, 10, 20, 30 and 40% calcium peroxide coatings (wgt basis) on stand establishment and crop yields.

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GENERAL SUMMARY OF CURRENT YEAR'S RESULTS

1. Improved rice plant types, with short plant stature, greater resistance to lodging and increased nitrogen fertilizer responsiveness offer significant rice production advantages. The experimental variety 78-Y-38+41 was outstanding among the early varieties evaluated in nitrogen fertilizer trials.

2. Fertilizer nitrogen use efficiency is significantly improved where all of the crop nitrogen requirements can be applied 4 to 6 inches deep prior to flooding. Losses of nitrogen resulting from denitrification and ammonia volatilization are significantly reduced by pre-flood placement compared with top-dressings.

3. Applying fertilizer nitrogen pre-flood, is always as effective and frequently superior to split nitrogen applications within the range of optimum nitrogen roots. Split applications do not improve fertilizer use efficiency and are more easily to employ.

4. The critical nitrogen values for the short-statuted, nitrogen responsive varieties must be readjusted to higher values. Tentative values have been suggested, but recent findings must be studied in detail for varietal and location effects.

5. The Orange 6-colorimetric test for diagnosing the critical nitrogen levels in rice must take into consideration the fact that regression lines change with different rice developmental stages.

6. Land levelling and/or subsoiling can expose limestone hardpan material which elevates soil pH and induces zinc deficiency. The chlorosis can be corrected with zinc fertilizer, which enhances Zn uptake, plant growth and rice yields.

7. Calcium peroxide is an effective source of oxygen for rice germination and seedling emergence. When coated on seed planting can be accomplished with a grain drill, or seed can be broadcast and covered with soil before flooding. When oxygen deficiency is corrected and seds are placed in soil, higher plant survival is obtained, seedling drift is eliminated, seedlings are well anchored and growth is superior to water sowing.