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COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE: Reassessing Soil N Availability and Fertilizer Recommendations Under Alternative Rice Residue Management Practices.

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SUMMARY OF 1999 RESEARCH RESULTS BY OBJECTIVE

Specific Objectives:

1. To assess changes in grain yield as affected by alternative residue management practices in rice cropping systems.

2. To reevaluate nitrogen fertilizer recommendations and optimize nitrogen use efficiency in rice cropping systems under alternative residue management practices.

Summary of 1999 research results:

Introduction

One of the essential questions to be addressed is how prolonged incorporation of rice straw residue will affect the total N supplying power of soil to the subsequent rice crop uptake. Soil organic N is the major source of N for fertilized rice. Past research has shown that 50-80% of N taken-up by the plant comes from native soil N. Incorporating rice residues will add on average 75 lbs. N/A to the soil annually compared to 25 lbs. N/A with burned residues. This residual straw N is initially tied up as organic N but following decomposition, N will be released and become available to the crop. The question to be answered is not only how much of the N (and other nutrients) from the residue will become available but also how well this N can be used by the crop in order to reduce fertilizer-N input. In addition, the availability of soil N impacts the incidence of weeds and pests. Related to this question is how specific straw management practices such as straw removal through baling versus incorporation will impact long term soil quality and nutrient availability. Although we have concentrated on N, the long term effect of straw removal on K and P availability should not be ignored and should be addressed in relation to N use efficiency and the general health of the rice crop. In particular on the east side of the Sacramento Valley where, in general, soil extractable K is significantly lower than on the west side of the Sacramento Valley. Deficiencies in K in the eastern portion of the Valley will become apparent once straw is baled on a regular basis.

The impact of winter flooding on N availability remains an intriguing question. Whereas the argument can be made that winter flooding would reduced decomposition because of the anaerobic conditions, we know from practical experience that winter flooding results in less surface residue in the spring which suggest strongly that decomposition was enhanced. Whether more rapid straw decomposition leads to an increase in nutrient availability for crop uptake or improved the overall quality of the system to improve and sustain yield is currently being investigated.

OBJECTIVE 1 **To assess changes in grain yield as affected by alternative residue management practices in rice cropping systems.**

Grain Yield

At the two long-term straw management sites (Maxwell and Biggs), grain yields have not been affected significantly whether straw was incorporated or removed at present fertilizer application rates. It should be stated that N fertilizer input has been kept more or less constant over all those years. This pattern of unchanged grain yield continued in 1999 and yield at both the Biggs and Maxwell did not increase nor declined compared to the control treatment (burned and non-winter flooded) (Figs. 1 and 2). It should be pointed out that the field variability at Biggs is large and it will always remain difficult to find statistical significant differences between treatments at Biggs. For example, baling straw at Biggs showed a lower grain yield than the other straw treatments but the difference was not significantly different. At both sites, baling and winter flooding led to the lowest yield whereas at both sites straw incorporating, rolling and burning showed the highest grain yield. In the long-term straw management experiment, the main difference between incorporating and rolling is that straw incorporation occurs in the fall whereas when the treatment calls for rolling the straw is rolled in the fall and the incorporation occurs in the spring. In both cases, all the nutrients in the straw are retained at the site in contrast to burning and baling the straw (loss of all most of the N).

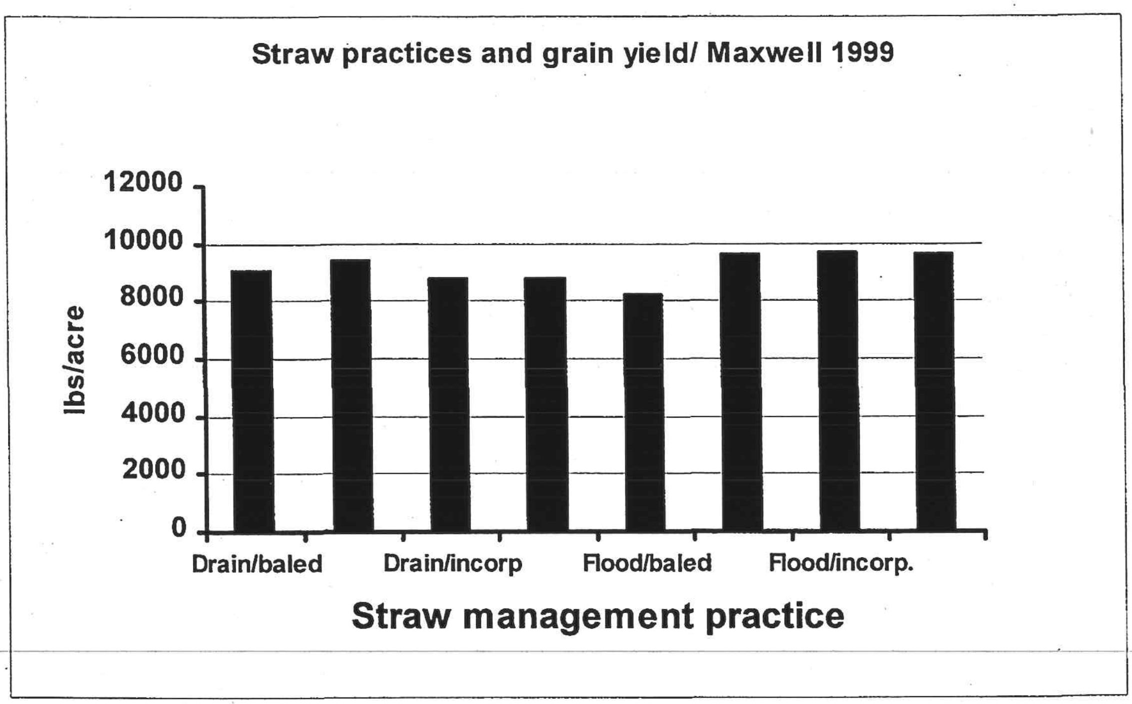

Figure 1. Yield of rice grain Maxwel 1999, after 6 seasons of alternative straw management practices.

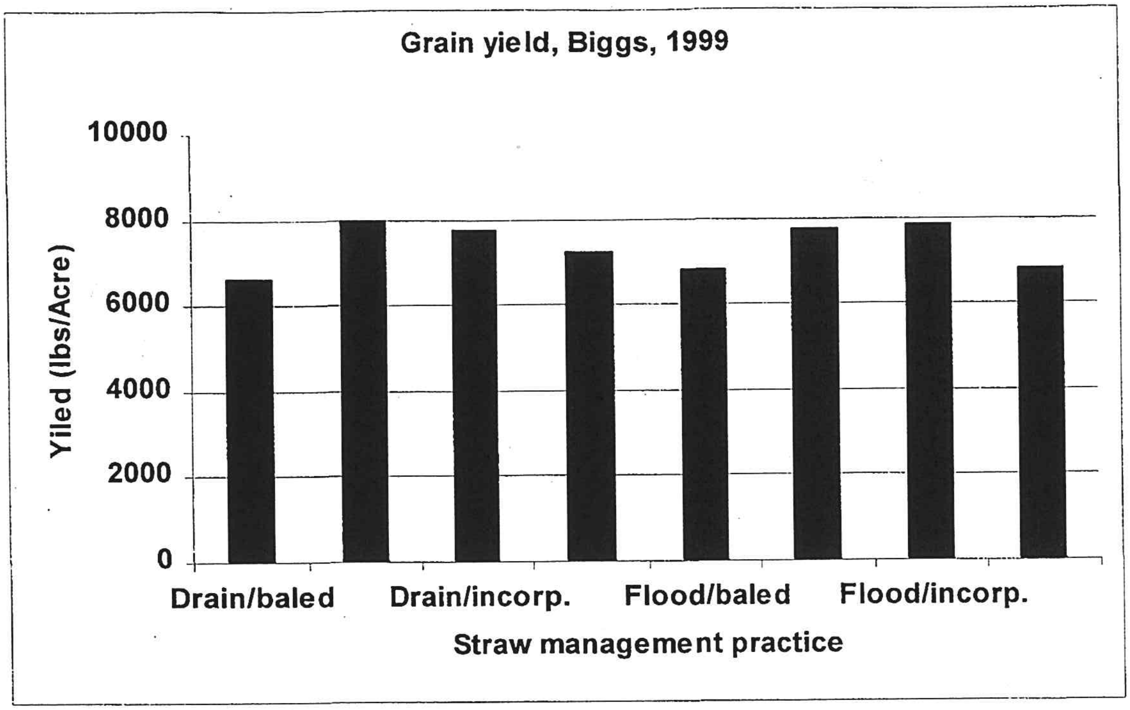

Figure 2. Yield of rice grain Biggs 1999, after 5 seasons of alternative straw management practices.

In general, the amount of straw produced was not affected by any of the alternative straw management practices and was 6500 lbs./A at Maxwell and 6900 lbs./A at Biggs (Table 1). Because the average amount of straw produced at Biggs was higher than at Maxwell and the overall grain yield was lower, the harvest index (defined as the amount of grain produced divided by the total amount of biomass produced x 100) was significantly lower at Biggs (Table 2). Clearly, management practices that improve the harvest index and, therefore, grain yield at Biggs, and elsewhere where a low harvest index is observed, should receive attention. The method by which fertilizer-N is applied (drilled versus aerial application) or the removal of any other nutrient deficiency (possible K) should be considered. At Maxwell in 1998, harvest straw samples were analyzed for essential nutrient to identify any non-N nutrient deficiency or toxicity that may be causing yield effects (Table 3). No significant differences in straw nutrient concentrations were found among straw management treatments at Maxwell.

The amount of N that is required to produce a ton of grain also has to be taken into consideration. The amount of N needed for a ton of grain is the sum of the plant-available N in the spring plus the amount of N released from soil organic matter plus the amount of N fertilizer, minus the amount of available N in the fall. Currently, the amount of N that is needed at Biggs to produce a ton of grain is calculated to be 64 lbs. of N whereas at Maxwell, only 37 lbs. of N per ton is needed. Great improvements in N utilization efficiency can be made at Biggs. Method of N application and possible removing other nutrient deficiencies like K should be the first issue to be considered.

Table 1. Impact of winter flooding and straw management on residue production in 1999.

Straw management		Maxwell	Biggs
		lbs./A	lbs./A
winter flooded	burned	5982	7728
drained	burned	6554	6784
winter flooded	incorporated	6537	6396
drained	incorporated	6367	7309
winter flooded	baled	6365	6427
drained	baled	6840	7754
winter flooded	rolled	6140	7307
drained	rolled	7162	5727

Table 2. Impact on straw management practice on harvest index defined as (total grain weight/total biomass)*100, in 1999.

Straw management		Maxwell	Biggs
		Harvest index (%)	
winter flooded	burned	56	45
drained	burned	57	50
winter flooded	incorporated	55	50
drained	incorporated	55	48
winter flooded	baled	52	47
drained	baled	54	44
winter flooded	rolled	57	47
drained	rolled	55	51

Table 3. Straw nutrient concentration, Maxwell site, harvest 1998.

TRT	N	P	K	S	Ca	Mg	Na	Cl	B	Zn	Cu	Mo
	%	g kg-1						ppm				
Burn	0.61	1.40	7.23	1.04	2.85	1.81	7.93	0.80	14.6	41.0	30.9	2.26
Incorporated	0.67	1.33	7.96	1.03	2.79	1.83	7.71	0.77	13.8	41.3	30.6	2.36
Roll	0.69	1.30	7.53	1.00	2.78	1.83	7.94	0.78	15.8	42.4	36.5	2.61
Bale	0.70	1.40	7.91	1.04	2.73	1.89	7.39	0.79	14.8	40.8	23.2	1.84
winter flood	0.66	1.34	8.13	1.02	2.81	1.84	7.35	0.87	14.6	40.8	32.1	2.40
non-w. flood	0.69	1.38	7.18	1.03	2.76	1.83	8.13	0.69	14.8	41.9	28.5	2.14
Mean	0.68	1.35	7.65	1.03	2.78	1.84	7.75	0.78	14.72	41.4	30.80	2.27

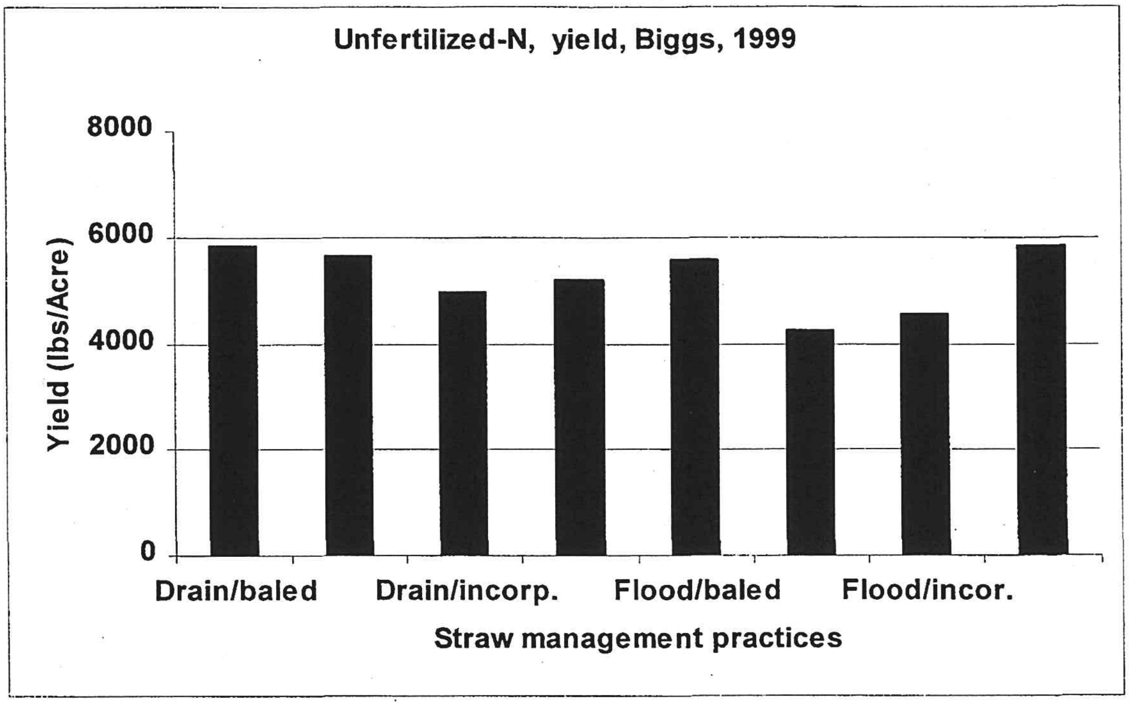

Fig. 4. Grain yield at Biggs without N fertilizer added, 1999.

In order to determine the effects of straw management on fertilizer use efficiency and soil N supply, we determined the amount of N taken-up by rice plants from applied fertilizer N and native soil N at the Maxwell in 1997, Biggs in 1998, and on a red soil (Yuba) in 1998 using stable isotope N tracers (Table 4). Fertilizer use efficiency at Maxwell was 37% in 1997, 28% at Biggs and 15% at Yuba in 1998. Fertilizer use efficiency by incorporated treatments was less than burned at Maxwell and Biggs. At Biggs, fertilizer use efficiency was 24% for incorporated plots; while burned plots had an N fertilizer use efficiency of 31%. However, native soil N supplied more N to the rice crop in incorporated plots than burned at Maxwell and Biggs showing the influence of straw incorporation on the availability of soil organic N. Further, N uptake was much greater at Maxwell due to greater soil N (0.17% at Maxwell versus 0.10% at Biggs). Loss of applied fertilizer N below the root zone and to the atmosphere was similar at both long-term sites (36%) and among straw management treatments. Lower fertilizer use efficiency by incorporated straw plots versus burned did not result from higher losses; unused fertilizer N was likely converted into organic N by microbes in the incorporated plots. Organic N in the rapidly mineralizable N pool of humic acid N has been found to be greater in the incorporated treatments that the burned (Fig. 5). This pool of organic N has been built up by five successive seasons of straw incorporations and provides incorporated plots with greater N supplying power than burned plots. At the Yuba site, applied fertilizer loss was very high at 71% of applied fertilizer. The Yuba site has a coarser soil texture and losses of fertilizer may have occurred through leaching.

In general, we can conclude that the different alternative straw management practices (baling, rolling and incorporation in the spring, and incorporation in the fall with or without winter flooding versus the control, i.e., burning) have not led to an increase nor a decrease in grain yield after 5 and 6 years of alternative straw management practices. There are differences in grain and straw yield between the two sites but the general response to the alternative rice straw management at the two sites remains consistent. The concern that grain yield would decline because of an increase in pest or weeds did not manifest itself at this stage. However, it remains to be seen whether pest and weed pressure will increase due to of changes in seed bank and inoculum potential. Further, would this weed and pest pressure reduce grain yield? If this decline in yield does occur, grain yield can then only be sustained through an increase in pesticide input.

OBJECTIVE 2 **To reevaluate nitrogen fertilizer recommendations and optimize nitrogen use efficiency in winter flooded and non-flooded rice cropping systems.**

To determine differences in soil N supply power as affected by residue management, rice was grown without any N fertilization. At Maxwell, the highest grain yield was observed when straw was incorporated or rolled followed by winter flooding whereas the lowest yield was observed when straw was baled, burned and rolled without winter flooding (Fig. 3). At Biggs, grain yield without any N-fertilization was much higher than at Maxwell which suggest that the background fertility level at Biggs is higher than at Maxwell (Fig. 4). However, it was more difficult to decipher a pattern at Biggs as the response to winter flooding and straw removal on grain yield remains variable at this site. In addition, the high background N fertility at Biggs may create a residual N effect masking the outcome of any treatment effect.

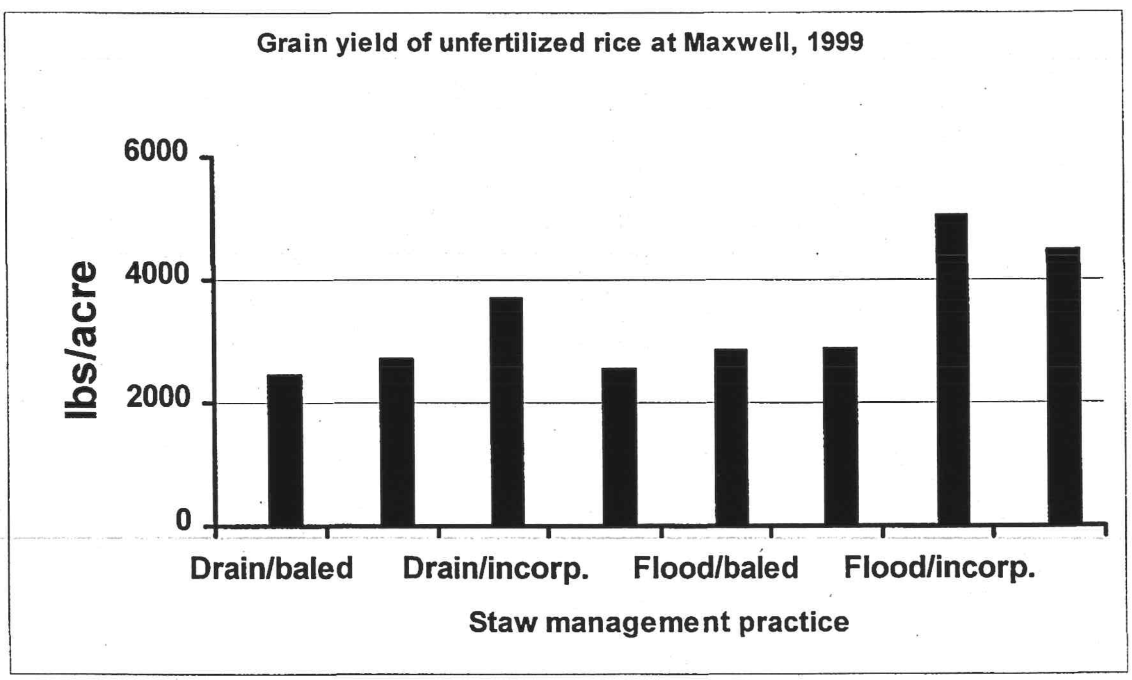

Fig. 3. Grain yield at Maxwell without N fertilizer added, 1999.

Table 4. N uptake from fertilizer N and native soil N at Maxwell, 1997, Biggs, and Yuba sites 1998. Only incorporated, flooded straw was examined on the red soil site (Yuba). Applied fertilizer N at Maxwell in 1997 was 168 lbs. N/A , 126 lbs. N/A at Biggs, and 100 lbs. N /A at Yuba.

Straw Treatment	Plant uptake of N sources								
	Maxwell			Biggs			Yuba		
	Total N	Soil N	Fert N	Total N	Soil N	Fert N	Total N	Soil N	Fert N
	lbs $Acre^{-1}$								
burn/winter flood	157	88	69	116	78	38			
burn/non-winter flood	169	100	69	117	77	40			
incorp./winter flood	173	109	64	125	96	29			
incorp./non-winter flood	171	116	54	112	80	32	104	89	14

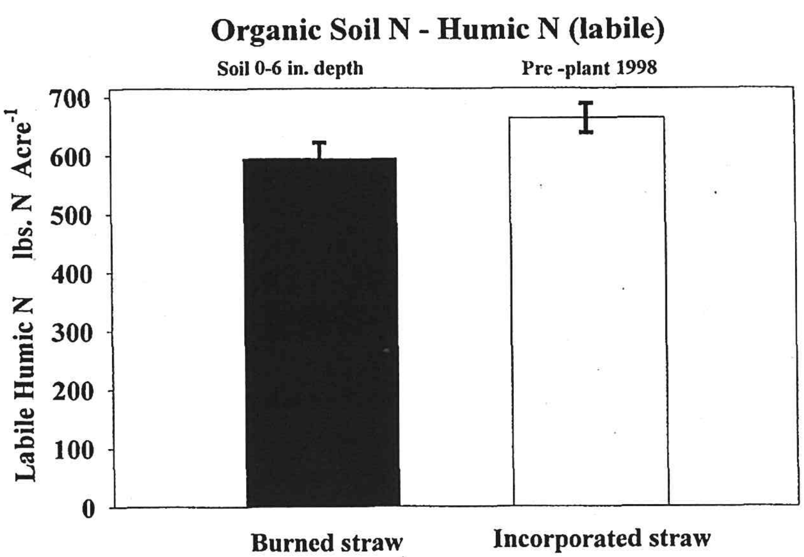

Fig. 5. Soil organic N (labile humic N) after 5 seasons of straw management, Maxwell 1998.

To determine the overall impact of burning or incorporating straw grain yield was further assessed in an N rate trial conducted at Maxwell. Different rates of N were applied (0 to 150 lbs. N/A) and a response curve was established (Fig. 6). Clearly, the burning of the straw led to a decline in overall soil-N availability and grain yield of unfertilized rice when straw was burned compared to about half of the grain yield obtained when straw was incorporated. From Fig. 6 it can also be calculated that about 50 lbs. N/A more fertilizer-N would be needed when straw was burned to achieve a grain yield that was equivalent to a grain yield obtained under zero N fertilizer application following straw incorporation. Clearly, when straw in incorporated, the plant-available soil N pool was increased significantly.

It is also clear that an N rate higher than 100 lbs. N/A when straw is incorporated did not lead to any increase in grain yield. A similar fertilizer-N response to grain yield was observed last year and no further increase in grain yield was observed above 100 lbs. N/A. Therefore, we recommend that when incorporating rice straw for a number of years (5 or more), the rate of fertilizer-N application does not have to surpass 100 lbs. N/A. Although a similar result was obtained at another field site (Mathews Farms), it remains to be seen how accurate this value is for the entire rice growing area in CA.

However, some caution on N fertilization practices is required when the straw is burned. By increasing the rate of N-fertilizer under burned conditions, the N response curve did not reach a maximum yield at the highest rate of N applied (150 lbs. N/A) (Fig. 6). Similar results were obtained last year at the same site when the highest rate of N applied did not lead to a maximum grain yield. In contrary, maximum grain yield when straw was incorporated was already obtained at a rate of 100 lbs. N/A. Therefore, it appears that under straw incorporated conditions, the N supply of the soil has improved but the maximum yield potential might have been jeopardized. When straw is burned, the supply power of the soil has declined but a higher maximum yield can be achieved when sufficient N is made available. In other words, for a rice system that incorporates straw for an extened period, factors other than available N control maximum yield at higher rates of N fertilization. In contrast, an increase in grain yield under straw burning management practices still occurs. Possible causes of N yield constraints under straw incorporation, called the non-N effects, could be an increase in weed population and diseases when straw is incorporated (Fig. 6).

Winter flooding showed a consistent increase in grain yield under different levels of N fertilizer input (Fig. 7). Because the two response curves to increased N application are parallel to each other (except for the highest rate of N), the difference may not be induced by N availability but rather a non-N effect. Plant available N, monitored at the Maxwell site from spring 1997-spring 1999, show that winter-flooded burned and incorporated treatments resulted in more plant available inorganic N than the respective non-winter flooded treatments, both during and prior to the growing season (Fig. 8). These differences were generally small, with the exception of available N during July in the 1997 season. At present time, we do not have a clear indication what caused such an increase in grain yield under winter flooded conditions. Again, a reduction in pests (insects or weeds) may be a factor. For example, stem rot and rice water weevil may decline when fields are flooded during the winter months, leading to a reduction in the pest pressure.

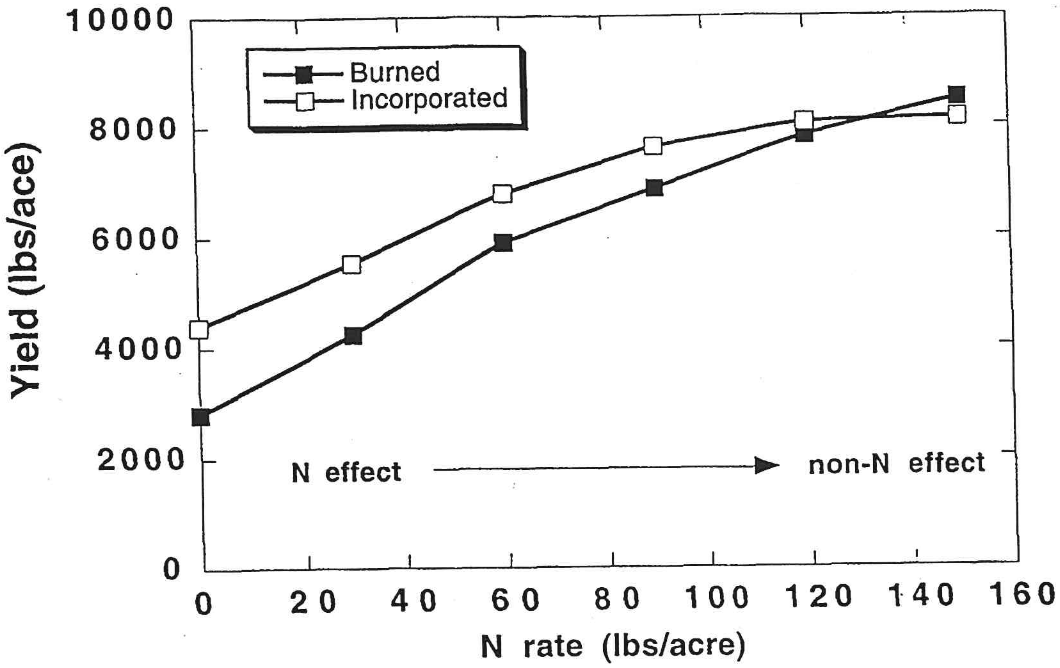

Fig. 6. Yield of rice grain at various N rates of burned and incorporated straw treatments, Maxwell, 1999.

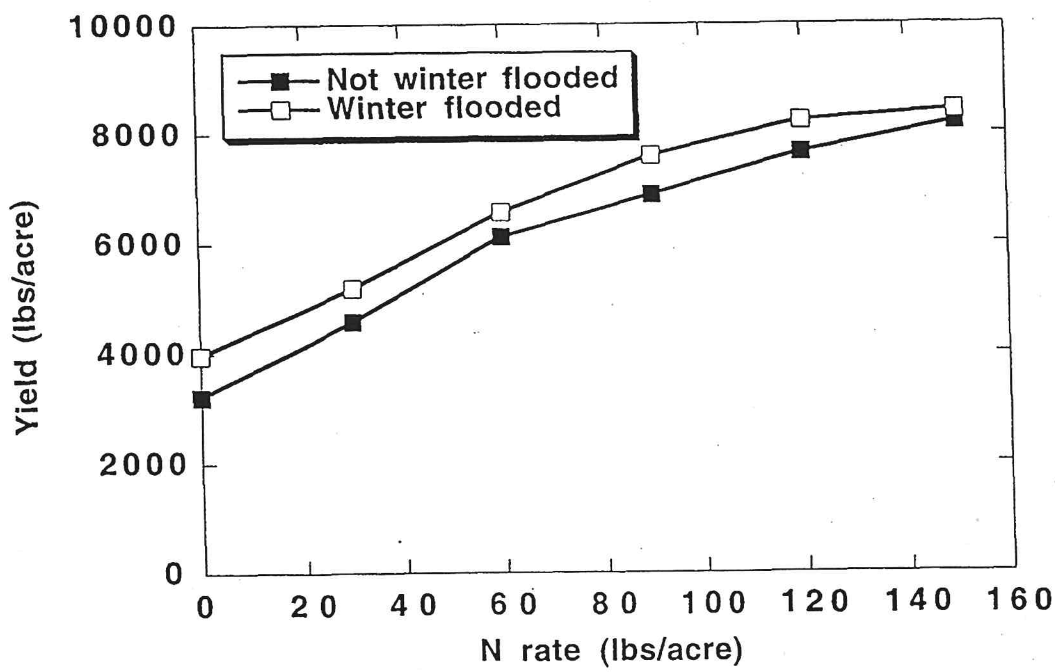

Fig. 7. Yield of rice grain at various N rates of winter-flooded and non-winter flooded treatments, Maxwell, 1999.

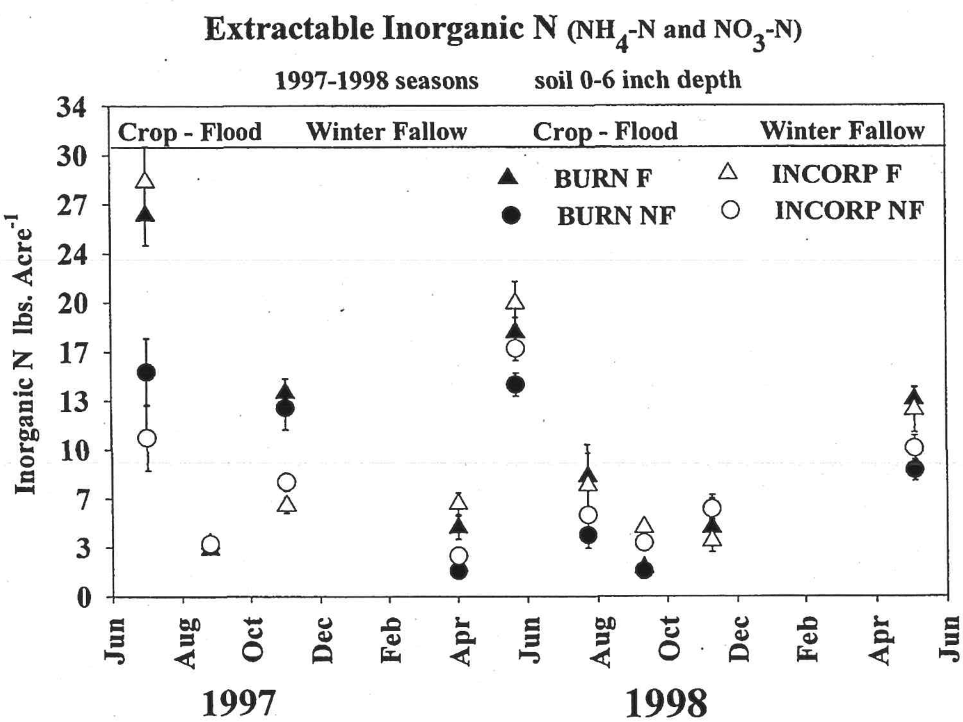

Fig 8. Plant available soil inorganic N at Maxwell for the winter-flooded and non-winter flooded burned and incorporated plots, 1997-1999.

CONCISE GENERAL SUMMARY OF CURRENT YEARS RESULTS:

1. To assess changes in grain yield as affected by alternative residue management practices in rice cropping systems.

After six years of implementing alternative rice straw management practices, grain yield did not decline compared to burning rice straw. The possible increase in disease pressure when straw is incorporated or rolled was not severe enough that it would lead to a grain yield decline under current fertilizer practices. It remains to be seen whether such an increase in pest will become severe enough in the future that a decline in yield does become apparent. An increase in soil N availability could lead to an increase in weed and disease pressure. A notably example is Blast, which is sensitive to available soil N.

2. To reevaluate nitrogen fertilizer recommendations and optimize nitrogen use efficiency in rice cropping systems under alternative residue management practices.

When straw has been incorporated and winter flooded for 6 years or more, no further yield increase was observed when the rate of N application exceeded 100 lbsN/A. Therefore, the rate of the amount of N fertilizer applied can be reduced to 100 lbsN/A. At Maxwell, the rate of N application can be reduced at least by 25 lbsN/A of the rate of N fertilizer currently recommended, approximately 140 lbs/A. This reduction would be supported by greater N supplying power from soil organic N (humic N) built-up over years of straw incorporation.

When straw is burned, the grain yield under zero N fertilizer application is about half of the grain yield when straw is incorporated. However, there is now some evidence that the grain yield when straw is burned may well exceed the maximum grain yield that can be obtained when straw is incorporated. The possible causes for a decline in the maximum yield obtained under straw incorporated conditions may be due to non-N effects like an increase in weed pressure or diseases.