ANNUAL REPORT
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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OBJECTIVE AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

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

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

The field site is an on-going, four-year-old rice straw residue management trial located in Maxwell, CA on a Willows clay (fine, montmorillonitic, thermic, Typic Pelloxerert). The soil is 51% clay with a total C content of 19.7 g kg^{-1} and 1.70 g kg^{-1} N. The site has large field-scale plots (2 ha) representing different rice straw residue treatments including burning, incorporation, winter flooding and winter fallow without flooding. The plots are managed with agronomic practices typically for California rice production (i.e., tillage, burning, flooding, fertility, and pests). In May 19972, 16, 4 * 3 meter microplots were established in the following four treatments: 1) residue incorporated and winter flooded, 2) residue burned, winter-flooded, 3) residue incorporated, non-winter flooded and, 4) residue burned, non-winter flooded in all four repetitions of the main field study.

Enriched urea fertilizer (^{15}N, 9.99 % atom excess) was uniformly applied to microplots at a rate of 2.4g of ^{15}N per plot just prior to planting in a dilute water solution and immediately incorporated. A nitrification inhibitor was applied with the N fertilizer (N-Serve 24E, nitrapyrin: 2-chloro-6-(trichloromethyl) pyridine- Dow-Elanco, Indianapolis, IN) at a half-strength field rate of 0.4 L ha^{-1} to reduce losses of applied N during the few days prior to flooding. Aluminum barriers were placed around the exterior of the microplots to a soil depth of 0.3 m to reduce lateral flow and dilution of the applied fertilizer N.

Straw residue management in the microplots for the incorporated treatments was accomplished using a small-scale chopper and tiller to simulate field-scale operations while conserving the integrity of the microplots. Straw residue on the burned microplots was removed for accompanying studies and replaced with equivalent amounts of unlabeled rice straw from the adjacent main plots. Microplots were harvested with a micro-plot combine-harvester. All other agronomic operations on the microplots will be accomplished using field-scale equipment.

Soil and plant samples were taken throughout the growing period. Soil samples were taken every two months while samples for plant N determination were taken approximately every 3 weeks. Soil samples were stored at 4°C and analyzed within 3 days. Inorganic N (NO_3^- and NH_4^+) was extracted with 2 N KCl (5:1 extractant to soil) and determined on an auto-analyzer (Lachet, Mequin, WI). Labeled NO_3^- and NH_4^+ was diffused onto Whatman #1 filter paper for ^{15}N analysis (Brooks et al. 1989).

Microbial biomass determinations were done using the Chloroform-Fumigation Incubation method. The movement of ^{15}N labeled fertilizer into microbial biomass was analyzed according to Brooks et al. (1989) and Horwath and Paul (1994). Additional soil sample was air dried, then dried at 40°C, and finally ball milled. Plant samples were separated into shoots and roots, dried at 60°C and ball-milled. Labeled and total N in soil and plant samples was determined on a Gas Chromatograph-Mass Spectrometer (Europa Scientific, Crewe, England).

SUMMARY OF 1997 RESEARCH RESULTS BY OBJECTIVE

OBJECTIVE ONE

Preliminary two year results indicate that winter flooding increases straw decomposition without impacting rice yield at the Maxwell and Biggs research sites (Kraus and Linquist, personnel communication). However, the long-term impacts of rice straw decomposition can not be evaluated with limited short-term studies. Nitrogen immobilization and mineralization process will be affected by organic matter additions. Initially, the high C to N ratio rice straw may immobilize N. After many years of residue incorporation, a large pool of organic may build up and supply mineral N through mineralization processes. We examined available N at both Maxwell and Biggs sites.

Available soil N at both the Biggs and Maxwell site was similar during flood and non-flood periods (Figure 1 and 2). During the winter and summer flood periods, the dominant form of mineral N was ammonium. During the drained periods the dominant form of N was nitrate. There was a significant straw effect at Biggs during the spring between the winter flooded and non-flooded plots with straw incorporated plots showing more available N. The opposite trend was found following draining of all plots just before harvest. At Maxwell, there was a significant flood interaction with more N being available in the winter flooded plots regardless of straw additions. At both sites, significant nitrification occurred in all plots following the draining of winter flooded plots. It can be assumed that the nitrate N would be lost following flooding of the newly seeded crop. This essentially means that most of the available N that accumulated following winter was lost to denitrification.

OBJECTIVE 2

Fertilizer nitrogen availability trials and plant nitrogen uptake use efficiency was done through the use of ^{15}N labeled nitrogen (stable isotope). The use of labeled nitrogen permitted us to follow the fate of fertilizer nitrogen under the different straw management practices. This technique allowed us to determine the uptake of fertilizer N by rice and determine fertilizer use efficiency. It will also allow us to quantity the uptake of N that was present in the 1997 rice straw which will become available for plant uptake through decomposition and net N mineralization in 1998.

The labeled nitrogen fertilizer trial was done at the Maxwell site during 1997. The uptake of fertilizer N was completed by the first week in July or about 7 weeks after planting in the winter flood burned and incorporated treatment (Figure 3). Results for the winter non-flood treatments are not yet available, but would be expected to follow the same trend. Fertilizer use efficiency reflected the same trend as N uptake and peaked at the same time as N uptake (Figure 4). Fertilizer use efficiency averaged between 36 to 37 % for the winter flooded treatments and non-flood treatment (Figure 5). Fertilizer use efficiency in the winter non-flood incorporated treatment was 30%. The discrepancy in fertilizer use efficiency was not reflected in the total N uptake of the plants at final harvest. All treatments had between 160 and 185 kg N ha^{-1} in the above ground biomass (Figure 6). This raises an interesting question and suggests that a significant amount, approximately 60%, of the plant N came from other soil N sources other than fertilizer N.

Table 1 shows the fate of the added fertilizer ^{15}N. As stated above the rice plant took up approximately 37% of the labeled fertilizer. The microbial biomass contained 29% of the labeled fertilizer approximately 3 month after application. This shows that the microbial biomass was a strong sink and competed effectively with the rice for the fertilizer. Approximately 5% of the fertilizer was present as inorganic soil N late in the growing season. The loss of fertilizer amounted to 30%. The large loss of fertilizer shows the importance of volatilization and denitrification processes in controlling the fate of fertilizers in rice cropping systems. Some ^{15}N could have been leached or lost from the enclosed plot through horizontal flow. In addition, the amount of root ^{15}N was not considered and may represent a significant portion of the labeled fertilizer that was defined as lost from the system.

Table 1. The fate of labeled fertilizer N in plant and soil components in August of 1997 expressed as mg of ^{15}N and percent of applied fertilizer ^{15}N as an average of all treatment plots. A total of 2.4g of ^{15}N was added per plot.

Crop/Soil Component	^{15}N mg / plot	% of ^{15}N Applied
Plant	0.89	37.1
Microbial Biomass	0.69	28.8
Inorganic N	0.11	4.6
Soil Organic Matter	0.0	0.0
Apparent fertilizer loss	0.71	29.6

SUMMARY OF THE 1997 RESEARCH BY OBJECTIVE:

OBJECTIVE ONE

Available soil N at both the Biggs and Maxwell site was similar during flood and non-flood periods. During the winter and summer flood periods, the dominant form of mineral N was ammonium. During the drained periods the dominant form of N was nitrate. At the Biggs site, there was a significant effect of straw incorporation showing an increase in available soil N with rice residue addition. This trend was not observed at the Maxwell site where instead winter flooding increased available straw N regardless of straw treatment. At both sites, most of the available soil N that was mineralized during the winter period was nitrified to nitrate. This nitrate was most likely lost through denitrification and was not available for rice uptake.

OBJECTIVE TWO

Fertilizer nitrogen availability trials and plant nitrogen uptake use efficiency was determined through the use of ^{15}N labeled nitrogen (stable isotope). This technique allows us to determine the uptake of fertilizer N by rice and determine fertilizer use efficiency. The uptake of fertilizer N by the rice amounted to approximately one third of the applied fertilizer. The remaining plant N apparently came from other soil sources. This shows the importance of soil N in supplying N for crop uptake. The microbial biomass contained 29% of the added fertilizer N. This shows that the microbial biomass was a strong sink and competed effectively with the rice for the fertilizer N. There was a large apparent loss of fertilizer N amounting to 30% of the applied. The large loss of fertilizer shows the importance of volatilization and denitrification processes in controlling the fate of fertilizers in rice cropping systems. Some of the fertilizer loss may be accounted for through horizontal escape from the microplots and N in the rice roots that was not determined.

PUBLICATIONS OR REPORTS:

Devevre, O. C. and W. R. Horwath*. 1997. Influence of temperature and flooding on nitrogen immobilization in organic matter. Agronomy Abstract, Anaheim, CA, p. 214.

Horwath, W. R. and O. C. Devevre*. 1997. Effect of C to N ratio, temperature and flooding on the degradation of rice straw. Agronomy Abstract, Anaheim, CA, p. 214.

* Also presented at the Rice Field at Biggs, 1997.

CONCISE GENERAL SUMMARY OF CURRENT YEARS RESULTS:

Changes in the efficiency of rice under different management practices may affect the ability of rice to retain added nutrients, i.e., fertilizer-N. The availability of soil N was controlled by different factors at the Biggs and Maxwell sites. At Biggs, soil N availability was controlled by straw addition. Incorporating rice straw increased available N pools prior to the growing season, but decreased available N following rice harvest. The increase in available N during the spring probably resulted from the decomposition of the prior years rice residue. This shows the importance of straw in promoting sustainable N cycling. Unfortunately, the available soil was most likely lost through denitrification processes following flooding and seeding and was not available for plant uptake. In the fall, the straw incorporated plots showed a tendency to immobilize N. The immobilization of N would increase sustainable N cycling by preventing soil N loss through denitrification during the wet winter months. Overall, straw incorporation tended to have positive effects on the N status of the soil.

We studied the fate of fertilizer N by using a heavy isotope of N (^{15}N) that can be traced to the plant, microbial biomass, and other soil pools. The uptake of ^{15}N labeled fertilizer provides information on fertilizer nitrogen recommendations and plant nitrogen use efficiency under the different flood and residue treatments. We found that only about one third of the fertilizer N was taken up by the rice crop. We also found that N uptake was completed by the seventh week following planting. The low fertilizer N use efficiency shows the importance of soil N in supplying N for rice crop uptake. A significant portion of the fertilizer N was found in the microbial biomass late in the growing season. This shows that the microbial biomass was a strong competitor for the fertilizer N. It also exemplifies the importance of the microbial biomass in controlling the fate of soil N. The activity of the microbial biomass controls the rate at which soil N will become available for rice crop uptake. The majority of the N taken up by the rice was soil N and shows the dependency of the rice on the mineralization activity of the microbial biomass. The results also showed that a significant amount of fertilizer was apparently lost through volatilization and denitrification activity. This loss may be minimized by taking into account microplot effects and N found in rice roots.

REFERENCES

Brooks, P.D., Stark, J.M., McInteer, B.B., and T. Preston. 1989. Diffusion method to prepare soil extracts for automated nitrogen-15 analysis. Soil Sci. Soc. Am. J. 53:1707-1711.

Horwath, W.R., and E.A. Paul. 1994. Microbial Biomass. *In* R.W. Weaver, J.S. Angle, and P.S. Bottomley (eds.) Methods of Soil Analysis: Part 2-Microbiological and biochemical properties. pp. 753-773. SSSA Book Series, no. 5, Madison, Wisconsin.

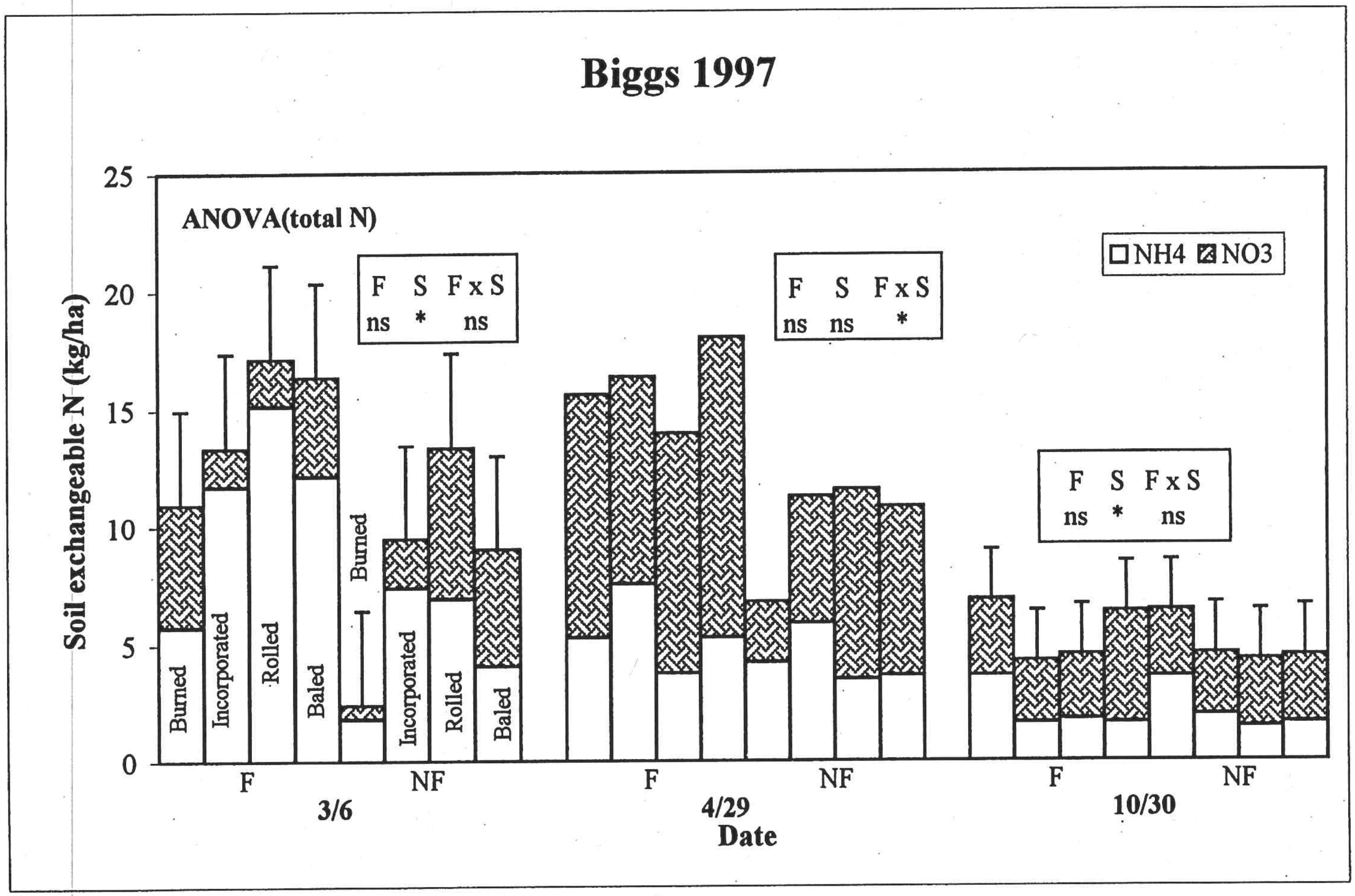

Figure 1. Changes in soil available N following residual rice straw incorporation and winter flooding at Biggs in 1997. **Error bars representing LSD (p=0.05) are used to compare straw treatments within the same flooding level. ns=not significant; *=significant at 0.05 level.**

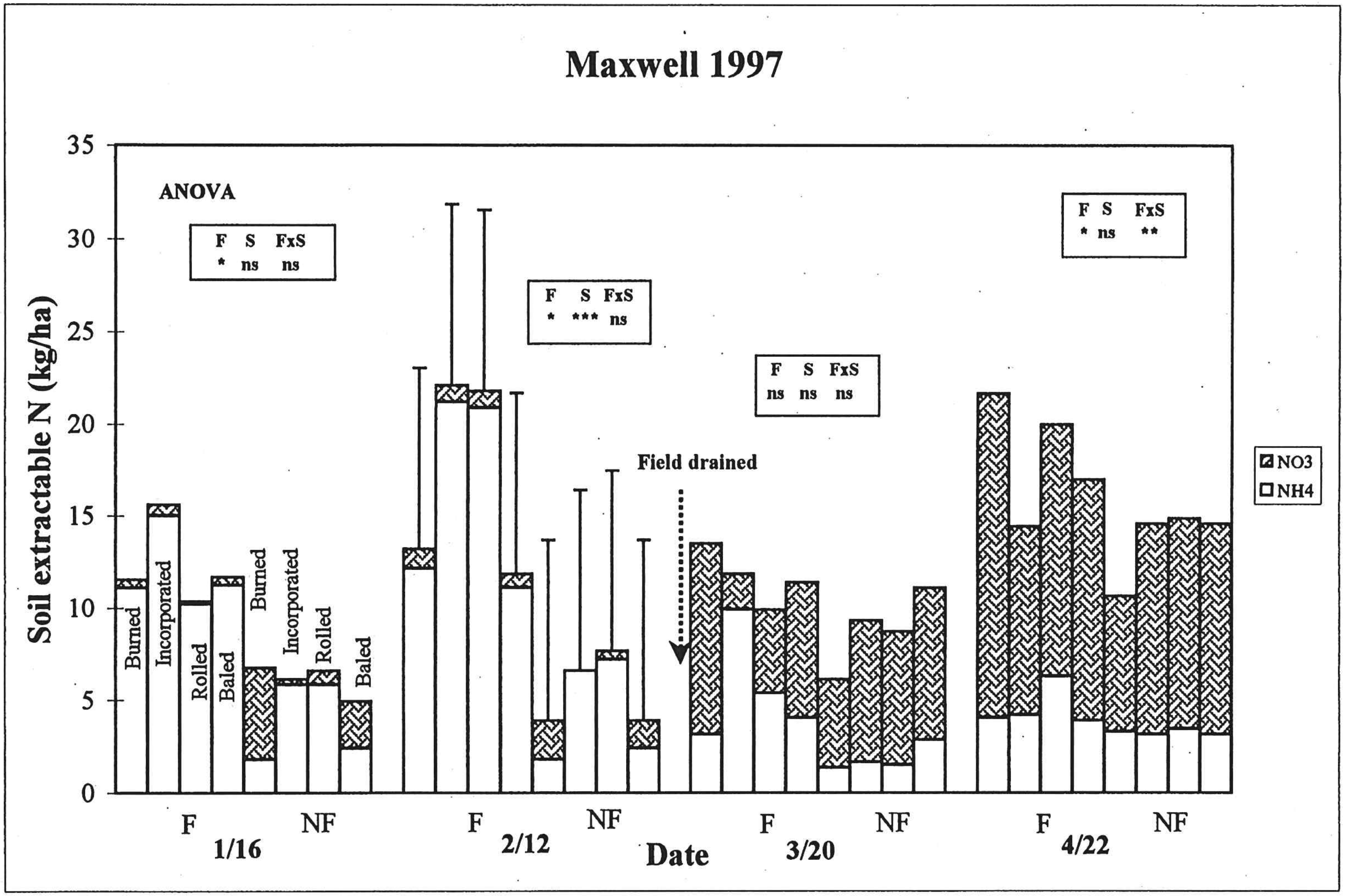

Figure 2. Changes in soil available N following the incorporation of rice straw and winter flooding at Maxwell in 1997. Error bars representing LSD (p=0.001) are used to compare straw treatments within the same flooding level. ns=not significant; *,** and***=significant at 0.05, 0.01 and 0.001 levels, respectively.

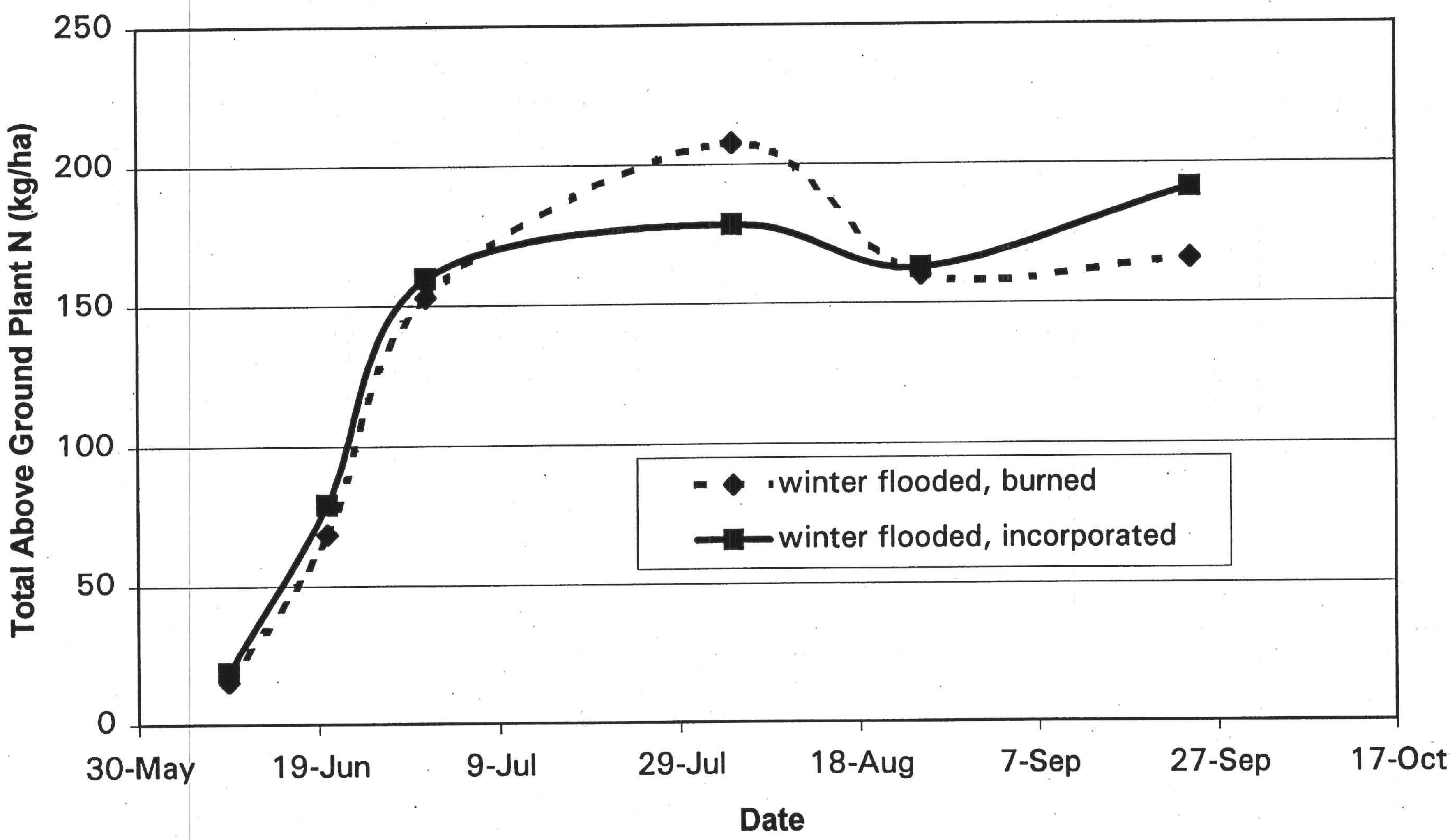

Figure 3: Total Nitrogen in Above Ground Biomass at the Maxwell Research Site--1997 Growing Season

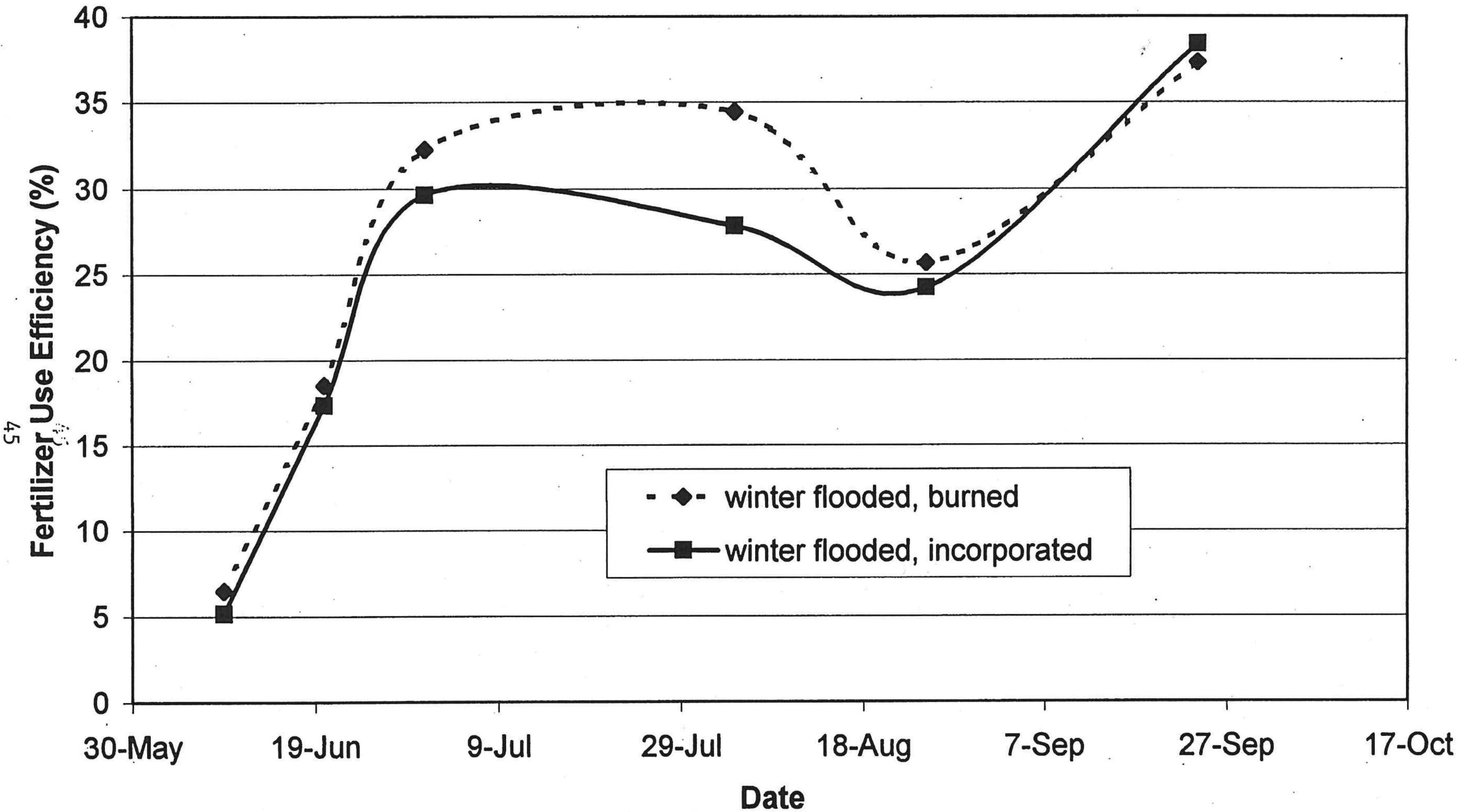

Figure 4: Fertilizer N Use Efficiency in Rice at the Maxwell Research Site--1997 Growing Season

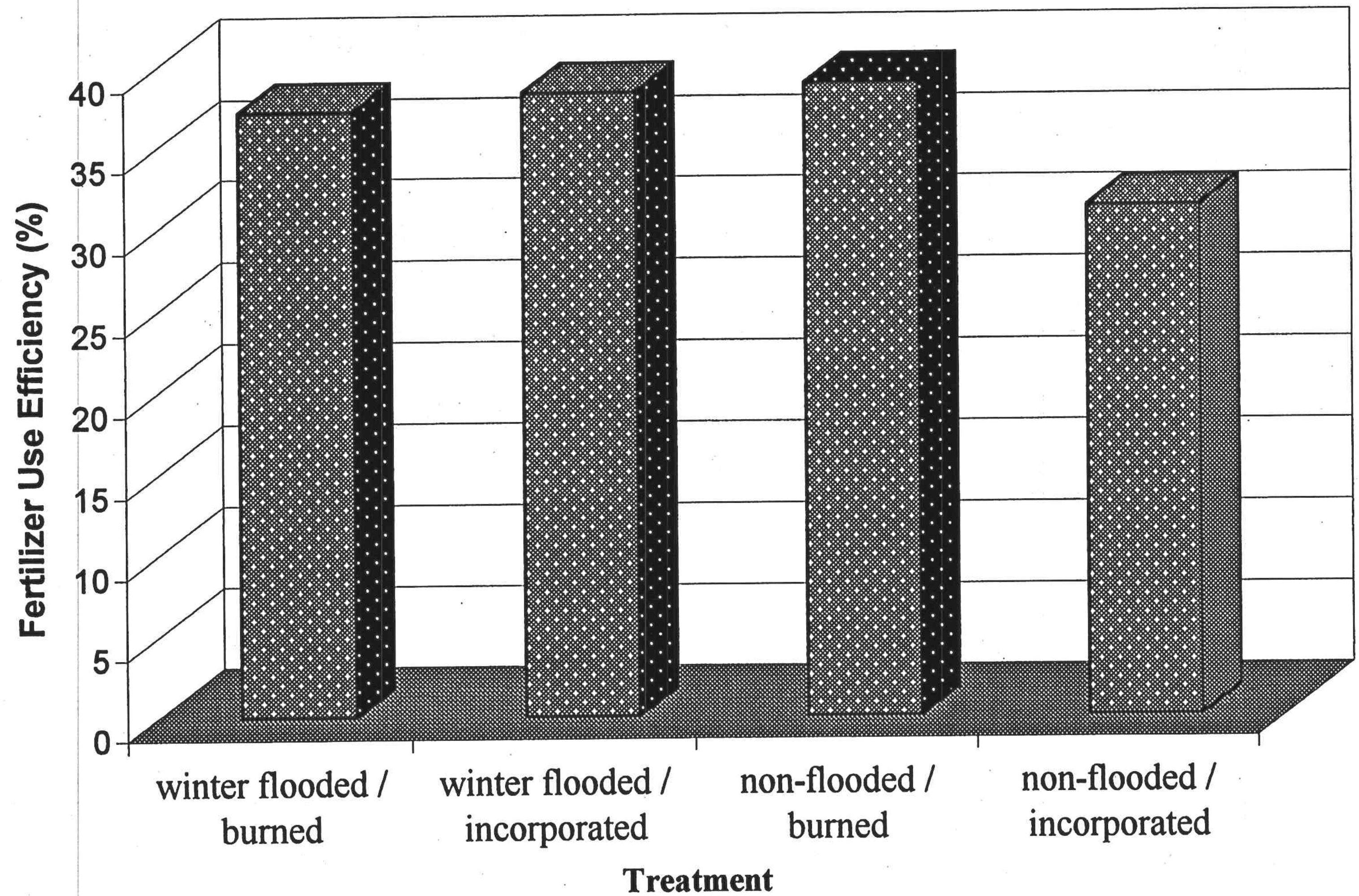

Figure 5: Fertilizer N Use Efficiency at Final Harvest at the Maxwell Research Site

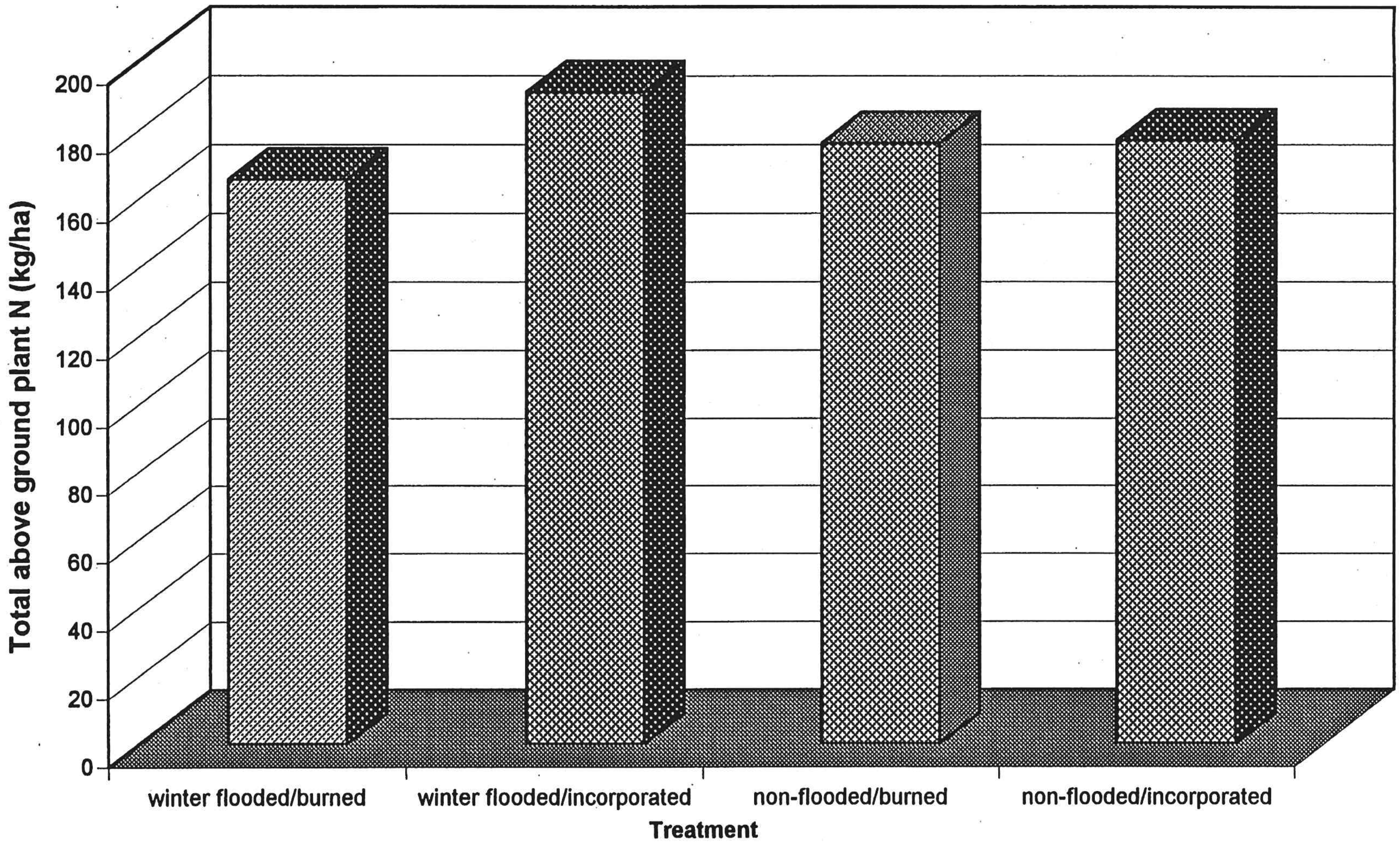

Figure 6: Total Above Ground Plant Nitrogen at the Maxwell Research Site--Harvest 1997