Nitrogen Fertilization and Severity of Stem Rot of Rice

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ABSTRACT

Field trials comparing the effects of foliar nitrogen levels and times of nitrogen (N) fertilizer applications on severity of stem rot of rice, indicated increased disease severity on plants which contained increased amounts of N. Split N application, 28 kg/hectare (ha) (25 lb/acre) before seeding and 84 kg/ha (75 lb/acre) as a topdressing 84 days after seeding, delayed disease development and increased yield as compared with those plants receiving topdressings at earlier stages of rice development.

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Stem rot is a serious disease of rice (*Oryza sativa* L.) (12) caused by the fungus, *Sclerotium oryzae* Catt. It occurs in most rice-producing countries of the world (1, 10, 13, 15, 17). It is widespread in California, being most prevalent in the northern rice-producing areas of the state (18).

Investigations have shown that sclerotia of this fungus overwinter in the soil and plant debris and serve as the primary source of inoculum for subsequent rice crops. The sclerotia float to the surface of the water as fields are flooded and infect young rice plants at the water line when environmental conditions are favorable. Blackened lesions form on the leaf sheaths and develop inward. In severe infections, the culm is attacked and mycelium may be seen growing on the inner surface of the diseased area of the culm, which may collapse resulting in excessive lodging. More frequently, infection does not prohibit the panicles from maturing, but its effects are expressed in smaller panicles which result in reduced yields. Sclerotia are formed in infected areas of maturing rice plants.

Nitrogen (N) in the ammonium form is the most needed and used fertilizer applied to rice in California (9). It is generally applied preplant before a field is flooded. However, it may also be split between a preplant application and a topdressing applied 50 to 85 days from seeding. Growers are able to detect N deficiencies by leaf analyses (8) which are the basis for planning topdressing fertilizer applications.

Fertilization practices have an effect on the severity of certain diseases. Streets (16) recommended ammonium sulfate or ammonium phosphate to minimize Phymatotrichum root rot on several perennial crops, and Leach et al. (7) reported that nitrogenous fertilizers reduced southern Sclerotium rot on sugar beets. Reyes (14) in the Philippines, and Nakata and Kawamura (11) in Japan reported that nitrogenous fertilizers stimulated stem rot of rice. In Arkansas, Cralley (2) found that N increased stem rot on plants over those receiving no N, that phosphorus (P) acted similarly, but that potassium (K) applied in combination with N and P helped maintain disease severity at a level close to that observed on check plots without added fertilizer. Our greenhouse trials (4) indicated that increasing amounts of N in rice leaves increased severity of stem rot, but that P and K levels had no significant effect on disease development.

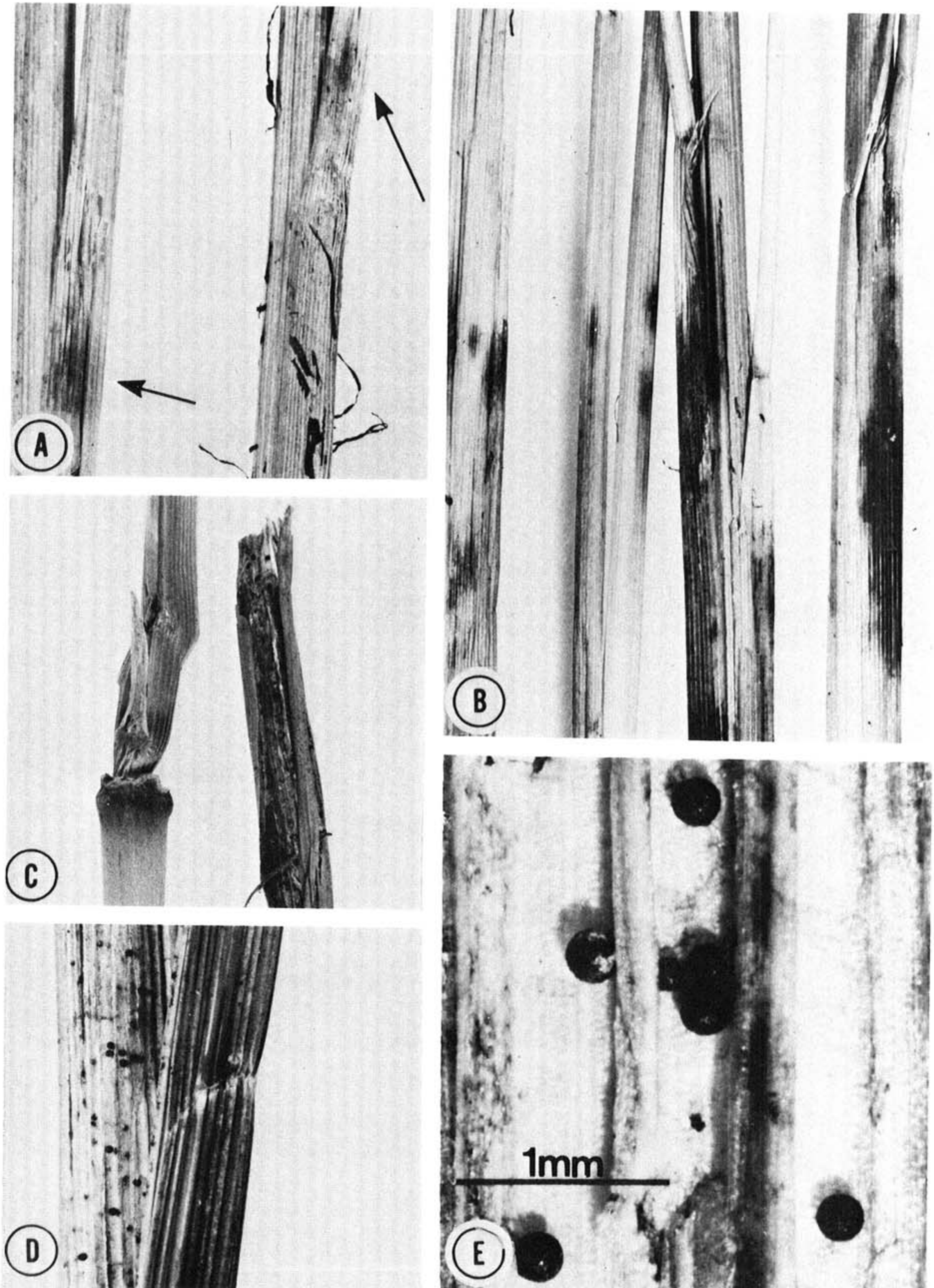
This paper reports on various N fertilizations in field trials comparing levels of detectable N in leaf tissue and severity of stem rot disease of rice.

MATERIALS AND METHODS.—The effect of N rates and times of application on stem rot disease was tested in a field in Butte County with a known history of stem rot disease and high native levels of P and K. The rice cultivar 'Calrose' was grown under standard recommended grower practices except for variations of N-fertilization. Ammonium sulfate (21% N) preplant applications were broadcast 56, 112, 168, and 224 kg N/ha (50, 100, 150, and 200 lb/acre) and incorporated prior to flooding. Split applications consisted of three different combinations of 112 kg N/ha: 84 kg N (75 lb) preplant plus 28 kg N (25 lb) topdressed, 56 kg N preplant plus 56 kg N topdressed, and 28 kg N preplant plus 84 kg N topdressed. Topdress applications were hand-broadcasted into the water and with each of the three combinations, the topdressings were applied at three different stages of rice plant development: tillering (54 days from seeding), panicle initiation (67 days) and early boot (84 days). The 14 treatments, including the one without fertilizer, were replicated four times. Individual plots were 2.44 × 15.25 m and were harvested with a combine cutting a 2.135-m swath which allowed 0.305 m between plots to reduce plot border effects.

Leaf samples were collected at various times and analyzed by standard methods (3, 8). N-content was expressed as percent on a dry wt basis. Stem rot disease index was determined for each treatment at specified times by selecting ca. 50 plants at random from each plot and rating each tiller according to the method adopted by Krause and Webster (6). Essentials of the index rating method are as follows:

Healthy (H) - No visible symptoms.
Light (L) - Infection on leaf sheaths only (Fig. 1).
Medium (M) - Infection on the outer surface of the culm (Fig. 2).
Moderate (Mo) - Infection symptoms penetrating to the inner surface of the culm (Fig. 3).
Severe (S) - Culm shriveled from weakened, diseased tissue, or fungus mycelial growth on inner surface of culm; sclerotia often present (Fig. 4).

Fig. 1-(A to E). Stem rot of rice rated "light" - **A)** Small black spots indicating early infected areas on outer leaf sheaths (arrows). **B)** Advanced stages of light infections. **C)** Most advanced stage of a light infection showing a diseased inner leaf sheath but a healthy culm. **D)** Inner surface of a leaf sheath with mature sclerotia. **E)** Detail of mature sclerotia on inner leaf sheath surface.


A
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1mm
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Disease index is calculated from the following formula in which it is understood that "#" represents "number of tillers classed as":

$$\text{Disease index} = \frac{1(\#H)+2(\#L)+3(\#M)+4(\#Mo)+5(\#S)}{\text{Total number of tillers examined}}.$$

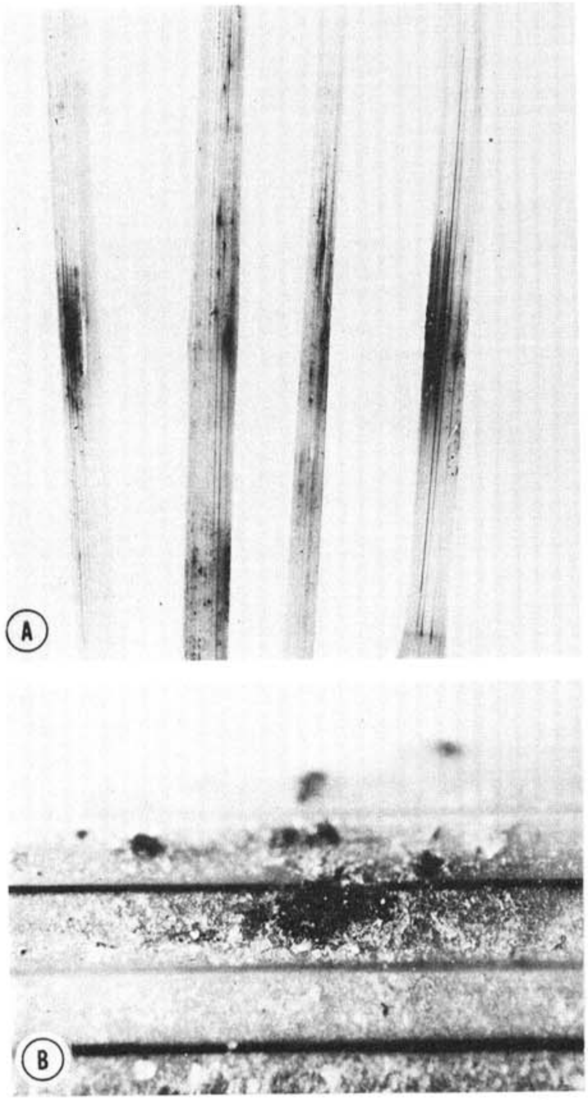

Fig. 2-(A, B). Stem rot of rice rated "medium" - **A)** Various degrees of infection on the outer surfaces of culms (leaf sheaths removed). These lesions did not reach the inner surfaces of the culms. **B)** Detail of an infection site formed on the outer surface of a culm from which lesions develop. Note darkening of fibrovascular bundle in both directions from the infection site.

RESULTS.—*Preplant applications.*—As shown in Table 1 and Fig. 5, disease severity increased as the level of nitrogen increased in the leaves from higher rates of N fertilization. Yields, however, also increased with higher preplant rates of N up to 168 kg/ha; with the preplant rate of 224 kg N/ha yield did not increase significantly which fact is supported by the conclusion of Mikkelsen and Hunziker (8) that foliar content of N over 2.6-3.2% (2.6% line is marked "minimum adequate" in Fig. 5) at the 80-90 days growth period does not result in greater yields.

Split applications.—There were no significant differences in leaf N content, disease severity, or yield in the combination of 84 kg/ha preplant plus 28 kg/ha topdressed when compared to 112 kg/ha all applied preplant.

The results of the trials with the other two split applications shown in Table 2 indicate that disease severity was reduced when the topdressing was delayed until boot stage of rice plant development (84 days from seeding) when compared to treatments with all N applied preplant and when topdressings of the same rates were applied at 54 or 67 days from seeding. The reduction was highly significant when only 28 kg N/ha was used at preplant followed by 84 kg N/ha topdressed. The reduced disease severity closely correlated with levels of N found in the leaves at 84 days from seeding which were significantly lower in both boot-stage topdressing treatments than in all other treatments with the 56-56 and 28-84 combinations and the all-preplant treatment. Yields of the split-application treatments were less than the all-preplant treatment except in those with the topdressings delayed until boot stage. This correlated with disease severity which was least in the boot-stage treatments.

DISCUSSION.—Fertilization of rice fields in northern California with N is considered essential for max production. The results presented here indicate that the amount of disease in an infected field can be expected to increase with increasing rates of applied N. Therefore, it is important for each rice grower to make every effort to assess accurately the amount of N required and to apply no more than that amount. This practice can help avoid increasing inoculum levels and increasingly severe stem rot disease conditions in fields farmed continuously to rice.

The split application comparisons indicate that growers finding a need for additional N through leaf analysis can minimize disease effects in infected fields by delaying their topdressing applications until the boot stage of plant development. They also suggest that growers whose rice crops are becoming more severely infected each year may benefit by splitting the N applications with the topdressings at boot stage. The results in Table 2 indicate that yields from such a practice should be no less than those expected from a preplant fertilization, but with less disease and reduced inoculum build-up.

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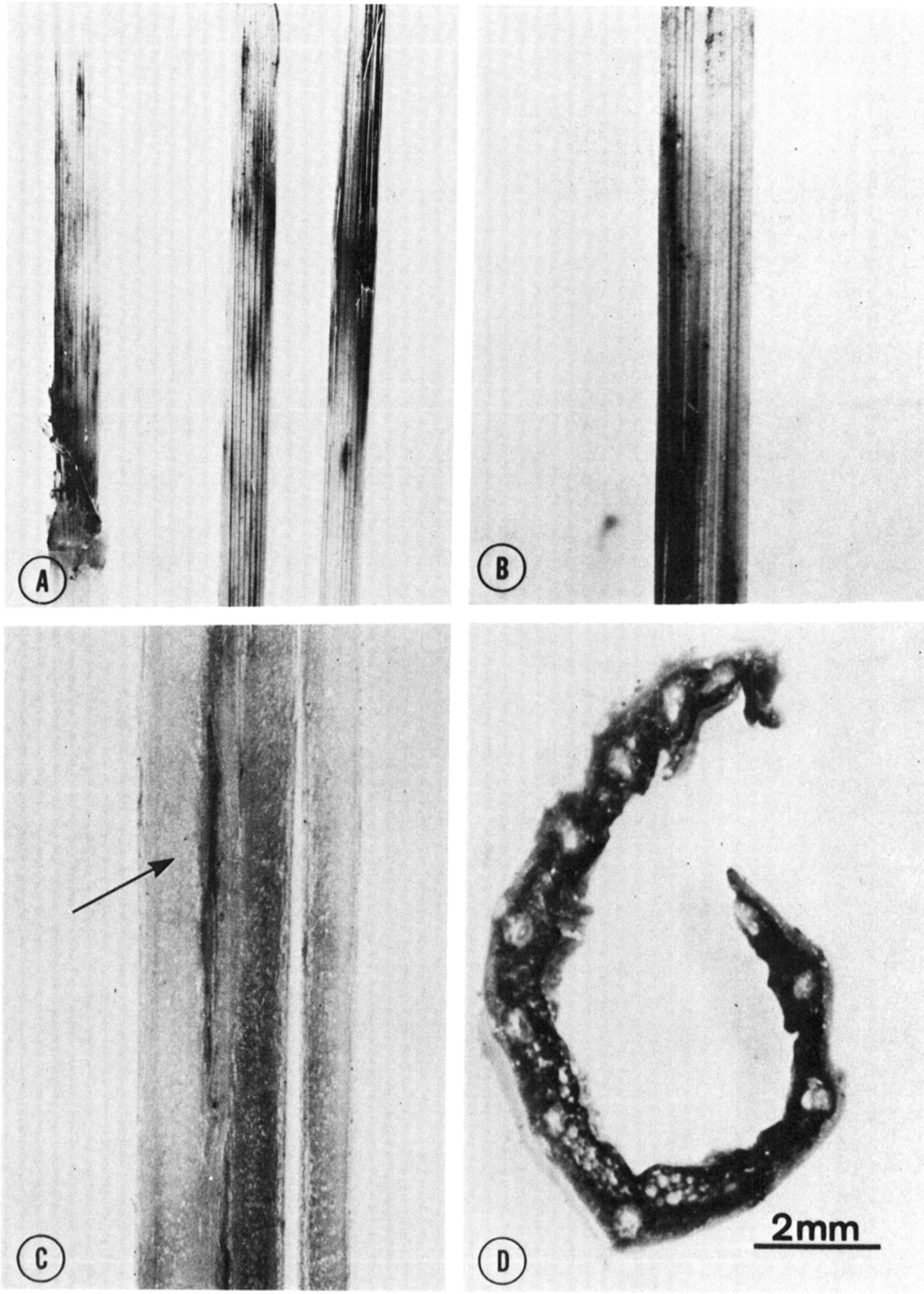
Fig. 3-(A to D). Stem rot of rice rated "moderate" - **A)** Infected culms (leaf sheaths removed). **B)** Infected culm. **C)** Inside the same culm showing the lesion (arrow) which has progressed to the inner surface. **D)** Cross section of a culm with an infection rated moderate showing tissue necrosis.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The data presented in Table 2 gives an indication of the amount of yield reduction attributable to stem rot disease. In both the 56-56 and 28-84 treatments with the topdressings at tillering and panicle initiation stages, the N content of the leaves were as much or more as in the all-preplant treatments. The disease indices of those same treatments were statistically similar, but the yields were consistently less in the split applications than in the preplant applications, and significantly so in the 28-84 treatments. This seems to indicate that split applications of N do not produce yield increases as great as those from single preplant applications, an observation supported by the results of Mikkelsen and Hunziker (8). However, delaying the topdressing until boot stage, which resulted in reduced disease severity, resulted in yields as great or

TABLE 1. Effect of different rates of preplant nitrogen (N) fertilization (derived from ammonium sulfate) on the leaf (N) analysis, stem rot index, and yield of 'Calrose' rice

Preplant N kg/ha[w]	Leaf N (%) by days after seeding[x] 54 days	67 days	84 days	Disease severity index[y] 139 days	Rice yield[z] (kg/ha)
0	3.58 a	2.50 a	2.17 a	2.12 a	3,942 a
56	3.84 ab	2.50 a	2.17 a	2.06 a	5,398 b
112	4.22 bc	3.18 b	2.54 b	2.58 b	6,810 c
168	4.45 c	3.65 c	2.82 c	2.87 bc	7,482 d
224	4.64 c	4.42 d	3.40 d	3.06 c	7,638 d

[w] kg/ha = lb/acre × 1.12.

[x] Adequate leaf content of N for obtaining maximum yields of field-grown rice according to Mikkelsen and Hunziker (8) on dry wt basis is as follows: 50-55 days – 3-4%; 60-65 days – 2.8-3.6%; ca. 80 days – 2.6-3.2%.

[y] Disease index at 139 days after seeding. Ratings at 84 and 104 days were not significantly different. Disease index is calculated from the summed weighted ratings [1 (healthy) to 5 (severe)] of all tillers on 50 plants, divided by the total no. of tillers.

[z] Yield in kg/ha adjusted to 14% moisture. Values in the same column followed by common letters do not differ significantly at the 5% level as determined by Duncan's multiple range test.

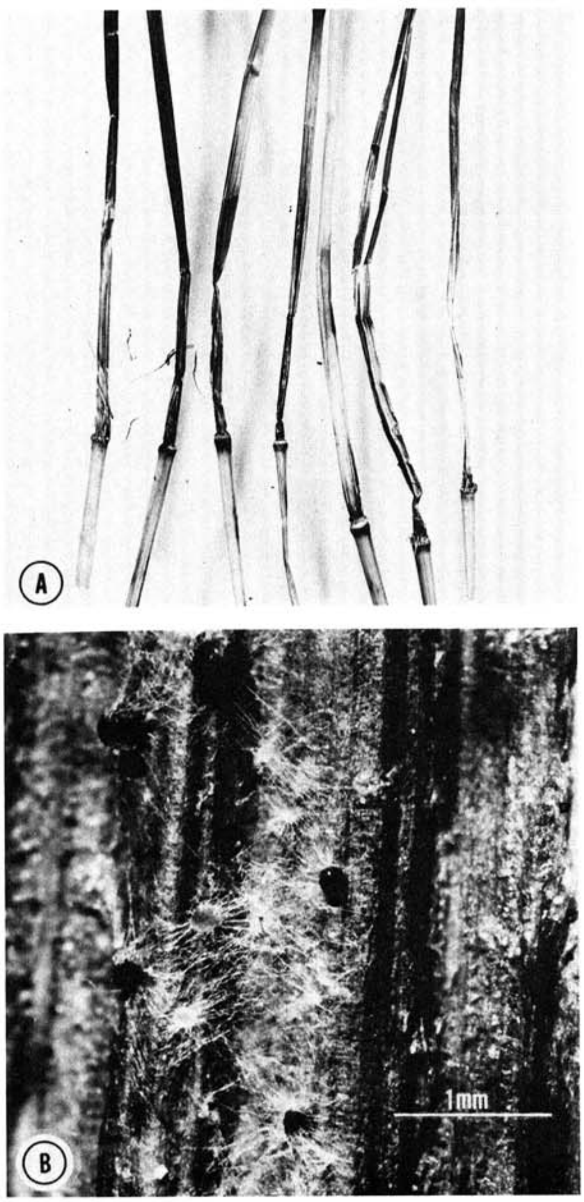

Fig. 4-A(A, B). Stem rot of rice rated "severe" - **A)** Severely diseased culms. **B)** Inner surface of "severely" diseased culm, showing sclerotia among mycelial growth.

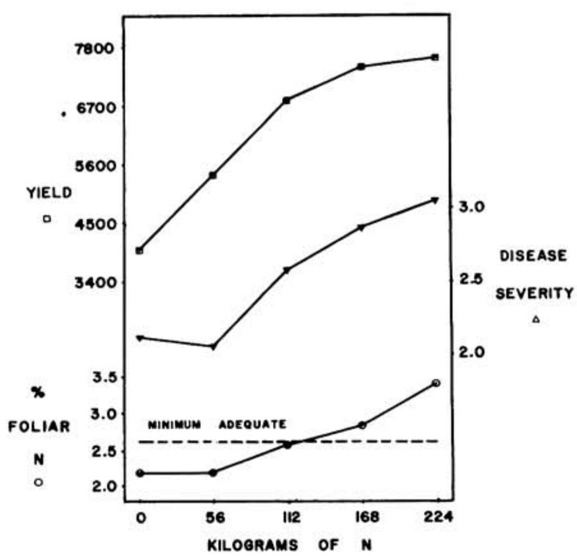

Fig. 5. Effects of preplant application of ammonium sulfate upon 'Calrose' rice: foliar nitrogen (N) content, dry wt basis (O); stem rot disease severity rating (1 = healthy, to 5 = severe) (▲); and yield [kg/hectare (ha), adjusted to 14% moisture] (■). Leaf samples taken for foliar analysis at 84 days from seeding. "Minimum adequate" represents the minimum foliar N content at 84 days needed for maximum yield (Note: kg/ha = lb/acre × 1.12).

TABLE 2. Effect of different combinations of nitrogen (N) [applied at the rate of 112 kg/hectare (ha) (= 100 lb/acre) part at preplant and part at one of three stages of rice plant development] on leaf N analysis, stem rot index, and yields of 'Calrose' rice compared to 112 kg/na applied perplant

Fertilizer applications in kg N/ha[v]		Time of topdressing		N in leaves at 84 days[x] (%)	Disease index 139 days[y]	Yield[z]
Preplant	Top-dressed	Stage	Days from seeding			
112	0	Preplant		2.54 b[w]	2.58 b	6,810 cd
56	56	Tillering	54	2.56 b	2.66 b	6,563 bc
		Panicle initiation	67	2.77 b	2.50 b	6,440 abc
		Boot	84	2.27 a	2.33 ab	7,123 d
28	84	Tillering	54	2.57 b	2.65 b	5,992 a
		Panicle initiation	67	3.17 c	2.47 b	6,238 ab
		Boot	84	2.15 a	2.08 a	6,821 cd

[v] Nitrogen derived from ammonium sulfate (21% N).

[w] Values are means of four replications and those followed by common letters in the same column do not differ significantly at the 5% level by Duncan's multiple range test.

[x] Adequate leaf content of N for maximum yields of field-grown rice according to Mikkelsen and Hunziker (8) on dry wt basis for ca. 80 days is 2.6 to 3.2%.

[y] Disease index is from 1 (healthy) to 5 (severe) calculated from the summed weighted ratings of all tillers on 50 plants, divided by the total no. of tillers.

[z] Yield in kg/ha adjusted to 14% moisture kg/ha = lb/acre × 1.12.

greater than those in the all-preplant fertilization treatments. The average yield of the two earlier 28-84 topdressing treatments was 6,115 kg/ha which was a 10.4% yield loss due to the average disease index of 2.56 compared to the 6,821 kg/ha yield and 2.08 index of the boot-stage treatment.

An identical study was carried out with the rice cultivar 'Colusa' which requires ca. 16 fewer days to reach maturity than Calrose (5). It did not respond to the split applications of N as did Calrose which may be a result of their different maturity requirements. Therefore, the recommendations indicated here for Calrose cannot necessarily be considered applicable to other rice cultivars.

The results suggest that in the case of Calrose rice, it may be possible to minimize stem rot disease and obtain higher yields through properly timed split applications of higher rates of N-fertilization. The need for additional work is indicated to determine the nutritional requirements and habits of the fungus, *Sclerotium oryzae*, as they relate to severity of stem rot disease of rice and what physiological mechanisms are involved in changes in disease susceptibility or resistance.

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