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# REPORT ON MUSCLE SHOALS GREENHOUSE EXPERIMENT 203: NITROGEN SOURCES FOR RICE: EFFECT OF PREFLOOD INCUBATION

R. D. Haack, et al

Tennessee Valley Authority
Muscle Shoals, Alabama

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R.D. Hauck et al

Tennessee Valley Authority
Office of Agric. & Chemical Development
Muscle Shoals, Ala. ~~[illegible]~~ 35660

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Research Report

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Report on Muscle Shoals Greenhouse Experiment 203:

# NITROGEN SOURCES FOR RICE: EFFECT OF PREFLOOD INCUBATION

R. D. Hauck, O. P. Engelstad, and Greenhouse Staff

January 1972

## SUMMARY

A greenhouse pot experiment with flooded rice was conducted on Mountview silt loam to determine whether grain yields from several N sources were related to their rates of nitrification during the preflood period. Of seven N fertilizers used, four of them--urea, urea-ammonium phosphate (UAP), ammonium polyphosphate (APP), and diammonium phosphate (DP)--form alkaline solutions in the fertilizer-soil reaction zone. The remaining three--monoammonium phosphate (MAP), ammonium sulfate (AS), and ammonium chloride (ACl)--form acid solutions.

In soil of pH 5.5, grain yields and N contents of grain were lower from alkaline-forming, as compared to acid-forming materials. This was probably because the alkaline materials nitrified at a faster rate and, therefore, more nitrate derived from these materials was lost via denitrification. Differences among N sources increased with increase in N rate and period of incubation preceding flooding. In soil limed to pH 7.2, less grain was obtained from AS than from equivalent amounts of N from urea. In all cases, yield and N content of grain decreased with length of preflood incubation period, indicating losses of N from the system.

The results of this experiment are consistent with the observation that in acid field soils, AS usually is slightly more efficient than urea for direct-seeded rice.

## BACKGROUND AND OBJECTIVE

A review of the domestic and foreign literature on N sources for rice indicates that urea often is less efficient than AS. Dissimilar nitrification rates may be involved in the apparent lower effectiveness noted for urea. In an acid soil, urea often nitrifies at a faster rate than AS because urea forms an alkaline solution around the particle which favors nitrifying activity. Similarly, depending on soil nitrifying activity and rate and mode of fertilizer application, UAP and DP (alkaline-forming materials) may nitrify faster than AS, ACl, and MAP.

Therefore, when either of these two classes of materials (alkaline vs. acid-forming) is applied to soil 2-3 weeks before flooding, the chance for significant nitrate formation and subsequent denitrification may be greater for the alkaline-forming materials.

For direct-seeded rice, flooding usually follows 10-30 days after seeding and fertilizer application to dry soil. Fertilizer usually is broadcast and harrowed in, although the practice of drilling the seed is gaining favor.

The objective of this experiment was to determine whether dissimilar nitrification rates, as affected by N source, concentration, soil pH, and incubation before flooding can explain some observed differences in efficiency among N sources for rice.

## MATERIALS AND METHODS

All materials except UAP and APP were prepared from reagent chemicals pelletized at 10,000 psi, crushed, and screened to pass -8+10 mesh. TVA pilot plant UAP and APP were used after screening to the above size limits. Mountview silt loam (5 kg/pot) was limed to pH 5.5 or 7.2 with a 2:1 mixture of $CaCO_3$:$MgCO_3$. These pH values were established 17 days after mixing 10 mg of P as CSP, 40 mg of K as $K_2SO_4$, and 50 mg of complete micronutrient mixture per kg of soil. Supplemental amounts of CSP were added at the time of N application to equalize P additions to a total of 500 mg of P per pot. Nitrogen treatments were made before 0, 10, or 20 days of preflood incubation at 2/3 field capacity (18% moisture). All N fertilizers were placed in a layer 2 inches below the soil surface. Characteristics of the N sources used are listed in Table 1. Only urea and AS were compared in the high pH series. All treatments were replicated three times except those with urea and AS, which were replicated five times. Three replicates of the latter treatments were cropped after flooding, while soil nitrate after each incubation period preceding flooding was determined on the remaining replicates.

After the required period of incubation, the pots were cropped to Nato rice (12 plants per pot transplanted September 16, 1969) 3 weeks after germination in sand treated with nutrient solution. Weights and N contents of grain but not of straw were determined at maturity.

## RESULTS AND DISCUSSION

Grain weights and N contents of rice grown in soil of pH 5.5 and 7.2 are reported as the average of three replicates per treatment in Tables 2 and 3 respectively. Response to N was marked for both pH levels. Further yield increases probably would have been obtained at higher N rates. Yields and N uptake for both treated and control plants were greatest when N was added immediately before flooding. There was a progressive decline in yield with length of incubation period. This is consistent with the view that nitrification during incubation under aerobic soil conditions is followed by denitrification after flooding.

Fig. 1 gives a plot of grain yields at either N rate vs. N source after 0, 10, and 20 days incubation in soil of pH 5.5. The N sources were arranged so as to make a linear plot of N source with yield. This plot also corresponds to their arrangement from left to right in approximate order of decreasing nitrification rates in acid soil, as expected on the basis of previous observations. Certain trends are apparent. For both N rates there was essentially no difference among N sources when they were applied immediately before flooding. When applied 10 or 20 days before flooding, differences among N sources appear as functions of both period of incubation and N rate.

In acid soils, differences among N sources with respect to nitrification appear when either the N rate or the disposition of N fertilizer particles in soil are such that alkaline or acid microenvironments persist in the fertilizer-soil reaction zone. At the 400-mg rate, urea, UAP, APP, and DP are expected to nitrify at a faster rate than AS and ACl. Nitrification followed by denitrification lowers the available N supply and thus yield. Lower grain yields were obtained for the alkaline-forming materials added at the 400-mg rate 20 days before flooding. The same general trend, but to a much lesser degree, was obtained at the 200-mg N rate. At this lower rate, microsite efferts on nitrification are less pronounced.

An exception to the above trend is MAP, the nitrification of which has been found in previous studies to be not entirely predictable. This is perhaps due to the comparatively low N content of MAP and the resultant salt effects at high rates of N application.

Nitrification in soil appears to proceed at the most rapid rate when the combination of N source, rate, and disposition as well as soil

factors results in a fertilizer-soil reaction of pH 7.2-7.8. Therefore, one would expect different alkaline-forming materials to nitrify at different comparative rates, depending on the extent to which each fertilizer-soil microenvironment approaches the optimum conditions for nitrification. In acid soils, the alkaline-forming materials usually form a microenvironment which is more favorable for nitrification than acid-forming ones. Table 3 gives results which show that much more nitrate was formed during the preflood incubation period from urea than from AS.

In soil of high pH, urea nitrifies at a slower rate than AS whenever the combination of N rate and disposition creates a urea-soil reaction zone that is too high for rapid nitrification. On the other hand, the nitrification of AS is favored by the higher soil pH. Again, the differential nitrification rates of urea and AS are reflected in the grain yields of rice grown in the Mountview soil limed to pH 7.2 (Table 4). The faster rate of AS nitrification during the preflood period resulted in lower yields from AS.

The relationships between soil pH, period of preflood incubation, and N source are apparent from Table 5, which gives grain yields and N contents averaged over two rates of AS and urea N applied to soil of pH 5.5 and 7.2.

Total N in grain (Tables 2, 4, 5 and Fig. 2) followed the trends established for grain weights but the results were less consistent. The apparent recovery of N in grain is presented in Table 6. Without incubation comparatively high recoveries were obtained, averaging 57% and 60% for the soils of pH 5.5 and 7.2 respectively. With incubation, the recovery decreased rather markedly for both soils.

The results of this experiment validate the hypothesis that differential nitrification of different N sources added to direct-seeded rice is related to yield responses to these fertilizers.

Table 1. Characteristics of N Sources Used.

| Source | Total N % | Acid- or Alkaline-Forming |
|---|---|---|
| Urea | 46.1 | Alkaline |
| Urea ammonium phosphate (UAP) | 38.1 | Alkaline |
| Ammonium polypnosphate (APP) | 15.2 | Alkaline |
| Diammonium phosphate (DP) | 21.2 | Alkaline |
| Monoammonium phosphate (MAP) | 12.2 | Acid |
| Ammonium sulfate (AS) | 21.2 | Acid |
| Ammonium chloride (ACl) | 26.2 | Acid |

Table 2. Rice Grain Yields and N Contents, As Affected by N Sources, Rates, and Incubation Prior to Flooding (Mountview sil, pH 5.5).

| | | Days Incubation | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 10 | 20 | 0 | 10 | 20 |
| N Source | Rate of N mg/pot | Grain Weight g/pot | | | Grain N content mg/pot | | |
| Alkaline-forming sources | | | | | | | |
| Urea | 200 | 21.3 | 17.7 | 13.1 | 319 | 229 | 176 |
| | 400 | 28.6 | 26.3 | 19.5 | 446 | 347 | 251 |
| UAP | 200 | 20.5 | 17.1 | 13.1 | 331 | 224 | 168 |
| | 400 | 30.1 | 26.3 | 18.7 | 431 | 337 | 245 |
| DP | 200 | 21.3 | 18.3 | 12.2 | 293 | 240 | 165 |
| | 400 | 28.6 | 26.2 | 22.2 | 403 | 360 | 264 |
| APP | 200 | 21.4 | 18.8 | 14.1 | 300 | 251 | 178 |
| | 400 | 29.4 | 26.3 | 21.5 | 423 | 373 | 267 |
| Acid-forming sources | | | | | | | |
| AS | 200 | 20.6 | 18.0 | 14.1 | 316 | 23[illegible] | 185 |
| | 400 | 28.2 | 28.0 | 23.0 | 415 | 35[illegible] | 289 |
| ACl | 200 | 21.7 | 18.6 | 15.0 | 266 | 238 | 186 |
| | 400 | 29.5 | 27.5 | 24.3 | 403 | 354 | 286 |
| MAP | 200 | 22.2 | 18.3 | 13.5 | 306 | 252 | 190 |
| | 400 | 28.6 | 26.9 | 21.9 | 426 | 379 | 293 |
| No N | | 13.1 | 8.6 | 7.7 | 197 | 138 | 122 |

Note: Analysis of variance of yield shows highly significant effects of source, rate, incubation, and source-by-incubation interaction.

Table 3. Nitrate Formed During Preflood Incubation Period in Mountview sil of pH 5.5.

| N Source | Rate of N mg/pot | Days Incubation 10 | 20 |
|---|---|---|---|
| | | $NO_3^-$-N at time of transplanting mg/pot | |
| Urea | 200 | 110 | 200 |
| | 400 | 130 | 330 |
| AS | 200 | 75 | 135 |
| | 400 | 60 | 135 |
| No N | - | 65 | 75 |

Table 4. Rice Grain Yields and N Contents, As Affected by N Sources, Rates and Incubation Prior to Flooding (Mountview sil, pH 7.2).

| N Source | Rate of N mg/pot | Days Incubation 0 | 10 | 20 | 0 | 10 | 20 |
|---|---|---|---|---|---|---|---|
| | | Grain Weight g/pot | | | Grain N Content mg/pot | | |
| Urea | 200 | 22.9 | 18.8 | 19.2 | 332 | 217 | 229 |
| | 400 | 30.0 | 27.1 | 28.5 | 454 | 327 | 339 |
| AS | 200 | 21.9 | 18.6 | 17.8 | 317 | 224 | 210 |
| | 400 | 31.0 | 24.6 | 24.0 | 451 | 295 | 277 |
| No N | - | 15.6 | 12.9 | 12.1 | 217 | 166 | 159 |

Table 5. Grain Yield and N Content, As Affected by Source, soil pH, and Incubation Period (Averaged over Rate).

| | pH 5.5 | | | pH 7.2 | | |
|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 0 | 10 | 20 |
| Grain yield, g/pot | | | | | | |
| Urea | 24.9 | 22.0 | 16.3 | 26.5 | 23.0 | 23.8 |
| AS | 24.4 | 23.0 | 18.6 | 26.4 | 21.7 | 20.9 |
| N content, mg/pot | | | | | | |
| Urea | 332 | 288 | 214 | 393 | 272 | 284 |
| AS | 366 | 295 | 237 | 384 | 260 | 244 |

Table 6. Apparent Recovery of N in Grain, As Affected by N Source, Soil pH, and Incubation Period.

| N Source | pH 5.5 | | | pH 7.2 | | |
|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 0 | 10 | 20 |
| Urea | 63 | 54 | 38 | 61 | 40 | 45 |
| UAP | 62 | 52 | 36 | | | |
| DP | 52 | 58 | 39 | | | |
| APP | 57 | 62 | 41 | | | |
| AS | 57 | 56 | 46 | 59 | 35 | 31 |
| ACl | 50 | 56 | 46 | | | |
| MAP | 58 | 63 | 47 | | | |

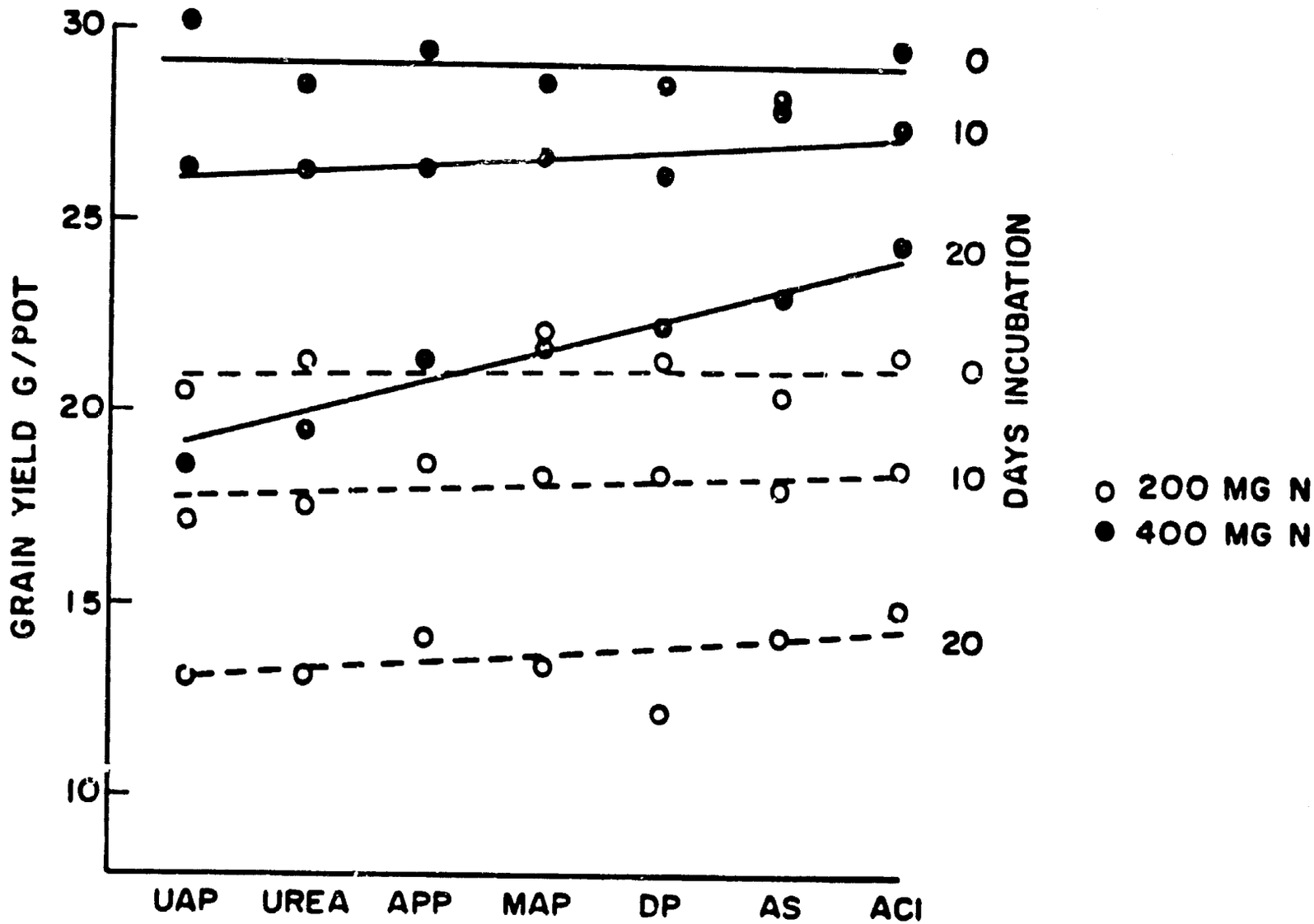


Fig. 1. Grain yield of rice, as affected by preflood incubation, source, and rate of N (pH 5.5).

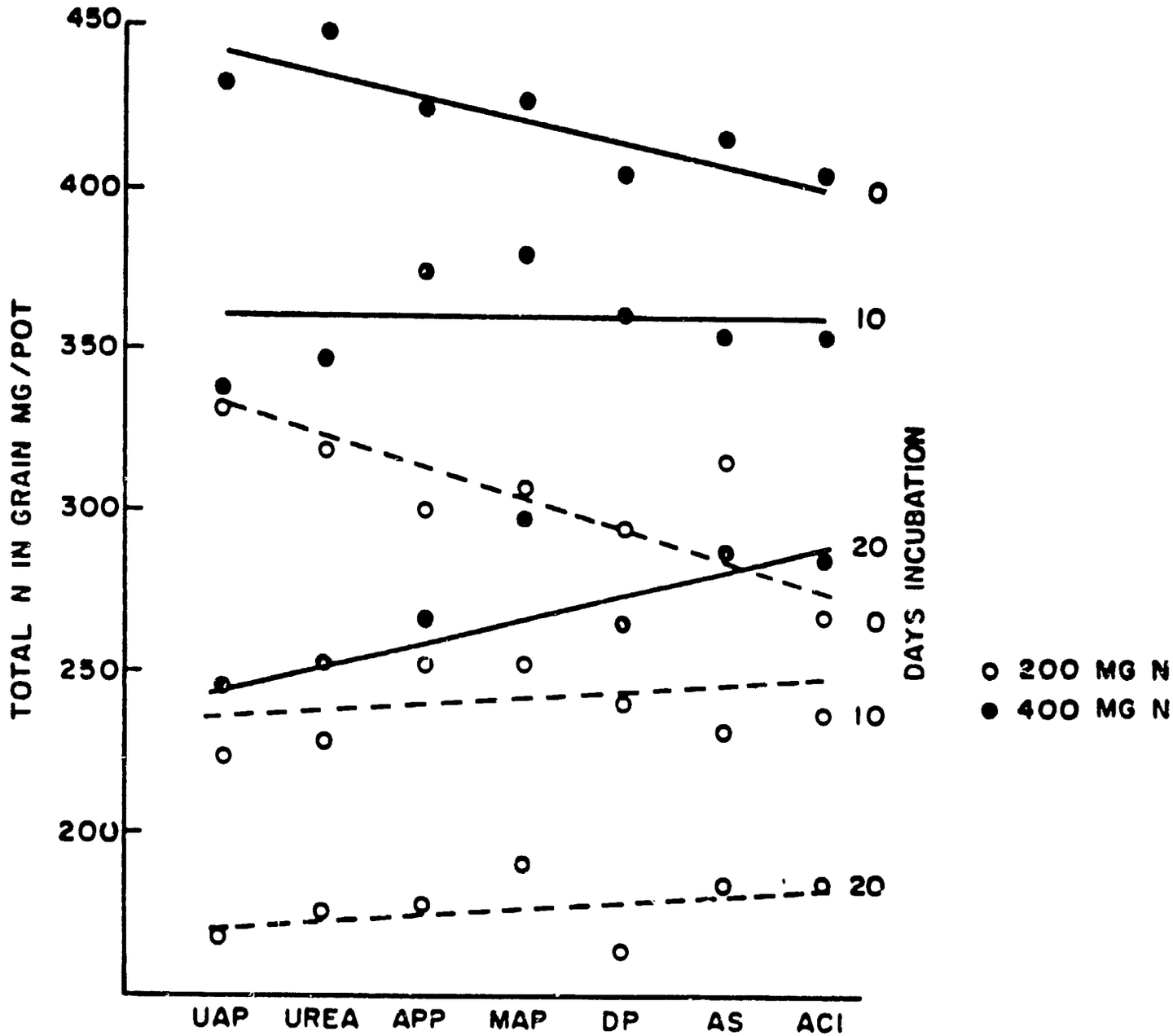


Fig. 2. Total N content of grain, as affected by preflood incubation, source, and ra of N (pH 5.5).