COMPREHENSIVE RESEARCH ON RICE
ANNUAL REPORT

January 1, 1990   December 31,1990

PROJECT TITLE: Rapid Survey of Rice Genotypes for Growth and Yield Potential, Tolerance to High and Low and Temperature, and Sensitivity to Herbicides or Other Chemicals.

PROJECT LEADER AND PRINCIPLE UC INVESTIGATORS:
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LEVEL OF 1990 FUNDING: $10,000

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

I. To correlate the metabolic heat rates of various rice tissues (germinating seed, young intact seedlings, leaf, stem and root sections) from selected genotypes with growth rates and yields obtained from published information or current experiments.

II. To evaluate the temperature response profiles for metabolic heat rates of leaf and/or root tissue from 0^oC to lethally high temperatures by scanning calorimeter methods and relate these to known temperature adaptation of selected genotypes.

III. To examine the interaction between temperature and chemical stresses (O_2, herbicides) for root or leaf tissues of selected genotypes as expressed by their effect on metabolic heat rates.

SUMMARY OF 1990 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVES

Objective I. Correlations among metabolic heat rate, efficiency and growth rate.

Rice cultivars SM101, M202, L202, Lemant, Mars, and CM101 were studied, with particular emphasis on M202, L202, and CM101 as models for developing techniques to define relationships between metabolic properties and growth rates. Seven day-old, dark grown seedlings were examined in a modified calorimeter to simultaneously determine not only heat rates per mg of tissue, but respiratory CO_2 and O_2 exchange. Our original proposal was premised only on measuring metabolic heat rates.

We have also developed a mathematical model based on the rice, as well as corn measurements, that relates the physiological measurements to plant growth properties. The model quantitatively defines a rather complex relationship for the rather intuitive suggestion that **biomass accumulation rate (growth rate) depends upon the rate at which a plant can metabolize to provide the building blocks and energy for growth, and the efficiency with which the metabolic energy can be coupled to biomass production.** The equation for rate of biomass accumulation and definition of the terms involved are presented in Fig. 1 below. The importance of this mathematical expression is that with our methods, **all of the quantities needed to solve it can be measured.** In combination with our calorespirometer measurements, this model allows prediction of relative plant growth rates and also allows determination of carbon use efficiency, energy efficiency, redox state of substrate, respiratory quotient and metabolic pathways dominant in energy production. It should be noted that this is the first procedure for determining the carbon use efficiency of plants. It yields values of central importance in improving crop productivity. Certainly other plant attributes must be exploited to achieve increased economic yield in rice, but if increased growth is distributed into early vegetative growth and partitioned into later reproductive growth, the consequences are obvious.

The first applications of our calorimetric methods to rice studies, and calculations of carbon use efficiencies are reported in Table 1. Agreement is noted among predicted growth rates, energy efficiencies, carbon use efficiencies and measured laboratory growth vigor for the seedlings.

Objective II. Responses of rice seedlings to low temperatures.

Examination of metabolic rates of rice cultivars as a continual function of temperature over the range from 20^o to 0^{o}C established that cultivar specific differences can be measured that differ for cultivars with known differences in cold tolerance. While the decrease in activity with lowered temperature and the recovery of activity of all tested cultivars are approximately the same, the time course and mechanism of recovery differ for the sensitive and more cold tolerant cultivars. This is illustrated in Figs. 2 and 3. After scanning to 0^{o}C and holding for 40 min, the scan back up shows that in the more stable cultivars activity recovery starts immediately and proceeds nearly linearly on the Arrhenius plot. Sensitive cultivars, such as Lemant, show a distinct lag in recovery at low temperatures, and then a rapid recovery phase starting around 10^{o}C so that both regain virtually all activity at 20^{o}C. Table 2 summarizes the results of scanning studies on 6 cultivars. Results present temperature coefficients for activity as apparent activation energies (EA), which are related to the slope of the Arrhenius plots (Fig. 2 and 3), over selected temperature ranges. The values of EA on the up scans and the ratios of EA values for the down and up scans correlates with known temperature sensitivities of the cultivars.

The simplest measurable parameter, i.e. whether cultivars showed differences in metabolic recovery after a fixed time of exposure to a stress temperature, was not effective in differentiating plants with known differences in thermal stability. For example, CM101 and Lemant showed nearly equal recovery of activity after repeated one hour exposures to 0^{o}C, though these two are reported to differ significantly in cold temperature tolerance. However, the specific protocol for these experiments (modeled after those used previously for tomato) were inappropriate for rice because of the complete recovery of activity for short exposures, as seen above in the scanning data. Further studies are required to define experimental stress conditions such as lower test temperature, longer exposures, change to more anaerobic conditions, etc., that may be effective allowing a simple correlation.

Objective III. Stress effects on rice metabolism

This project was funded for only the final six months of the year, making it impossible for us to get to this portion of the proposed research in the time available. The development of a model relating growth and efficiencies, however, makes this portion of the project much simpler and potentially much more meaningful since we can now relate stress responses to more defined alterations in plant physiology.

PUBLICATIONS OR REPORTS:

The six months spent in pursuing this new project have not yet generated publications directly related to rice. A number of descriptions of the general methods have been published or are in press. These methods will now be used to evaluate rice physiology as related to the objectives of our proposal.

1. Breidenbach, R.W. and R.S. Criddle. 1990. Heat rate measurements as predictor of seedling vigor, temperature tolerance and growth rates. Pioneer Report

2. Breidenbach, R.W., D.R. Rank, A.J. Fontana, L.D. Hansen, and R.S. Criddle. 1990. Calorimetric determination of tissue responses to thermal extremes as a function of time and temperature. Thermochim. Acta in press.

3. Criddle, R.S., R.W. Breidenbach, D.R. Rank, M.S. Hopkin, and L.D. Hansen. 1990. Simultaneous calorimetric and respirometric measurements on plant tissues. Thermochim. Acta 172:213-221.

4. Criddle, R.S., A.J. Fontana, D.R. Rank, D. Paige, L.D. Hansen, and R.W. Breidenbach. 1991. Simultaneous measurement of metabolic heat rate, CO_2 production and O_2 consumption by microcalorimetry. Analytical Biochemistry, (UnPub)

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

Our major accomplishments have been the development of equipment and methods that allow simultaneous measurement of calorimetry and respirometry and the subsequent derivation of a mathematical model that defines relationships among plant growth rates, energy and carbon use efficiencies, and our experimentally measurable parameters. This allows, for the first time, the measurement of carbon use efficiencies and the prediction of relative rates of biomass accumulation (growth rates) as a function of simply measured metabolic parameters of different test cultivars. This development provides uniquely important parameters to be used for evaluation of existing cultivars and for selection of new cultivars during genetic screening studies.

We have also demonstrated readily measurable differences in cold tolerant and more sensitive cultivars of rice that may be used in screening cold tolerance. The measurements do not yet provide simple quantitative procedures for large scale screening, but offer promise that these may be developed.

Figures and Tables

Fig. 1. Equation relating rate of biomass production with parameters measurable with combined calorimetric and respirometric methods.

$$\text{Growth rate} = dC_B/dt = [q_m/\Delta H]\, C_{eff}$$

$$= \frac{q_m C_{eff}}{(1-y/4)\Delta H_{O2} + [\Delta H_B - (1-y/4)\Delta H_{O2}]\, C_{eff}}$$

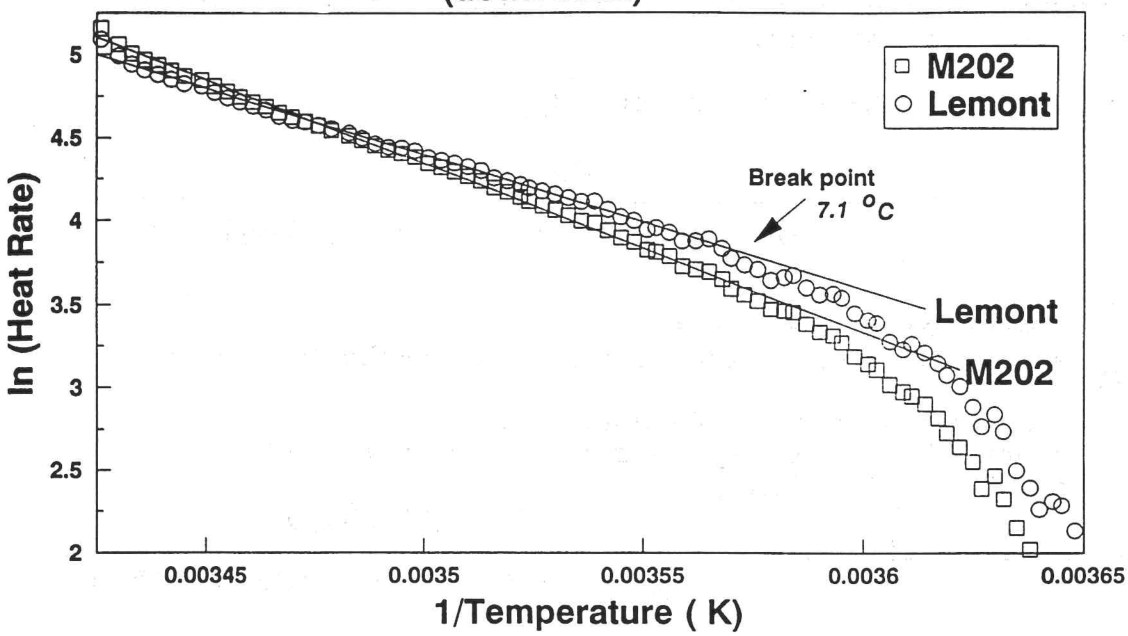
Where:
q_m = metabolic heat rate
ΔH_{O2} = heat of combustion of substrate/mole C = -470 kJ/mole
y = oxidation state of substrate
ΔH_B = enthalpy of biosynthesis/mole C = 10 kJ/mole
C_{eff} = carbon efficiency

$$\text{and carbon efficiency} = \frac{[RQ(1-y/4)\Delta H_{O2}}{[q_m/R_{O2} - \Delta H_B\, RQ + RQ(1-y/4)\Delta H_{O2}}$$

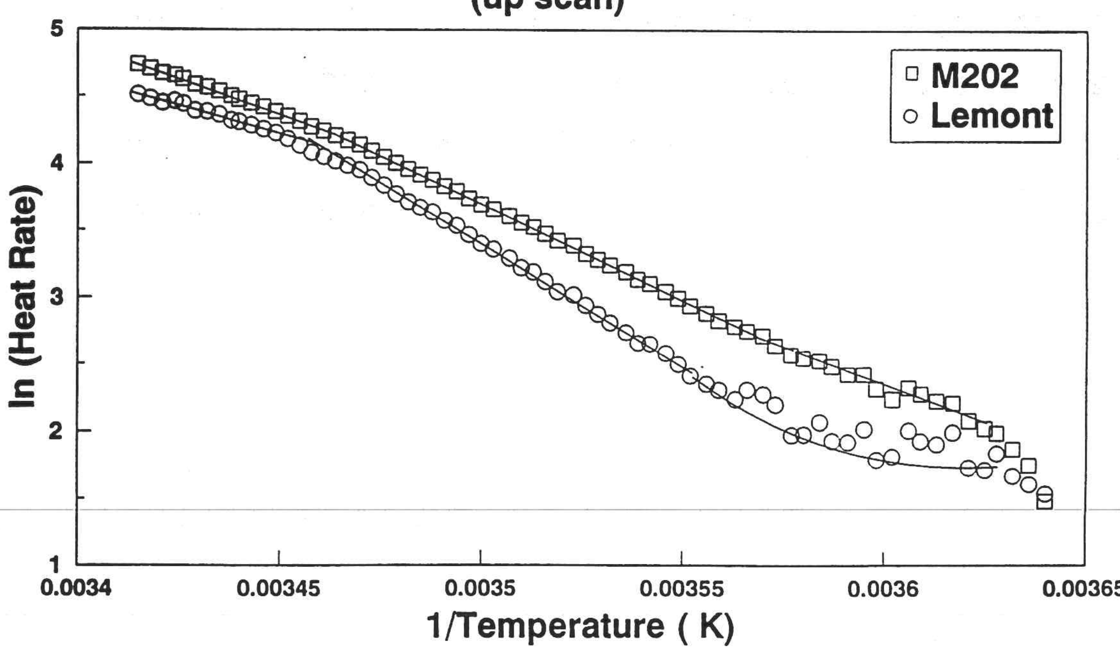
Table 1. Metabolic and growth properties of rice cultivars.

Cultivar	q_m/mg	O_2 rate	CO_2 rate	RQ	kJ/ O_2	Vigor
M202	27.7	3.91	2.76	.71	337	Mid
L202	32.6	3.26	3.00	.92	362	Poor
CM101					2.95	Good

Arrhenius Plot
(down scan)



Arrehenius Plot
(up scan)



Activation Energy of Rice Cultivars

	Comment	EA (down) region 1	EA (back up) region 2	Ratio
L202	Indica x Japonica	19,083	21,016	1.10
CM101	Japonica	12,333	21,163	1.72
M202	Japonica	19,157	28,156	1.47
Mars	Subtropical Japonica	11,801	25,493	2.16
Lemont	Subtropical Indica	17,050	32,943	1.93
S201	Japonica	19,106	24,988	1.31

Activation energy in cal/mole