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SENSITIVITY TESTS OF THE CROP VARIABLES IN RICEWOOD

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ABSTRACT

The rice crop simulation model RICEMOD (McMennamy, 1980a, b; and McMennamy and O'Toole 1983) was tested for sensitivity to the input crop variables. The model is most sensitive to changes in the light attenuation factor and the leaf nitrogen factor. It is less sensitive to changes in the respiration coefficients for growth and maintenance and axial root resistance coefficient. It is least sensitive to plant weight at transplanting. The reaction to the light attenuation factor depends upon climate as expressed by a date of transplanting test.

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SENSITIVITY TESTS OF THE CROP VARIABLES IN RICEMOD

The rice crop simulation model RICEMOD was developed by McMennamy (1980a, 1980b) and McMennamy and O'Toole (1983). The model was tested by changing environmental parameter inputs and evaluating the results through sensitivity analysis (Whisler 1983). The present report is an extension of that sensitivity analysis and was designed to consider crop growth and development parameters. RICEMOD equations and parameters were developed for IR36 grown at IRRI; therefore this sensitivity analysis is like examining other cultivars. Because most of the parameters and their equations are independent of each other they are discussed in alphabetic order.

METHOD

A version of the program known as RICE300 (McMennamy and O'Toole 1983) was prepared wherein a percentage of a single crop parameter could be changed. By changing the sign of the percentage, the variable could be increased or decreased from its standard value while all others were held constant. Variables were changed by ±10% and ±50%. The standard values of the crop variables are given in Table 1.

Environmental variables were also held constant between comparative simulations. However, as was discussed in the earlier analysis (Whisler 1983) planting date and associated weather data did change the magnitude of the model's responses. Therefore, simulations were made with 1 April and 25 June planting dates. A plot of the climatic variables is given in Figure 1.

Because the model is incompletely validated, the majority of the results are shown as % change from the standard simulation. Standard simulated values of plant part weights and other indices are shown in Table 2.

Detailed descriptions of the crop variables, references, and dimensions are given in McMennamy (1980b) and McMennamy and O'Toole (1983). Only a brief description of the functions are given here.

AF

The AF parameter is used in the light attenuation function to calculate the amount of incident solar radiation that reaches each leaf layer (L) in the canopy. An intermediate parameter XAF is calculated for each leaf layer by:

$$XAF_L = AF \times (1. - AF)^{(L-1)} \quad (1)$$

then

$$XLI_L = XAF_L \times PAR_H \quad (2)$$

where XLI is the amount of photosynthate produced at leaf layer L, by the amount of photosynthetically active radiation PAR in hour H. XLI is summed over all leaf layers and hours to get the daily amount of photosynthate produced by the crop. Changing AF is like increasing or decreasing leaf width or angle without increasing the leaf mass of a cultivar. Therefore, short, erect-leaf varieties have lower AF per leaf layer.

Table 1. Standard values of crop parameters used in RICEMOD.

Variable	Value
AF	0.55
AN	5.0
RG	0.28
RM	0.007
RP	500
XW	66.3

AN

The AN parameter is used in calculating the leaf nitrogen content PCTNL in:

$$PCTNL = AN - AN/150 \times D \quad (3)$$

where D is the age of the plant in days. Changing this parameter is like developing a more nitrogen efficient or less nitrogen efficient cultivar. For example, increasing AN would cause a plant to contain more nitrogen at any growth stage although it would have no more roots or transpiration than the standard plant.

RG

The RG parameter is the growth respiration coefficient. It is used in:

$$RGAMT = XDP \times RG \quad (4)$$

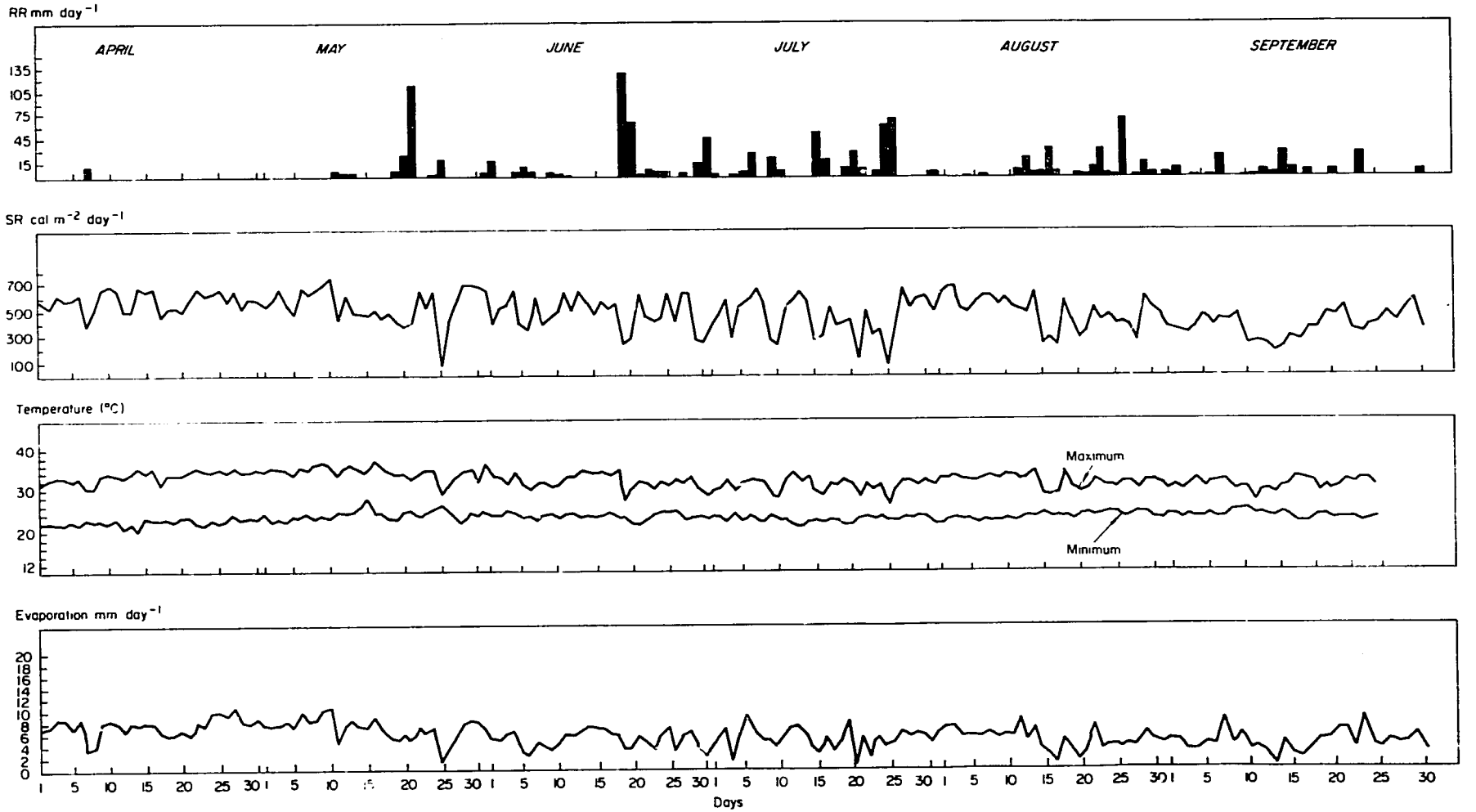
where RGAMT is respiration loss due to growth per day and XDP is gross photosynthate produced in that day. Changing RG is like developing a more photosynthetically efficient or less photosynthetically efficient cultivar. For example, decreasing this parameter reduces respiration losses while maintaining the standard amount of gross photosynthate.

RM

The RM parameter is the maintenance respiration coefficient. It is used in:

$$RMRATE = TCOEF \times RM \times (24\text{-}DL)/12 \quad (5)$$

where RMRATE is the maintenance respiration rate, TCOEF is a temperature coefficient calculated from daily maximum and minimum temperatures, and DL is photosynthetic day length. Changing this parameter, as with the RG parameter, is like developing a more energy efficient or



1. Daily values for rainfall (RR), solar radiation (SR), maximum and minimum temperature, and pan evaporation for Apr-Sep 1980 at the IRRI upland weather station.

Table 2. Standard simulated values of plant parts at harvest.

Variable	Weight or ratio	
	April planting	June planting
Leaf	25.1 g m^{-2}	95.6 g m^{-2}
Stem	402.8 g m^{-2}	577.0 g m^{-2}
Root	310.2 g m^{-2}	334.2 g m^{-2}
Panicle	362.0 g m^{-2}	527.9 g m^{-2}
Harvest index	0.46	0.44
Root-shoot ratio	0.39	0.28

less energy efficient cultivar. For instance, decreasing RM reduces the maintenance respiration rate and makes more photosynthate available for growth.

RP

The RP parameter is a coefficient for axial hydraulic root resistance. It is used in:

$$R_J = RS_J + RP \times J/(RL_J)^{1/2} \quad (6)$$

where R is total hydraulic resistance in soil and root layer J, RS is the soil resistance of that layer, and RL is root length density in that layer. Changing RP is like developing a more hydraulically permeable or less hydraulically permeable rooted cultivar.

XW

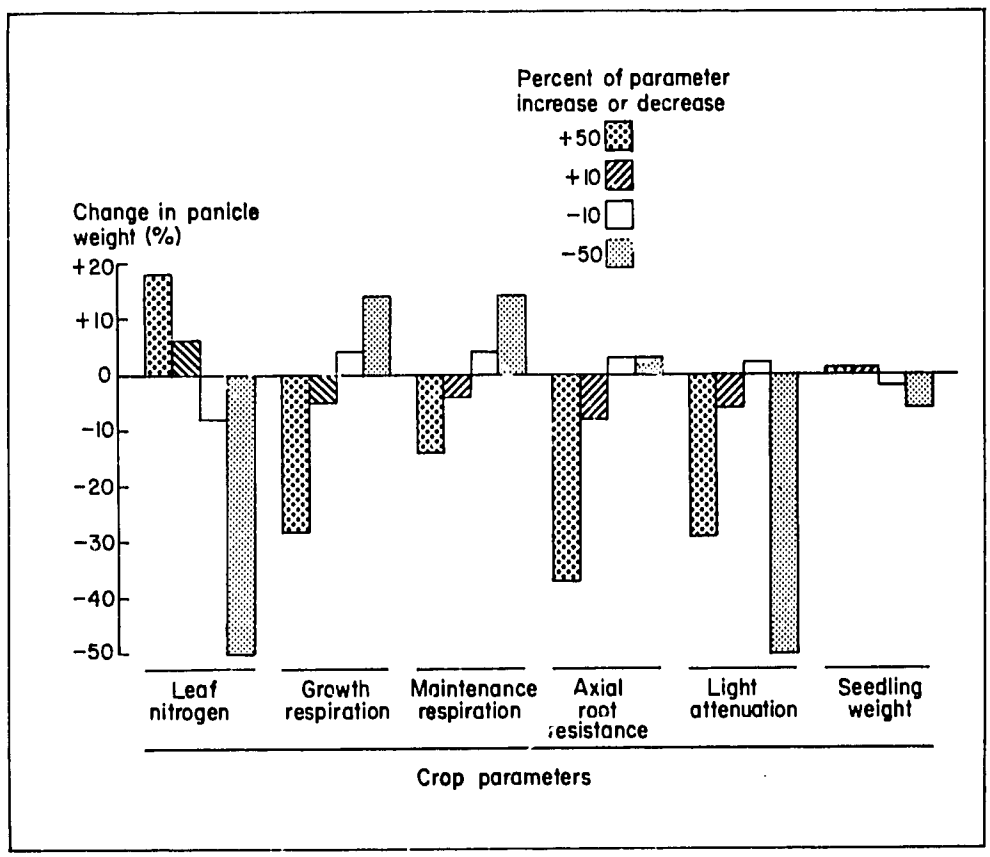
The XW parameter is the weight of rice seedlings at transplanting, which is the sum of leaf, leaf sheath and culm, root, and panicle weights if panicles are present at transplanting (TPAGE in the model). Changing this parameter is like developing a faster or slower vegetative growing cultivar. However, such growth rates are not entered into the model directly but are modified, from TPAGE onward, by other plant and environmental parameters. Another interpretation suggested by J. C. O'Toole (pers. communication) is that an increase in XW is the same as increasing plant population per unit area of land.

RESULTS AND DISCUSSION

Results of these tests, in terms of simulated panicle weights, are given in Table 3 and Figure 2. Planting date affects some variables more than others, and some variables respond monotonically. For example, a small increase in

Table 3. Simulated panicle weight, as % change from standard, for a given % change in the crop variable.

Planting date	% change of variable	Simulated panicle wt					
		AF	AN	RG	RM	RP	XW
Apr	+10	-5.7	6.5	-5.4	-4.4	-8.5	0.6
	-10	2.2	-8.1	4.3	3.6	2.9	-1.6
	+50	-29.2	17.5	-28.5	-14.3	-37.3	1.1
	-50	-50.4	-49.7	13.7	13.8	2.7	-5.5
Jun	+50	-30.8	16.6	-18.8	-13.8	-11.6	-0.8
	-50	15.4	-34.5	16.1	13.7	-0.4	0.5



2. Changes in panicle weight due to increasing or decreasing the crop parameters for an April planting.

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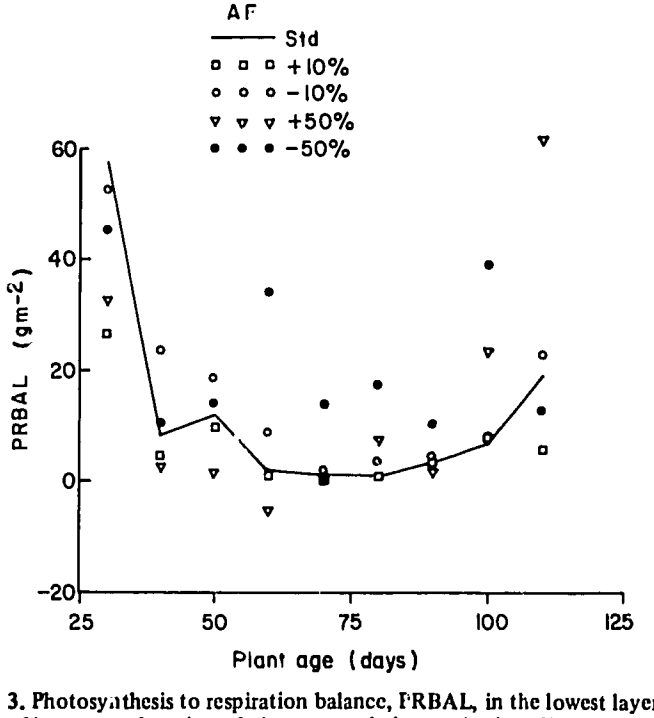
AN increased predicted yield, a larger increase in AN further increased yield, and reversing the sign and magnitude of the change had the opposite effect. For other variables, such as AF, the model response was not as orderly.

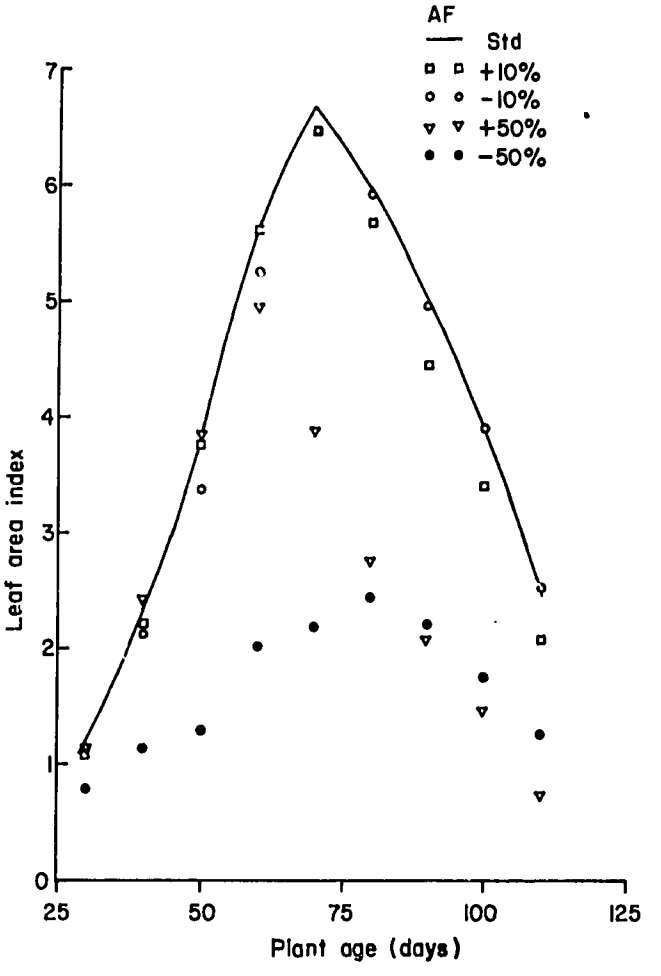
AF

As AF is increased in equation 1, the accumulated light interception is increased when there are the same number of nodes or leaf layers per plant (Fig. 3). However, as the crop grows and adds newer layers of leaves, the older, lower leaves are shaded sooner and become a sink for photosynthate rather than a supplier and in turn bring about their own senescence (note at least one negative value in Fig. 3). Because much of grain filling is a translocation of the dry weight process, increasing AF caused a pronounced decrease in yield. However, a simulated 10% decrease in AF caused a 2% increase in panicle weight over the standard value. For the early planting, a 50% decrease in AF predicted a 50% yield decrease, the largest decrease of any of the simulations.

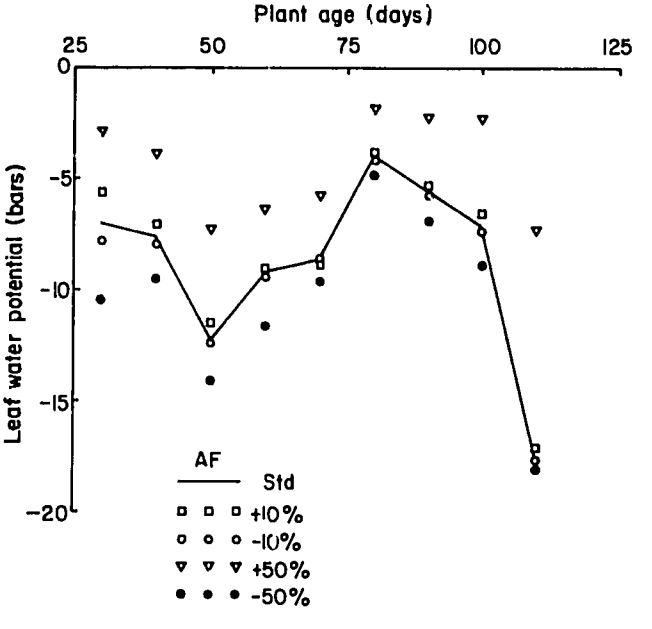
For the June planting the opposite was true. A 15% yield increase was predicted for a 50% decrease in AF. In the early planting, with a large decrease in AF, the plants appeared to have a smaller leaf weight and area (Fig. 4). However, with low rainfall and high radiation (Fig. 1) there was less shading of the soil, more evaporation, quite negative leaf water potential, and drought stress, especially early in the season (Fig. 5), which caused a yield reduction. Additionally, the feedback mechanisms in the model react to low leaf water potential by decreasing leaf area, which



3. Photosynthesis to respiration balance, PRBAL, in the lowest layer of leaves as a function of plant age and changes in the AF parameter for an April planting.



4. Leaf area index as a function of plant age and changes in the AF parameter for an April planting.



5. Leaf water potential as a function of plant age and changes in the AF parameter for an April planting.

means less material for translocation and lower yield. In the June planting, which had more frequent rainfall and lower radiation, plants were not stressed, lower leaves remained active longer, produced more photosynthate, and yielded more than the standard values and the April planting. These responses are similar to field observations and model responses of other crops (Baker et al 1979). This seems to be the nature of the new, erect-leaved rice varieties that allow more light penetration deeper into the canopy and thereby produce more grain weight.

Harvest index is defined as dry grain yield divided by total top dry weight (Yoshida 1981). Simulated panicle weight is the model estimate of grain dry weight, which divided by the total plant top (panicles + leaves + leaf sheath and culm) dry weight at harvest was used as harvest index. Results are given in Table 4 and Figure 6. A 10% change in AF had little effect on predicted harvest index, but a 50% change did affect the results in a manner similar to the effect on panicle weight results. The magnitude of the effects, however, was generally not as great.

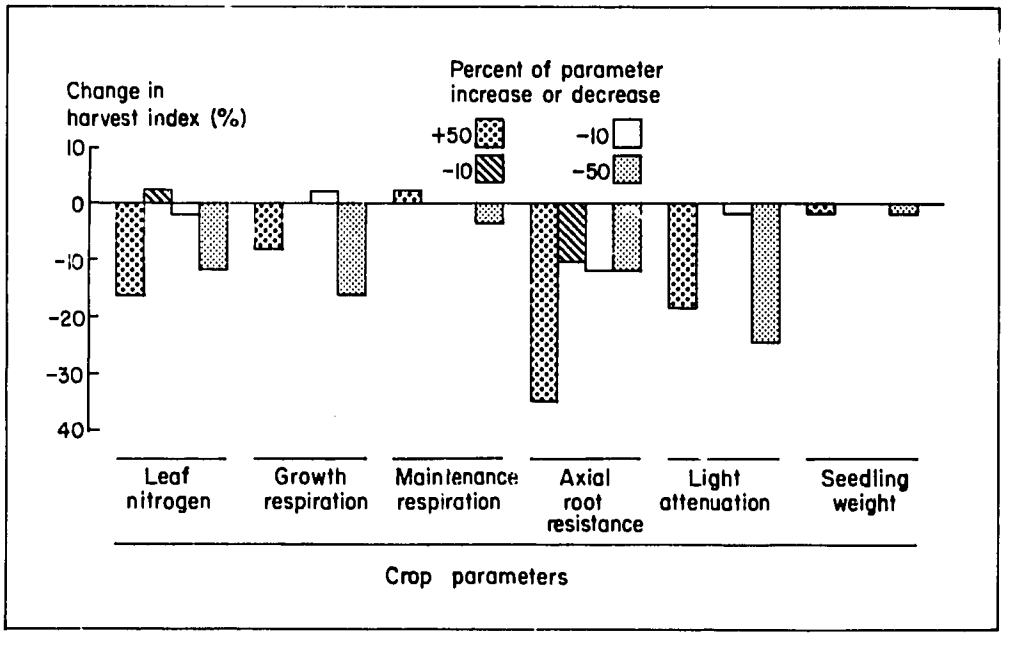
Another crop growth parameter is root-shoot ratio. Because the model calculates root mass, root-shoot ratio can also be predicted. Results are given in Table 5 and Figure 6. The April planting showed little effect of changes in AF but the June planting did show some effect, which was opposite in sign and smaller in magnitude than the panicle weights in Table 3. Increasing AF increased the weight of roots to shoots. Therefore, the available photosynthate that would normally have gone to the lower leaves, went to extra root mass when the leaves senesced. Conversely, when AF was decreased in the June planting, which had more favorable weather, higher panicle weight developed at the expense of root weight.

AN

The model's panicle weight response to changes in AN is monotonic, but not symmetrical, that is, a 50% increase increased yield by only 18% while a 50% decrease decreased yield by 50%. As McMennamy (1980a, b) points out, however, the crop is assumed to be well fertilized; therefore,

Table 4. Simulated harvest index, as % change from standard, for a given % change in the crop variable.

Planting date	% change of variable	Simulated harvest index					
		AF	AN	RG	RM	RP	XW
Apr	+10	0.0	2.0	0.0	0.0	-10.2	0.0
	-10	- 2.0	- 2.0	2.0	0.0	-12.2	0.0
	+50	-18.4	-16.3	- 8.2	2.0	-34.7	-2.0
	-50	-24.5	-12.2	-16.3	-4.1	-12.2	-2.0
Jun	+50	- 5.4	- 2.7	0.0	2.7	2.7	-2.7
	-50	27.0	2.7	- 2.7	-5.4	0.0	2.7



6. Changes in harvest index as a function of changes in the crop parameters for an April planting.

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this nonsymmetrical response is not surprising. Because crop nitrogen level is only a function of AN and plant age (equation 3) it is also not surprising that weather data and planting date do not appreciably affect the results. A more mechanistic approach to crop nitrogen level would produce different results (Baker et al 1979).

The effect of changes of AN on harvest index (Table 4) were not monotonic - both 50% changes predicted a decrease in the harvest index, indicating that even though a 50% increase in AN predicted an 18% increase in panicle weight in Table 3, there was an even greater increase in other top dry matter produced. A 50% decrease in AN also decreased the predicted panicle weight more than it did the other top material.

AN and the other crop variables (RG, RM, RP, and XW) slightly affected root-shoot ratios (Table 5 and Fig. 7). Only 50% changes in the variables produced 8% changes in the predicted ratios.

RG, RM, and RP

The model's response to changes in RG, RM, and RP parameters was generally similar for panicle yield (Table 3). Responses were monotonic but not symmetrical about zero changes. Planting date generally decreased the magnitude of the predicted change. If the model's responses are correct, they would seem to suggest that decreasing the respiration loss of an improved variety like IR36 would have only an appreciable effect if the respiration reduction was large.

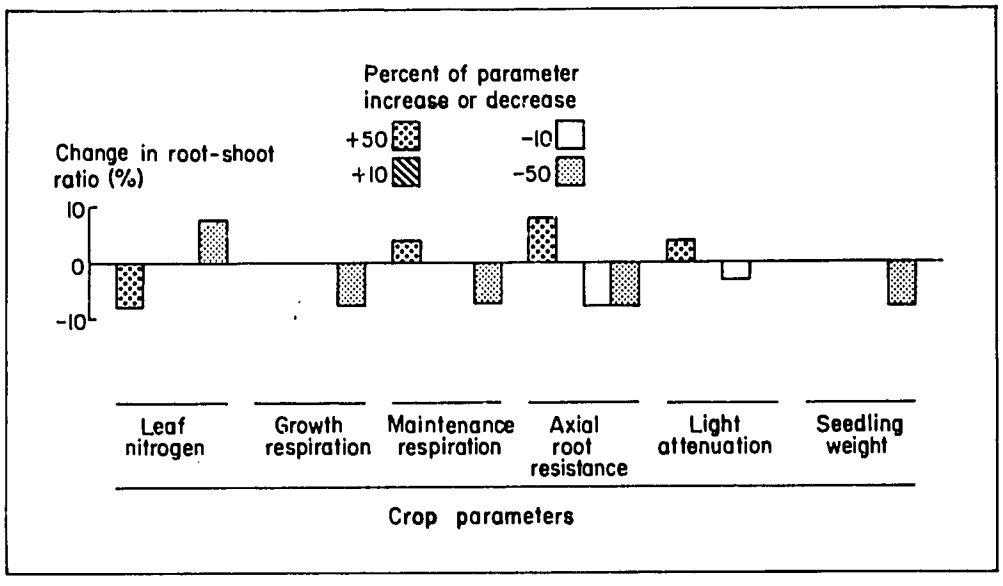
Changing these parameters produced non-monotonic changes in harvest index values (Table 4 and Fig. 6). Harvest index was most responsive to changes in RP. The April planting showed a decrease in harvest index for all RP changes and a 35% decrease when RP was increased 50%, and although there were some slight panicle weight increases predicted in Table 3 when RP was decreased, other top parts were increased even more.

XW

The model was least responsive to the XW parameter. Only a 50% decrease in XW caused an appreciable yield prediction decrease in Table 3, -5.5% in the April-planted crop, which probably is a good sign of the model's stability. The initial weight of healthy 15- to 25-day-old plants probably does not affect the final crop yield substantially. If changing XW is like changing plant population, then the model's response indicates yields are fairly stable over a

Table 5. Simulated root-shoot ratios, as % change from standard, for a given % change in the crop variable.

Planting date	% change of variable	Simulated root-shoot ratio					
		AF	AN	RG	RM	RP	XW
Apr	+10	0.0	0.0	0.0	0.0	0.0	0.0
	-10	- 3.8	0.0	0.0	0.0	-7.7	0.0
	+50	3.8	-7.7	0.0	3.8	7.7	0.0
	-50	0.0	7.7	-7.7	-7.7	-7.7	-7.7
Jun	+50	10.7	3.6	3.6	0.0	-3.6	3.6
	-50	-17.9	0.0	3.6	3.6	0.0	-3.6



7. Changes in the root-shoot ratio as a function of changes in the crop parameters for an April planting.

wide range of populations in the IRRI climate. The effect of changing XW on the harvest index value also was slight.

SUMMARY

RICEMOD reacts most to changes in the light attenuation factor and leaf nitrogen coefficient, has intermediate reaction to changes in growth and maintenance respiration coefficients and axial root resistance coefficients, and least reaction to the plant weight at transplanting. Reactions to the light attenuation factor are interdependent with climate as expressed by transplanting date tests. The leaf nitrogen coefficient reaction may be too severe because of an oversimplified approach.

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