Appendix

A．Leaf number

The morphogenesis process can be determined by the number of leaves on the main culm (Datta, 1981, Yoshida, 1981). According to Nakagawa et al. (unpubl. res.), the leaf number, L_N, and leaf emergence rate, L_R, are expressed as follows (Watanabe et al., 2005).

For $0 < D_{VI} < 1$

$$L_N = \sum L_R + L_{N0} \quad \text{(A.1)}$$

$$L_R = \left(\frac{1}{G_L}\right)\left(1 + e^{-A_L(TI_i - T_L)}\right)\left(\frac{1 - C_L}{1 + e^{B_L(D_{VI} - DL_i)}} + C_L\right) \quad \text{(A.2)}$$

For $1 < D_{VI} < 2$

$$LN = \text{leaf number (at } D_{VI} = 1.0) + 3.5 - \text{Min}\left(0, DL_i\left(1 - e^{-E_L(D_{VI}-1)}\right) - 3.5\right) \quad \text{(A.3)}$$

where G_L, A_L, T_L, C_L, D_L and E_L are parameters, L_{N0} is the initial leaf number at transplanting, in this case 1. The other symbols are the same as above.

B. Dry Matter Production

The actual dry matter accumulation rate in canopy for a given day i, DW_{CP} (i) in g m^{-2}, was determined by the following equation

$$DW_{CP}(i) = DW_{CP}(i-1) + \triangle DW_{CP}(i) \quad \text{(B.1)}$$

$$\triangle DW_{CP}(i) = NPD_i \times (1 - C_R) \times (1 - \varepsilon) \quad \text{(B.2)}$$

where DW_{CP} (i-1) is the actual dry matter accumulation rate on the (i-1)th day (in g m^{-2}), $\triangle DW_{CP}$(i) is the daily actual increments of dry matter in rice plants on the ith day (in g m^{-2}), C_R is the partitioning coefficient of NPD_i to root in rice plants, taking C_R=0.2 (Gao et al.,1992a), and ε is the mineral substance content in dry matter in rice plants, taking ε = 0.1 (Gao et al.,1992a; Wang et al. 1990). The other symbols are the same as above.

C. Leaf area index (LAI)

pre-transplanting (Gao *et al*.,1992a)

$$FD_i = 3.5/(1 + (\frac{3.5 - 0.01}{0.01}) \times e^{-KFS \times D_{VI}}) \qquad (C.1)$$

where FD_i is the LAI at rice development index, D_{VI}, and KFS is a parameter, taking KFS = 12.6.

from transplanting to heading and after heading (Gao *et al*.,1992a)

$$BI = ((24 - DL3) \times \left(2^{(\frac{LI3 - HI3}{20})} + DL3\right))/DL3 \qquad (C.2)$$

$$F3N = (NF0 \times (-\ln (BI \times II3 / QI3) / E1) \times 10 + 0.5) / 10 \qquad (C.3)$$

$$FD_i = F3N/(1 + (\frac{F3N - 0.5}{0.5}) \times e^{-KF1 \times D_{VI}}) \qquad (C.4)$$

where HI3, LI3, QI3, and DL3 is accumulative daily maximum temperature, accumulative daily minimum temperature, accumulative daily radiation per daylength, and accumulative daily daylength in 40 days around heading (D_{VI} =2), BI is a parameter for rice photosynthesis, F3N is the optimum LAI at heading, FD_i is the LAI at pre-heading, and KF1, E1, and II3 are the parameter, taking KF1=9.0, E1= 0.42, and II3 = 0.0334, and NF0 is effective factor of nitrogen on the optimum LAI (determined by cultivation practices)(Jin 1993, 1996).

after heading (Gao *et al*.,1992a)

$$FD_i = F3N/(1 + A_2 \times D_{VI}^2) \qquad (C.5)$$

where FD_i is the LAI after heading, A_2 is the parameter, taking A_2 = 2.3, and the other symbols are as above.

D. Photosynthesis

The Monsi equation (Monsi and Saeki,1953; Monteith,1965; Thornley,1977; Goudriaan and Laar, 1978) was employed to caculate the gross photosynthetical production (GPP) (in g $CO_2m^{-2}d^{-1}$) for a given day i, this is

$$GPP_i = TF_i \times (\frac{B1 \times DL_i \times 0.682}{E1 \times A1}) \times \ln(\frac{1 + A1 \times 0.47 \times (1 - R1) \times \frac{QD_i}{DL_i}}{1 + A1 \times 0.47 \times (1 - R1) \times \frac{QD_i}{DL_i} \times e^{-E1 \times FD_i}}) \quad (D.1)$$

$$RG_i = 0.3 \times GPP_i \quad (D.2)$$

$$RM_i = TNPD_i \times (1 - 0.1) \times 0.02 \times 2^{(TI_i - 25)/5} \quad (D.3)$$

$$NPD_i = GPP_i - (RG_i + RM_i) \quad (D.4)$$

$$TF_i = -0.434 + 0.1027TI_i - 0.00184TI_i^{\ 2} \quad (D.5)$$

where A1 and B1 are photosynthesis parameter values for cultivars determined by the experiment (taking A1=9.0, and B1=20.1), TF_i is the effective factor of temperature on photosynthesis as follows on the i^{th} day (Gao *et al*., 1992a), QD_i is the solar radiation intensity on the i^{th} day (in $MJ(PAR)m^{-2}s^{-1}$) computed by daily daylength (h), DL_i on the i^{th} day, and daily sun time (h), 0.47 is percentage of PAR_i to solar radiation intensity, E1 is the extinction coefficient for the canopy ranging, taking E1=0.42 for rice (Penning de Vries *et al*.,1989; Gao *et al*.,1992a), 0.682 is transformation coefficient from CO_2 to CH_2O ($\lambda =[CH_2O]/[CO_2]=0.682$) for rice (Gao *et al*.,1992a), R1 is the reflectivity of leaves with a value of 0.07 (Gao *et al*.,1992a), RG_i, and RM_i are the growth respiration and maintenance respiration (when $TI_i= T_O$), respectively, NPD_i is the daily net photosynthesis on the i^{th} day (in g $CO_2m^{-2}d^{-1}$) (presuming water and CO_2 concentration were proper for rice), $TNPD_i$ is the accumulative value of NPD_i on the i^{th} day, and TI_i is daily mean temperature on the i^{th} day (in ℃). The other symbols are the same as above.

E. Phenophase

The developmental index (DVI, D_{VI}) (Gao et al., 1992a; Nakagawa and Horie, 1995; Watanabe et al., 2005) was applied to represent the physiological development of the rice plant. The D_{VI} is a continuous variable and defined as 0 at first leaf emergence, 1. 0 at panicle initiation, 2. 0 at heading and 3. 0 at maturity.

The D_{VI} is an accumulation of developmental rate (DVR, D_{VR}), which is a function of daily mean temperature (TI_i) and daylength (DL_i) in hours within the development phase:

$$D_{VI} = \Sigma D_{VR,I} \quad \text{(E.1)}$$

where $D_{VR,i}$ is the developmental rate for the i^{th} day from the start, calculated according to Nakagawa and Horie (1995), and Watanabe et al. (2005), as functions (f and g) as follows.

When $D_{VI} < 1.0$

$$D_{VR} = f_1(TI_i), \text{ when } D_{VI} < D_{VR\cdot 1} \quad \text{(E.2)}$$

$$D_{VR} = f_1(TI_i)\, g_1(DL_i), \text{ when } D_{VI} \geq D_{VR\cdot 1} \quad \text{(E.3)}$$

When $1.0 \leq D_{VI} < 2.0$

$$D_{VR} = f_2(TI_i)\, g_2(DL_i), \text{ when } D_{VI} < D_{VR\cdot 2} \quad \text{(E.4)}$$

$$D_{VR} = f_2(TI_i), \text{ when } D_{VI} \geq D_{VR\cdot 2} \quad \text{(E.5)}$$

When $2.0 \leq D_{VI} \leq 3.0$

$$D_{VR} = a_3\,(TI_i - Tc) \quad \text{(E.6)}$$

$$f_j(TI_i) = (1/G_j)/(1 + e^{-a_j(TI_i - T_{hj})}), \text{ when } D_{VR} \leq 2.0 \quad \text{(E.7)}$$

$$g_j(DL_i) = 1 - e^{-b_j(DL_i - L_c)}, \text{ when } DL_i < Lc \quad \text{(E.8)}$$

$$\text{or } g_j(DL_i) = 0, \text{ when } DL_i \geq Lc \quad \text{(E.9)}$$

where g_j is the minimum number of days required for completing each phase, vegetative (j = 1) and reproductive (j = 2), and $D_{VR \cdot j}$ represents the start (j = 1) and end (j = 2) of the photosensitive phase. a_j, T_{hj}, T_c, b_j and L_c are parameters[1] for determining the shape of the functions. The other symbols are the same as above.

[1] T_{hj} is the maximum temperature at j^{th} stage in rice, T_c is the lower limit temperature in rice, and L_c is the critical day length in the photosensitive phase of rice.