Documentation of test runs with ORYZA_N reference model for potential and nitrogen-limited rice production

H. Drenth & H.F.M. ten Berge

ab-dlo

Rapport 4,
Wageningen, January 1994

Table of Contents

Summary (in Dutch)

Resultaten van test-runs met ORYZA_N referentiemodel voor potentiële en stikstof-gelimiteerde rijst produktie.

Deze handleiding beschrijft het ORYZA_N model. Het model is gebaseerd op MACROS L1D (Penning de Vries, 1989) en bevat elementen van het SUCROS-model. L1D is eerst aangepast voor stikstof-gelimiteerde groei en kreeg de naam L3C. In 1992 werd het L3C-model verbeterd, gelijktijdig met verbeteringen in het vroegere L1D. De basiselementen van deze modellen zijn consistent met elkaar, wat tot uiting komt in de nieuwe namen van beide modellen, ORYZA1 (voorheen L1D) en ORYZA_N (voorheen L3C). ORYZA_N omvat, naast deze basiselementen, subroutines die vraag van stikstof, de opname, en de allocatie naar de verschillende plant organen beschrijven. De opname van stikstof wordt als (gemeten) forcing functie opgelegd, of, in het geval van potentiële produktie, gelijkgesteld aan de vraag.
Leden van SARP-teams van verschillende nationale onderzoeksinstellingen en de SARP-IRRI-groep onder leiding van M.J. Kropff hebben meegewerkt aan de ontwikkeling en de evaluatie van het model. Zij hebben datasets verzameld voor verbetering en validatie van het model.

In dit rapport worden de verschillen tussen het oorspronkelijk L1D en ORYZA_N beschreven. Binnen het ORYZA_N model heeft de gebruiker een aantal switches tot zijn/haar beschikking, door middel waarvan de gebruiker het model kan definiëren naar eigen behoefte. Delen van het model kunnen met behulp van switches al of niet worden geactiveerd. Aan de hand van voorbeelden wordt het gebruik van de switches uitgelegd.
Voor de validatie is gebruik gemaakt van 6 datasets. Drie opties van het model zijn gedraaid met alle datasets.
Uit de validatie runs is gebleken dat naast bladscheden en stengels, ook wortels en bladeren een belangrijke bron bij redistributie van koolhydraten zouden kunnen zijn. De uiteindelijke fractie stikstof in de korrels kan waarschijnlijk beter gedefinieerd worden met behulp van de fractie stikstof in de plant bij de bloei en de opname van stikstof na de bloei. Door gebruik te maken van het verband tussen de vraag naar stikstof van de bladeren en van zowel stengels als wortels zouden twee input-variabelen kunnen komen te vervallen. Het netto-verlies van stikstof uit de plant is wel in het veld waargenomen, maar nog niet in het model opgenomen.

1. Introduction

This manual describes the model ORYZA_N. The model has been evolved from the earlier MACROS-L1D (Penning de Vries, 1989) and contains elements from the SUCROS model. It had first been extended to include nitrogen-limited crop growth and was named L3C. Teams from several national research centres participating in SARP have worked on evaluation and development of ORYZA_N. They also have collected data sets for improvement and validation of the model.

In 1992 the model has been updated, simultaneous with improvements in the earlier L1D which then became the ORYZA1 model. The basic elements of these two models were therefore made mutually consistent, which is reflected in their new names.

ORYZA_N is a starting point to further development into a structure which connects submodels of varying levels of detail, each submodel describing particular components of the crop-soil system. It is therefore intended as a research tool, rather than a standardized application model. The main use of such a framework is in evaluation and interpretation of experimental data, and development and testing of submodels.

For this purpose, a requirement is that the user can easily make choices between submodels of different complexity levels, according to particular interests. Similarly, submodels can be replaced by measured time series, thus reducing the simulated system to a smaller core section. This user-model interaction is via switches that can be set according to the user's preference.

The main difference between ORYZA1 and the current ORYZA_N version is that the latter includes nitrogen uptake and allocation to crop organs, via a number of subroutines. In addition, some processes are described in more detail.

2. Differences between ORYZA_N and L1D

(as described in Penning de Vries, 1989)

2.1. General changes at potential production level

2.1.1. Initial (Section 1. in ORYZA_N)

- The initial weights of the roots and leaves are not necessarily equal. Initial weight of the leaves (WLVI) and the roots (WRTI) are both input; in L1D the initial weight of the roots was set equal to the initial leaf weight.

2.1.2. Phenological development of the crop (Section 2. in ORYZA_N)

- The parameters DRCV, DRCR, DRER, DREW and the function tables DRVTT, DRDT, and DRRTT are not used anymore.
- DS has been changed into DVS.
- DRV has been changed into DVR.
- For the calculation of the development rate in the vegetative as well as the reproductive stage the procedure PRODVR was developed. In this procedure the DVR is calculated with the devlopment rate constants (DVRV and DVRR) and the daily heat units for plant development (HU). The DVRV and DVRR can be calculated with the programs DR1.csm and DR2.csm in CSMP. For information on the procedure PRODVR see ORYZA1 description (Kropff et al.,1993).
- A transplanting shock based on seedling age is included in the calculation of the development stage. The seedling age is expressed in degree days (Kropff et al., 1993).

2.1.3. Photosynthesis, gross and net (Section 3.1 in ORYZA_N)

See Paragraph 2.2.

2.1.4. Respiration (Section 3.2 in ORYZA_N)

See Paragraph 2.2.

2.1.5. Carbohydrates available for growth (Section 3.2 in ORYZA_N)

- The variables CAG(CR,SS,RT,LV,ST,SO) in this part have been removed.

- The carbohydrate export (CELV) calculation is changed. It is calculated from the difference of the gross photosynthesis (DTGA) and the maintenance respiration of the whole crop (RMCCO2), both expressed in CO_2. Maintenance respiration of the roots and storage organs are now accounted for, contrary to L1D.

2.1.6. Biomass growth and loss rates (Section 3.5 in ORYZA_N)

- GSTR: the rate calculation for the shielded reserves has changed. In L1D this rate was calculated within the formula for WIR (weight increment reserves (starch) since start simulation). In ORYZA_N the growth rate of the shielded reserves GSTR is calculated in a separate formula. The surplus of dry matter due to limitation (GSOM) in the growth rate of the storage organs is added to the shielded reserves. This is established with an INSW function.

- Dry matter distribution factors are defined as function of development stage or time. The growth rates of the shoots and the roots are obtained by multiplying the overall growth rate with the fraction allocated to these plant parts (FSH and FRT resp.). The shoot fraction is partitioned over the leaves, stems and storage organs by multiplying the growth rate of the shoot with the fractions allocated to these organs (FST, FLV, FSO). Therefore the variables CAG(CR, LV, RT, SO, SS, ST) are not used anymore. Carbohydrate partitioning is now directly based on observed dry matter yields of crop organs. See ORYZA1 description (Kropff et al., 1993).

- The growth rate of the crop (GCR) is calculated from the carbohydrates available for growth of the crop (in L1D the variable: CAGCR) and the carbohydrate required for the growth of the crop (in ORYZA_N: CRGCR). CRGCR is the weight of carbohydrates required for growth of average crop biomass (kg kg^{-1} crop biomass). This average is calculated from the requirements for the various organs by a weighing procedure.

- Within the procedure PARPRO the values of partitioning can either be read versus DVS (development stage) or DAT (days after transplanting) depending on the format of the data. With help of the switch SWIPAR a choice can be made.

- The tables LLVT and LRTT have been removed. The relative losses of weight of leaves and roots are calculated in the subroutine SLOSS. This calculation is based on the fraction of nitrogen in the leaves (FNLV) and the leaf area index (see also Subroutines).

- Maximum growth rate of grain, GSOM, is introduced from the TIL modules as described in Penning de Vries et al., 1989.

2.1.7. Weight of the crop component (Section 3.6 in ORYZA_N)

The formula's calculating the weights of the plant organs are the same except for some minor differences:

- WSTS: the correction for the remobilizable fraction of the stem weight is done in the formula for growth rate of the stems (GSTS), instead of in the equation of WSTS, as in L1D.
- WSTR is the new name for WIR (L1D); weight of the shielded stem reserves. WSTR is the INTGRL of the difference between the growth rate (dry matter) of the shielded reserves (GSR) and the loss rate of stem reserves (LSTR)
- WSO: instead of WSOI as first argument of the INTGRL, a value of zero is used; the weight of the storage organs is zero at the start of the growing period.
- WRR: rough rice yield; 10% of panicle weight is support structure; and 14% moisture in grain.
- HI: is the quotient of the weight of rough rice (WRR) and the weight of the total shoot (WSHT). In L1D the weight of the storage organs (WSO) was used instead of WRR.
- Suffix G for green and D for dead leaves; L for live and D for dead roots (WLVG, WLVD, WRTL, WRTD).

2.1.8. Leaf area (Section 4. in ORYZA_N)

- The variables GLA, GSA, LLA, SLN have been removed. Leaf area is not calculated as an INTGRL anymore but is directly derived from WLV.
- Previous name ALV has been replaced by LAI.
- Leaf area can be calculated in four different ways, selected with the help of switch SWILAI. NOTE: SWILAI in ORYZA_N differs from SWILAI in ORYZA1.
- Leaf area index LAI is now calculated directly from current WLVG and specific leaf area (SLA).
- Option 1 and 4 are identical with respect to the calculation of the specific leaf area. The specific leaf area constant is multiplied with a factor (SLAFAC) to adapt the specific leaf area to the development stage of the plant.
- The calculation of LAI Options 1 and 4 depends on the temperature sum of the leaves (TSLV; calculated in the weather section). Below a temperature sum of 89.7 the LAI is equal to the initial leaf area index (LAII). If the temperature sum of the leaves is more than 89.7 the leaf area index is calculated from the weight of the leaves and the specific leaf weight. In Option 1 the simulated weight of the leaves is used, whereas in Option 4 the measured weight of the leaves is used.

- Options 2 and 3 formulate LAI on the basis of experimental leaf area growth with the help of relative growth constant (Option 3) or tabulated values observed of ln(LAI) (Option 2).

- SWISAI is the switch with which you can choose to either include or exclude the stem area in the LAI.

2.1.9. Carbon balance check (Section 6. in ORYZA_N)

See description ORYZA1 (Kropff et al., 1993)

2.1.10. Weather data (Section 8. in ORYZA_N)

Some names of variables within the weather data section have been changed:

L1D	ORYZA_N
RDTMT	RDTT
TPLT	TMINT
TPHT	TMAXT
TPAV	TAV
TPAD	TAVD

2.2. Additions particular to N-limited production

2.2.1. Initial (Section 1. in ORYZA_N)

- ORYZA_N needs values of initial amounts of nitrogen in the organs. These are calculated from the initial fraction of nitrogen in the plant organ and the initial weight of that plant organ.

2.2.2. Photosynthesis, gross and net (Section 3.1 in ORYZA_N)

- The subroutine FUPHOT has been replaced by the subroutine TOTASN. TOTASN calls the subroutines ASTRO and ASSIM. For a more detailed description of these subroutines see the description of ORYZA1 (Kropff et al., 1993). The subroutine TOTASN includes the effect N in the leaves and of N distribution in the crop (KDIFN) on the photosynthesis.

- AMAXT and DTGA are outputs of the subroutine TOTASN. AMAXT is the value of maximum leaf photosynthesis at the top of the canopy and replaces the PLMX used in L1D. DTGA is the gross canopy photosynthesis and replaces the PCGW.

- AMAX is calculated within the subroutine as a function of depth in the canopy and N-profile. It is no longer an input as in L1D.

- The variable ANLVPH is the amount of nitrogen in the leaves (kg ha^{-1} ground surface) used for the calculation of photosynthesis in the subroutine TOTASN (see also Subroutines). Via the switch SWINLV either simulated or measured nitrogen content of the leaves is used.

- PARAM PCEW has been removed.

- The variable REDFT is a factor accounting for the effect of temperature on AMAX; it is read from the table REDFTT which expresses AMAX as a function of temperature.

- KDF is the extinction coefficient for diffuse light. In FUPHOT this coefficient has the value of 0.7155. In ORYZA_N KDF is related to leaf area index; it varies between 0.4 for LAI below 1.5 to 0.6 for LAI larger than 1.5.

- The relation between leaf nitrogen content and AMAX is expressed in two parameters, NB and ALPHAN. NB is the value of N content (g m_{leaf}^{-2}) where AMAX equals zero, and ALPHAN is the slope of AMAX vs N content (kg CO_2 ha^{-1} hr^{-1} (gN m_{leaf}^{-2})).

2.2.3. Respiration (Section 3.2 in ORYZA_N)

- In general, the more active tissue and the higher the nitrogen concentration, the higher the rate of maintenance respiration (Penning de Vries et al., 1989). In ORYZA_N the rates of maintenance respiration of the roots, leaves and stems are partly determined by their activity. The activity coefficients are based on the protein content of the organs.
  The 'active' fraction of nitrogen is equal to the actual fraction minus the residual fraction of nitrogen in the plant organ. The activity coefficient is the ratio of this active fraction to the potential nitrogen fraction in the plant organ, corrected again for residual nitrogen. The maintenance respiration rate is determined by the weight of the organ, temperature, the maintenance respiration coefficient, and the activity of the organ.

- TEFF: is the new name for TPEM.

- RMSO: the calculation of RMSO remain the same. The factor of 0.015 has been explicitly named as the parameter MAINSO.

- RMMA: the cummulated calculation remains the same. Through multiplication with 30./44. the RMMA is now expressed in CH2O instead of in CO_2 as in L1D.

- RCRT: the cumulated respiration of the crop, is assessed by integration of the total maintenance respiration (RMCR) plus the total growth respiration (RGCR).
  RMCT and RSH (L1D) are not used in ORYZA_N.

- RGCR: the calculation of the total growth respiration of the crop has changed compared to L1D. The calculation is based on the growth rates of the organs and the total amounts (kg) CO_2 respired for growth per kg organ.
  The parameters CPG(LV,RT,ST,SO) have been removed. Respiration losses associated with the process of remobilisation and transport are ignored in ORYZA_N (not in L1D).

2.2.4. Nitrogen uptake rate (Section 5.1 in ORYZA_N)

- With the switch SWINUP the user can choose for nitrogen limited production or potential production. Within the procedure UPPRO the nitrogen uptake rate is calculated depending on this switch setting.
  For potential production the model maintains the maximum concentration in organs, corresponding to development stage. (see section nitrogen allocation and loss rates).
  The nitrogen uptake rate (NUPT) is the sum of the nitrogen demand NDEMV and the demand associated with the new growth of the leaves, stems and roots.
  For nitrogen limited production the nitrogen uptake rate is calculated within the subroutine SNUPT. The subroutine calculates daily nitrogen uptake from values observed in live biomass at sampling dates. The table with the total amount of nitrogen measured (NTOTMT) should contain the measured cumulative uptake (in kg N/ha), at the Julian days specified in DNOST. The table DNOST should contain the Julian dates at which NTOTMT was measured. The parameter NS represents the number of sampling dates for which total nitrogen in the crop is given in NTOTMT. The number of data prints in NTOTMT should be equal to NS. The number of split nitrogen applications is given as the parameter NA. The table DNAPT contains the Julian day numbers at which nitrogen was applied. For seasons across January 1st the daynumbers for DNOST and DNAPT proceed as 365., 366., 367., 368. etc untill the end of the season.

2.2.5. Total nitrogen uptake (Section 5.2 in ORYZA_N)

- The total nitrogen uptake (cumulative since initial) is obtained by integration of NUPT. The total amount of nitrogen in the crop (live and dead material) is obtained by integration of the NUPT starting from the initial value ANTOTI (see initial).

- NUPNEG is a variable used to keep track of 'negative uptake'. It represents, of course, no real physiological process, but is a numerical 'counter' to indicate whether losses through leaf and root dying are properly parameterized. Negative values of NUPNEG imply that in reality losses were higher than modelled.

2.2.6. Nitrogen allocation and loss rates (Section 5.3 in ORYZA_N)

- The maximum and minimum nitrogen contents in leaves, stems and roots are dependent on the development stage.

- The nitrogen demands of plant organs (NDEML, NDEMS, NDEMR, NDEMG) are calculated in the subroutine SNDEM. This subroutine currently includes only the component associated with existing biomass (N demand for new growth is added in the subroutine SNALLC). N demand of the existing biomass is specified per organ. The demand is calculated from the the difference between the actual amount of nitrogen in the organs (ANLV, ANST, ANRT, ANSO) and the maximum possible amount of nitrogen for a given stage in the plant organs (NMAXL, NMAXS, NMAXR, MAXSO), and the time coefficient for nitrogen acquisition (TCNA). The course of the portential N fraction with development stage is based on observations from high-N crops. The time coefficient is currently set at a value of 1 d.

- The nitrogen allocation rates to the different plant organs are calculated in the subroutine SNALCC. Within the subroutine the daily available N pool is composed of N redundant in (some of) the organs, and new uptake by the total crop. Redundant N is defined as the amount of N present per organ in excess of the maximum value at given development stage (negative demand). The sum of all negative demands is pooled with new uptake. When crop N uptake rate is positive (total N in crop increases), the available N pool is distributed to all organs with positive demand, in proportion to their demands. If excess N remains, this amoun is allocated to the leaves. When uptake rate is negative (total crop N decreases), then all organs are supposed to loose N in proportion to their total N content. All these positive and negative allocations occur, implicitly, with a time coefficient of 1 d.
  For potential production where no N uptake is externally forced, N allocation equals N demand as defined by the subroutine SNDEM, augmented with the amount of N associated with N saturated new growth.

- N supply to the panicle is calculated in the subroutine SNSUPG. All panicle N supply is derived by translocation from leaves, stems and roots. The translocatable amounts are determined per organ from the difference between available amount of N in the organ and the residual amount, and a time coefficient. This entire pool of translocatable N is transferred to the growing panicle if panicle N demand exceeds the pool size. If this is not the case, only part of the translocatable pool (equivalent to total panicle N demand) is mobilized. The relative contributions by translocation from the different organs is in all cases proportional to the relative sizes of the N pools in those organs.

2.2.7. Nitrogen in biomass (Section 5.4 in ORYZA_N)

- In this section the amounts of nitrogen in the plant organs (kg N ha^{-1}) is calculated. The amounts of nitrogen in the various plant organs (ANLV, ANRT, ANST, ANSO, ANLD, ANRD) are obtained through integration of the respective allocation, translocation and loss rates. The total amount of nitrogen in the crop is the sum of all the amounts in the organs.

- The fractions of nitrogen in the plant organs (FNLV, FNST, FNRT, FNSO) are calculated from the amounts of nitrogen and the weights of the plant organs.

2.2.8. Nitrogen balance check (Section 5.5 in ORYZA_N)

- A nitrogen balance check is included, similar to the carbon balance check. It compares the amount of N in the crop in excess of the initial amount (CKNIN) vs the integral of uptake (CKNFL).

2.2.9. Sink limitation: tiller and grain development (Section 6. in ORYZA_N)

- This section in the program is almost equal to the TIL module as described by Penning de Vries et al. (1989). This section is still provisional and needs updating and calibration.

- The part where the number of florets are calculated has been removed.

- The initial number of tillers (NTII) is replaced by the number of plants (PLNUM). The fraction FADL to adapt time period to account for daylength is not needed here, because in ORYZA_N time periods of one day are used.

- Potential tiller number NTIP is calculated as the minimum of two values: (1) the available carbohydrates divided by the amount of carbohydrates needed to initiate and maintain one tiller (CNTI); (2) the number of plants (PLNUM) multiplied with the maximum number of tillers per plant (TIL).

- The maximum number of tillers per plant (TIL) is dependent on the fraction of nitrogen in the leaves (FNLV). The function RTILT gives the relation of relative tillering capacity to nitrogen content of leaves. Multiplication of the maximum number of tillers per plant (TILMX) with RTILT gives the value of TIL.

- To prevent a division by zero, the NOT function is introduced in the formula for grain filling period (GFP).

- The maximum number of grains (NGRMX) is now calculated from the the number of tillers (NTI) multiplied by 100.

- ORYZA_N can run with or without sink limitation. Through the switch SWISIN the user can make a choice. For SWISIN=2, the maximum growth rate of grains GSOM is calculated on the basis of tiller and grain development section. For SWISIN=1, GSOM is given an arbitrary high value (1000 kg ha^{-1} d^{-1}).

3. Philosophy of switches

ORYZA_N requires that the user set a number of switches, which define the model. By choosing a particular switch value, some parts of the model are activated, others are skipped. Each of the current switches and the associated options is described in Appendix III.

The idea behind this approach is to provide the researcher with a toolbox for analyzing experimental data. For example, if differences are found in total grain yield between treatments, one can evaluate whether that is to be fully attributed to N uptake differences. The N uptake as measured per treatment is then used as input, and the model predicts grain yield. If predicted differences are similar to measured differences, N uptake is accepted as the explanation. Similarly, switches can be used to evaluate whether sink or source size was limiting the grain production.

As an alternative, switches are used in developing new model sections. For example, if a tillering module is to be developed and tested with the help of experimental data, some sections of the model, e.g. on dry matter production, photosynthesis, or leaf area, can be replaced by observed values of these variables. In this manner, feedbacks between the 'submodel-in-state-of-development' and other model components are eliminated. In this example of tillering: if photosynthesis was calculated erroneously, that would result in erroneous simulated tiller numbers. Yet, the newly developed tillering submodel may have been correct by itself. Although such feedbacks are necessary in a completed and well tested model, it may be essential to eliminate them during model development.

4. Validation

Validation of the ORYZA_N model was carried out with six datasets. The datasets vary in location, season, variety and nitrogen treatment (Table 4.1) . For the complete sets of data, as used for validation, see Appendix V. Paragraphs 4.1 to 4.6 give detailed information about the experiment.

Table 4.1 Basic information on the datasets used for validation of the ORYZA_N model

Paragraph	Location		Year	Season	Variety	Treatment (kg nitrogen per ha)
4.1	India	Tamil Nadu	1988/1989		ADT 39	0, 100, 200, 300, 400
4.2	India	Cuttack	1990	dry	IR 36	0, 50, 100, 150
4.3	India	Pantnagar	1987	wet	PD 4	0, 60, 120, 180, 240
4.4	Philippines	Los Baños	1990/1992	wet	IR 64	130
4.5	Philippines	Los Baños	1991	wet	IR72	0, 80, 110
4.5	Philippines	Los Baños	1991	wet	LINE	0, 80, 110
4.6	Philippines	Los Baños	1992	dry	IR72	0, 180, 225
4.6	Philippines	Los Baños	1992	dry	LINE	0, 180, 225

For each dataset the model was run for three Options, (1) potential production and nitrogen limited production using (2) measured nitrogen contents in leaves or (3) simulated nitrogen contents in leaves (all green leaves averaged) in photosynthesis. In the latter case, measured total nitrogen uptake was used as forcing function, and leaf nitrogen content was evaluated by the model.
The switch settings corresponding to these three groups of simulation runs are listed in Table 4.2. For the potential production runs, dry matter partitioning and crop development data required to run the model were taken from the treatment that received highest N application.

Table 4.2 Switch settings used for the validation runs

Switches	Potential production	N-limited production measured N content	N-limited production simulated N content
SWILAI	1	4	4
SWIMEA	*	*	*
SWINPH	1	0	1
SWINPR	1	1	1
SWINUP	2	1	1
SWIPAR	*	*	*
SWISAI	0	0	0
SWISIN	1	1	1

*) optional

4.1 TNAU-TNRRI, Tamil Nadu (India), 1988-1989

Experimental data from: T.M. Thiyagarajan & S.N. Mohandass

General information

variety: ADT 39
year: 1988-1989
seeding: 1 nov (306)
planting: 10 dec (345)

N treatment	50% Flowering		Harvest	
kg N	DAT	DOY	DAT	DOY
0	53	32	89	68
100	53	32	89	68
200	58	37	94	73
300	58	37	94	73
400	61	40	97	76

DAT= days after transplanting

Nitrogen application scheme

Calendar date		DOY	DAT	Quantity applied	
10	Dec	345	0	50%	of the treatment level
05	Jan	5	26	16.66%	of the treatment level
27	Jan	27	48	16.66%	of the treatment level
04	Feb	62	62	16.66%	of the treatment level

DAT= days after transplanting, DOY= day of the year

Switch setting SWIPAR = 0
SWIMEA = 1

4.2 CRRI, Cuttack (India), 1990

Experimental data from: R.N. Dash & K.S. Rao

General information

variety: IR 36
year: 1990

	Calendar date		DOY	DAT
seeding	18	Dec, 89	352	
transplanting	25	Jan	25	0
flowering	9	Apr	99	74
harvest	28	Apr	118	93

DAT= days after transplanting, DOY= day of the year

Nitrogen application scheme

Calendar date		DOY	DAT	Quantity applied	
25	Jan	25	0	50%	of the treatment level
14	Feb	45	20	25%	of the treatment level
19	Mar	78	53	25%	of the treatment level

DAT= days after transplanting, DOY= day of the year

Switch setting SWIPAR = 0
SWIMEA = 1

4.3 PUAT, Pantnagar (India), 1987

Experimental data from: B. Mishra and B.P. Dhyani

General information

variety: PD 4
year: 1987

	Calendar date		DOY	DAT
seeding	10	Jun	161	
transplanting	9	Jul	190	0
tillering	3	Aug	215	25
panicle initiation	27	Aug	239	49
flowering	19	Sep	263	72
harvest	25	Oct	298	108

DAT= days after transplanting, DOY= day of the year

Nitrogen application scheme

Calendar date	DOY	DAT	Treatment (kg N/ha)				
			0	60	120	180	240
9 Jul	190	0	0	30	60	90	120
4 Aug	216	26	0	30	30	45	60
28 Aug	240	50	0	0	30	45	60

DAT= days after transplanting, DOY= day of the year

Switch setting SWIPAR = 1
SWIMEA = 1

4.4 IRRI, Los Baños (Philippines), 1990-1991

Experimental data from: L. Bastiaans

General information

variety: IR 50
year: 1990-1991

	Calendar date	DOY	DAT
seeding	23 Nov '90	327	
transplanting	5 Dec '90	339	0
flowering	6 Feb '91	402	63
harvest	9 Mar '91	433	93

DAT= days after transplanting, DOY= day of the year

Nitrogen application scheme

Calendar date	DOY	DAT	Quantity applied (kg N /ha)
5 Dec	339	0	60
27 Dec	361	22	30
23 Jan	388	49	20
31 Jan	396	57	20

DAT= days after transplanting, DOY= day of the year

Switch setting SWIPAR = 1
SWIMEA = 1

4.5 IRRI, Los Baños (Philippines), 1991

Experimental data from: M.J. Kropff, K.G. Cassman, S. Liboon, R. Torres

General information

year: 1991

	Calendar date		DOY	DAT
variety: LINE				
seeding	1	Jul	182	
transplanting	13	Jul	194	0
panicle initiation	6	Sep	249	55
flowering	6	Oct	279	85
harvest	20	Oct	302	108
variety: IR72				
seeding	1	Jul	182	
transplanting	13	Jul	194	0
panicle initiation	28	Aug	241	46
flowering	18	Sep	261	67
harvest	15	Oct	288	94

DAT= days after transplanting, DOY= day of the year

Nitrogen application scheme

Calendar date	DOY	DAT	N Treatment (kg N/ha)		
			0	80	110
12 Jul	193	0	-	50	30
12 Aug	224	30	-	30	-
06 Aug	218	24	-	-	30
10 Sept	253	59	-	-	20
03 Oct	276	82	-	-	30

DAT= days after transplanting, DOY= day of the year

Switch setting SWIPAR = 0
SWIMEA = 0

4.6 IRRI, Los Baños (Philippines), 1992

Experimental data from: M.J. Kropff, K.G. Cassman, S. Liboon, R. Torres

General information

year: 1992

	Calendar date		DOY	DAT
variety: LINE				
seeding	4	Jan	4	
transplanting	16	Jan	16	0
panicle initiation	11	Mar	70	54
flowering	8	Apr	98	82
harvest	8	May	128	112
variety: IR72				
seeding	4	Jan	4	
transplanting	16	Jan	16	0
panicle initiation	11	Mar	58	42
flowering	25	Mar	84	68
harvest	24	Apr	114	98

DAT= days after transplanting, DOY= day of the year

Nitrogen application scheme

Calendar date	DOY	DAT	N Treatment (kg N/ha)			
			0	180	225	
					LINE	IR72
16 Jan	16	0	-	120	60	60
3 Feb	34	18	-	60	60	60
27 Feb	58	42	-	-	-	60
11 Mar	70	54	-	-	60	-
25 Mar	84	68	-	-	-	45
8 Apr	98	82	-	-	45	-

DAT= days after transplanting, DOY= day of the year

Switch setting SWIPAR = 0
SWIMEA = 0

4.7 Results of validation

4.7.1. Potential production

For almost all the potential production runs the weights of the crop and the storage organs were clearly underestimated (Appendix VI, pages: 5, 10, 15, 20, 25, 30, 35, 40). The model needs to be improved before it can be used for runs with the potential production option. Including the stem area increased the weights, but not enough. Running without the nitrogen profile did not lead to satisfactory changes. Running with a nitrogen profile becomes disadvantageous when extra N in the upper leaves does not lead to extra photosynthesis. In that case running without a nitrogen profile could have led to more production of dry matter. The leaf area development had a slow start, by which the dry matter production remains behind throughout the whole growing season. In potential production run leaf area was calculated from the simulated weight of the leaves and the specific leaf area corrected for the development stage. The specific leaf area constant (SLAC) and the correction factor of specific leaf area to development stage (SLAFAC) were calculated for a dataset only where leaf area had been measured. SLAC as well as the SLAFAC did not differ much from the used standards.

4.7.2. Nitrogen-limited production

Weights of the crop
The weights of the crop were well simulated when using measured as well as simulated leaf nitrogen in the photosynthesis calculation (Figs 4.7.1 and 4.7.2). An extreme underestimation occured for the PUAT dataset. This singular deviation may indicate erroneous values for experimentally determined N contents in leaves. Looking into the results of the separate datasets (Appendix VI) the 300 and 400 kg N per ha treatment of the Tamil Nadu set show a slight overestimation at the end of the season (Appendix VI, page 1). Overestimation also occurs for the highest nitrogen application treatment (150 kg N per ha) of the Cuttack dataset, using the measured amount of nitrogen in the leaves (Appendix VI, page 6). The use of the simulated amount of nitrogen in the leaves leads to an overestimation of biomass for all treatments of the Cuttack dataset. This is because the amount of leaf nitrogen is overestimated by the model (Appendix VI, page 8).
Crop biomass is well simulated for all the IRRI datasets. When using the simulated amount of nitrogen in the leaves an underestimation occurs after flowering (Appendix VI, pages 21, 26, 31, 36). The amount of nitrogen in the leaves could be too low due to too much translocation from the leaves to the storage organs. The value of NMAXSO could be cultivar dependent.

Weights of the storage organs
Apart from the Tamil Nadu dataset there is a tendency to underestimate the weights of the storage organs (Figure 4.7.3 and 4.7.2). The use of simulated nitrogen in the leaves for photosynthesis calculation enlarge this underestimation in the IRRI datasets, whereas for the Cuttack data this results in less underestimation (Appendix VI, pages 22, 27, 32, 37, 7). Since the weights of the crops are well simulated the underestimation of the weights of the storage organs must be due to the redistribution of the carbohydrates to the plant organs. Perhaps the remobilization of the shielded reserves from the stems to the storage organs is too low and remobilization from the leaves should also be taken into account.

Amounts of nitrogen in the plant organs

Figs 4.7.5, 4.7.6, 4.7.7 and 4.7.8 show the simulated amounts of nitrogen in the plant organs, plotted against the observed values. The total amount of nitrogen uptake is a forcing function and therefore equal to the observed values. Therefore these figures give information about the the partitioning of nitrogen to all the plant organs.

The amounts of nitrogen in the roots show a lot of scatter. This may be due to errors easily made with the root sampling. Amounts of nitrogen in the stems are underestimated, especially at higher levels of nitrogen. Increasing of the maximum nitrogen fraction of the stems (NMAXS) increases the nitrogen demand of stems, which decrease the gap between simulation and measurements.

The amount of nitrogen in the storage organs seems to be overestimated at higher levels of nitrogen. The overestimated values however belong to one dataset; Tamil Nadu. Too much translocation from the leaves, stems and roots might be the cause of this. Again the demand of the storage organs might be too high. Adaptation of NMAXSO could be desirable.

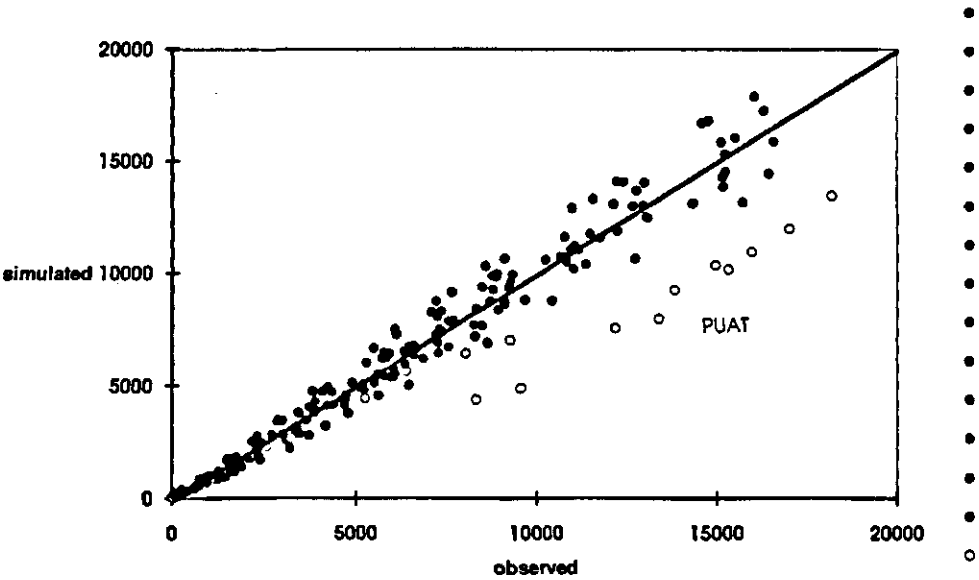


Figure 4.7.1 Weights of the crop (kg ha^{-1}) simulated versus observed for the dataset PUAT (white dot) and the other datasets (black dot). The simulated values were obtained for simulation runs using measured leaf nitrogen (kg N ha^{-1}) as forcing function.

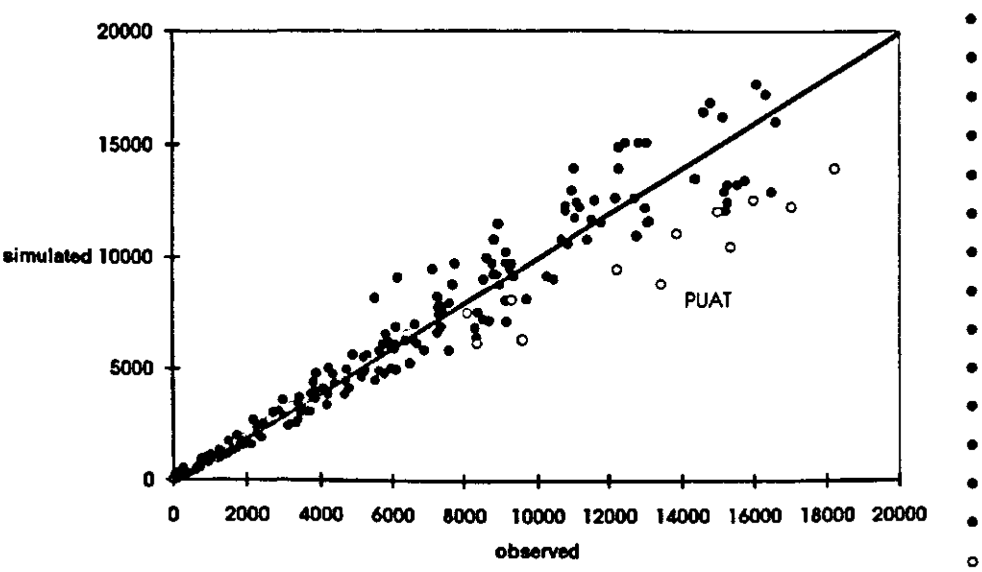


Figure 4.7.2 Weights of the crop (kg ha^{-1}) simulated versus observed for the dataset PUAT (white dot) and the other datasets (black dot). The simulated values were obtained for simulation runs using simulated leaf nitrogen (kg N ha^{-1}).

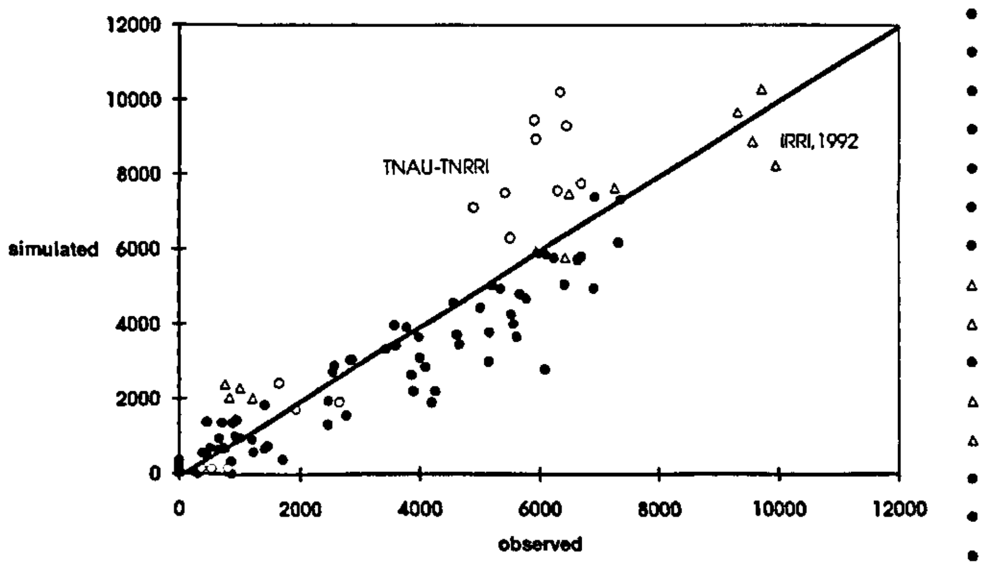


Figure 4.7.3 Weight of the storage organs (kg ha^{-1}) simulated versus observed for the dataset TNAU-TNRRI (white dot), IRRI-1992 (white triangle) and the other datasets (black dots). The simulated values were obtained for simulation runs using measured leaf nitrogen (kg N ha^{-1}) as forcing function.

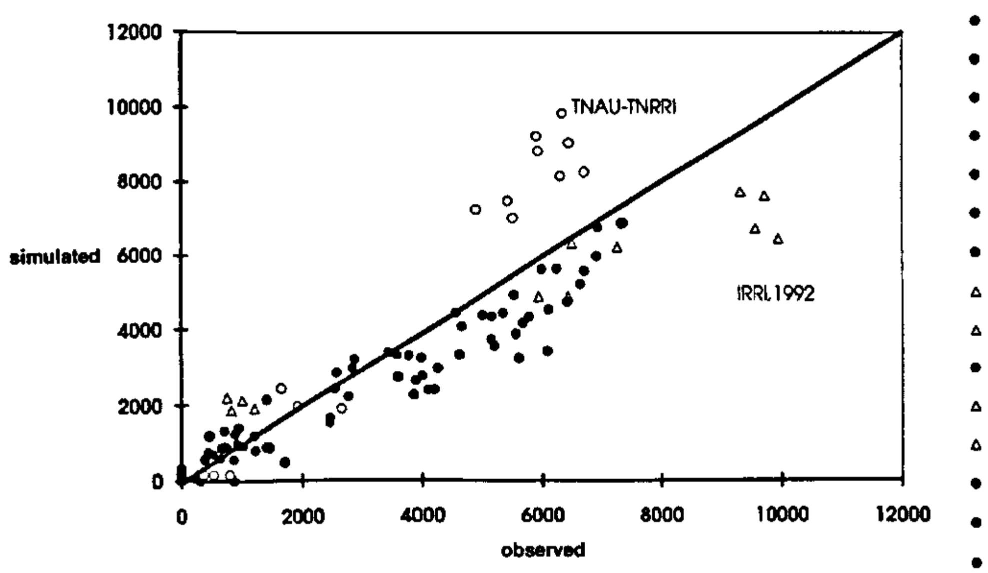


Figure 4.7.4 Weight of the storage organs (kg ha^{-1}) simulated versus observed for the dataset TNAU-TNRRI (white dot), IRRI-1992 (white triangle) and the other datasets (black dots). The simulated values were obtained for simulation runs using simulated leaf nitrogen (kg N ha^{-1}) in photosynthesis.

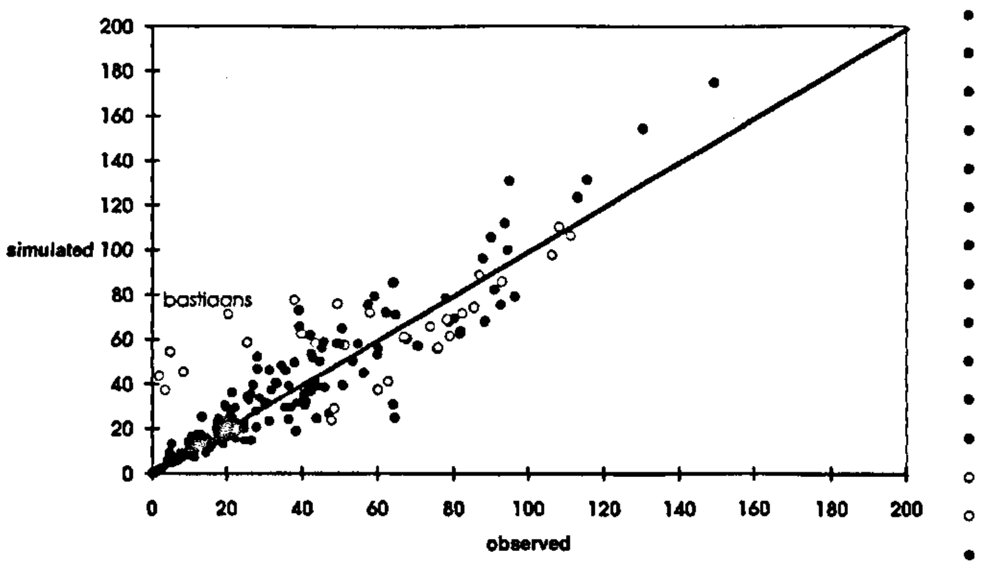


Figure 4.7.5 Amount of leaf nitrogen simulated versus observed for the dataset of Bastiaans (white dot) and the other datasets (black dots) at sampling dates. The simulated values were obtained for simulation runs using simulated leaf nitrogen (kg N ha^{-1}) in photosynthesis.

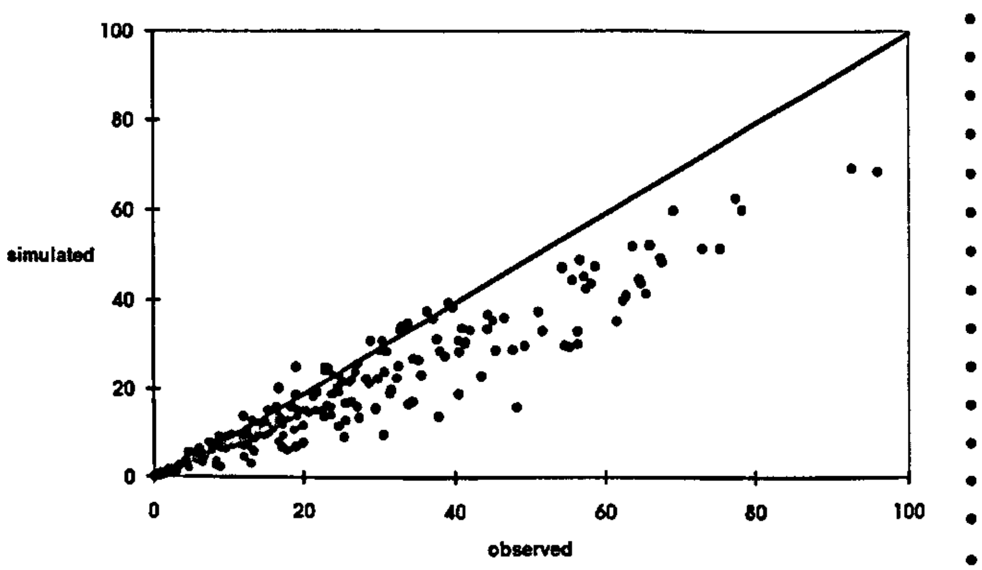


Figure 4.7.6 Amount of stem nitrogen simulated versus observed for all datasets at sampling dates. The simulated values were obtained for simulation runs using simulated leaf nitrogen (kg N ha^{-1}) in photosynthesis.

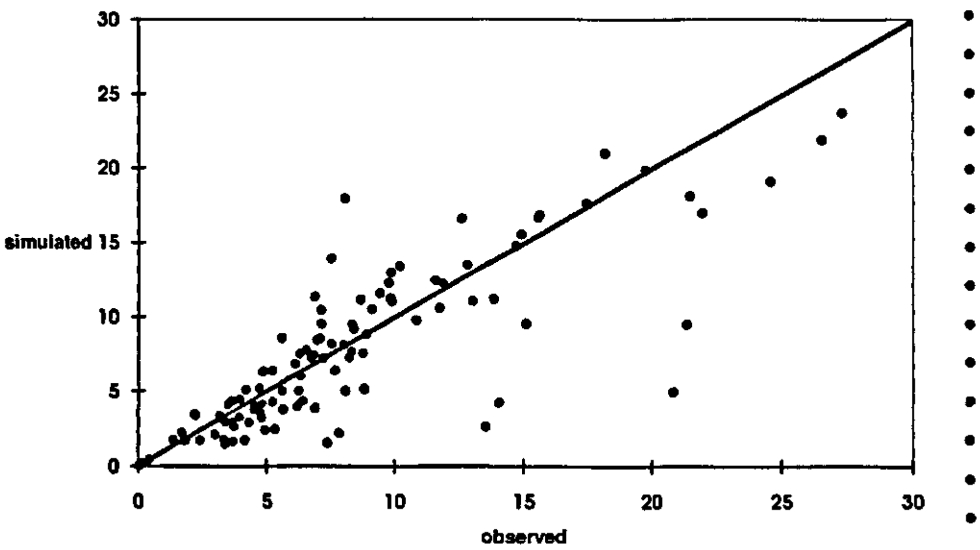


Figure 4.7.7 Amount of root nitrogen simulated versus observed for the datasets PUAT, CRRI and TNAU-TNRRI at sampling dates. The simulated values were obtained for simulation runs using simulated leaf nitrogen (kg N ha^{-1}) in photosynthesis.

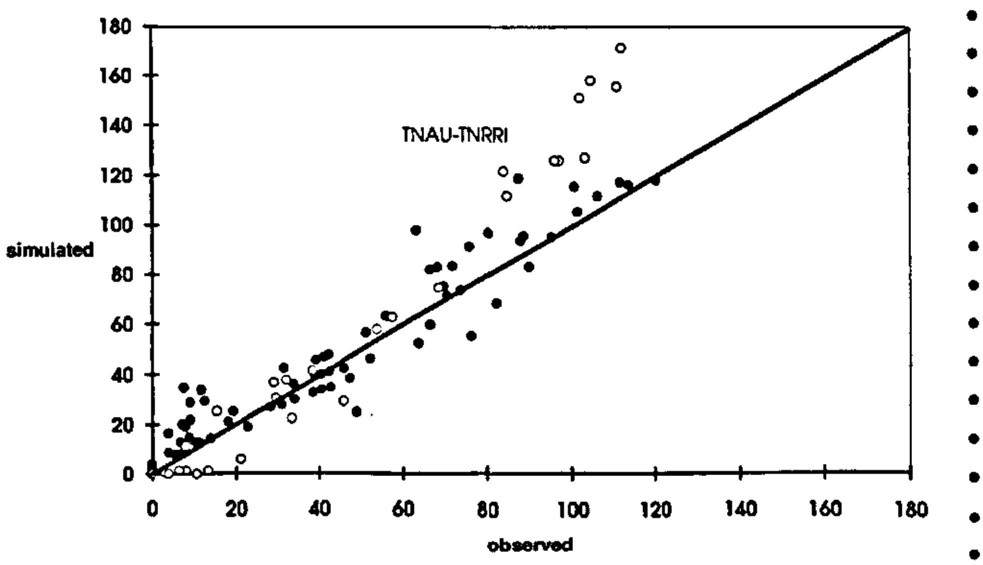


Figure 4.7.8 Amount of nitrogen in storage organs simulated versus observed for the datasets TNAU-TNRRI (white dots) and the other datasets (black dots) at sampling dates. The simulated values were obtained for simulation runs using simulated leaf nitrogen (kg N ha^{-1}) in photosynthesis.

4.8 Conclusions

From the validation results it is concluded that improvements can be made in various aspects of the model.

- The carbohydrate sources for panicle growth are at the moment photosynthesis and shielded reserves stored in the stem. Reallocation from roots and leaves could be an important additional source under specific conditions.

- The nitrogen demand of the grain is now determined by a maximum possible nitrogen content (NMAXSO). NMAXSO is set at 0.0175 for all cultivars and appeared too high. It may be better to define the final grain N fraction from the availibility of remobilizable N at flowering in the crop, and post flowering N uptake as a supplementary process. These may be cultivar and soil dependent.

- The minimum and maximum nitrogen fractions in the plant organs can be improved on the basis of new observations.

- It seems attractive to relate N demand of stem and root directly with leaf N demand, thus removing two inputs from the model (NMAXRT vs DVS, NMAXST vs DVS, NMINRT vs DVS NMINST vs DVS).

- Loss of N from the plant has been observed in experiments, but is not taken into account in the model.

References

Kropff, M.J., H.H. van Laar & H.F.M. ten Berge (Eds), 1993.
ORYZA1. A basic model for irrigated lowland rice production.
Simulation and Systems Analysis for Rice Production (SARP), International Rice Research Institute, Los Baños, Philippines, 88 pp.

Penning de Vries, F.W.T., D.M. Jansen, H.F.M. ten Berge & A. Bakema, 1989.
Simulation of ecophysiological processes of growth in several annual crops.
Simulation Monographs, Pudoc, Wageningen and IRRI, Los Baños, 271 pp.

Appendix I:
ORYZA_N, CSMP version

```
*-----------------------------------------------------------------------*
*                                                                       *
*               A Model for Nitrogen Limited Rice Production            *
*                                                                       *
*                               ORYZA_N                                 *
*                                                                       *
*                              August 93                                *
*                             Version 1.0                               *
*                                                                       *
*                                                                       *
* Centre for Agrobiological Research (CABO-DLO),                        *
* Agricultural Research Department, P.O. Box 14, 6700 AA Wageningen,    *
* The Netherlands                                                       *
*                                                                       *
* International Rice Research Institute, P.O. Box 933,                  *
* 1099 Manila, The Philippines and                                      *
*                                                                       *
* Department of Theoretical Production Ecology, P.O. Box 430,           *
* 6700 AK Wageningen, The Netherlands.                                  *
*                                                                       *
*                                                                       *
* This model is based on the following models:                          *
* - MACROS-L1D by Penning de Vries F.W.T. et al., 1989. Simulation of   *
*                 ecophysiological processes of growth in several       *
*                 annual crops. Simulation Monographs 29, Pudoc,        *
*                 Wageningen and IRRI, Los Banos, 271 pp.               *
* - SUCROS     by Laar, H.H. van, J. Goudriaan & H. van Keulen, 1992.   *
*                 Simulation of crop growth for potential and water-    *
*                 limited production situations. Simulation Reports 27,*
*                 CABO-TPE, Wageningen, The Netherlands, 72 pp.         *
*                                                                       *
*-----------------------------------------------------------------------*

STORAGE RDTT(366),TMAXT(366),TMINT(366),HUAAT(366),WDST(366)
STORAGE RAINT(366),NTOTMT(15),DNOST(15),DNAPT(10)
FIXED I,IDOY,IDOYTR,NS,NA,SWIYR,SWILAI,SWINPR,SWINUP,SWISIN,SWIRES
FIXED SWINPH,SWIPAR,SWISAI,SWIMEA

*** 1.    Initial Conditions

          INITIAL

*         Initial leaf area index

          SLA    = SLAC*AFGEN(SLAFAC,DVS)
          LAII   = WLVGI*SLA
          LAIOLD= LAII
*         initial weight of the roots calculated with FRT/FSH
*          WRTLI = (WSTSI+WLVGI)*0.5/0.5

*         Initial amounts nitrogen organs

          ANSTI = FNSTI * WSTSI
          ANLVI = FNLVI * WLVGI
          ANRTI = FNRTI * WRTLI
          ANTOTI= ANLVI+ANSTI+ANRTI

          DYNAMIC

*** 2.    Phenological Development

          DVS    = INTGRL(DVSI,DVR)

PROCEDURE DVR,DRR,TSHCKD,TSTR= PRODVR (DVS,DVRV,HU,TSI,DVRR,SHCKD,...
                                       IDOY,IDOYTR)
            IF (DVS.LT.1.) THEN
               DVR    = DVRV * HU
               IF (IDOY.EQ.IDOYTR) TSTR = TSI
               TSHCKD = SHCKD * TSTR
               IF (IDOY.GT.IDOYTR.AND.(TS+TSI).LT.(TSTR+TSHCKD)) DVR=0.
            ELSE
               DVR    = DVRR * HU
               DRR    = DVR
            ENDIF
ENDPROCEDURE

*** 3.    Daily Dry Matter Production

*** 3.1   Daily Gross Canopy CO2 Assimilation

          AMAX0,DTGA=TOTASN(DOY, LAT, RDT,SCP,EFF,KDF,LAI,...
                            KDIFN, ANLVPH, ALPHAN, NB, REDFT)

          EFF    = AFGEN(EFFTB,TAVD)

PROCEDURE KDF    = PROKDF (LAI,DVS)
          KDF    = 0.6
          IF (LAI.LT.1.5 .AND. DVS.LT.1.) KDF=0.4
ENDPRO

          KDIFN = SWINPR*KDIFNP
          REDFT = AFGEN(REDFTT,TAVD)
          PCGT  = INTGRL(0.,DTGA)
          ANLVPH= INSW(0.5-SWINPH,ANLV,XXNLV)

*** 3.2   Maintenance Respiration

*         respiration, adapted for N content

          RMCR = SWIRES*(RMLV+RMST+RMSO+RMRT+RMMA)
*         in CH2O!
          RMLV   = WLVG*MAINLV*(1.+ACTLV)/2.*TEFF
          RMST   = WSTS*MAINST*(1.+ACTST)/2.*TEFF
          RMRT   = WRTL*MAINRT*(1.+ACTRT)/2.*TEFF
          RMSO   = WSO *MAINSO*TEFF
          RMMA   = 0.20*DTGA*0.5*30./44.

          TEFF   = Q10**((TAV-TREF)/10.)
          ACTLV = (FNLV-RFNLV)/(NMAXLX-RFNLV)
          ACTST = (FNST-RFNST)/(NMAXSX-RFNST)
          ACTRT = (FNRT-RFNRT)/(NMAXRX-RFNRT)

          RCRT   = INTGRL(0.,RMCR+RGCR)
          CELV   = DTGA-RMCR
          CELVN = INTGRL(0.,INSW(CELV,1.,-CELVN/DELT))

*** 3.3   Daily Dry Matter Growth Rates of the Crop

          CRGCR = FSH*(CRGST*FST*(1.-FSTR)+CRGSTR*FSTR*FST+...
```

Appendix I: ORYZA_N, CSMP version

```
*---------------------------------------------------------------------*
*                                                                     *
*           A Model for Nitrogen Limited Rice Production              *
*                                                                     *
*                           ORYZA_N                                   *
*                                                                     *
*                          August 93                                  *
*                         Version 1.0                                 *
*                                                                     *
*                                                                     *
* Centre for Agrobiological Research (CABO-DLO),                      *
* Agricultural Research Department, P.O. Box 14, 6700 AA Wageningen,  *
* The Netherlands                                                     *
*                                                                     *
* International Rice Research Institute, P.O. Box 933,                *
* 1099 Manila, The Philippines and                                    *
*                                                                     *
* Department of Theoretical Production Ecology, P.O. Box 430,         *
* 6700 AK Wageningen, The Netherlands.                                *
*                                                                     *
*                                                                     *
* This model is based on the following models:                        *
* - MACROS-L1D by Penning de Vries F.W.T. et al., 1989. Simulation of *
*                ecophysiological processes of growth in several      *
*                annual crops. Simulation Monographs 29, Pudoc,       *
*                Wageningen and IRRI, Los Banos, 271 pp.              *
* - SUCROS     by Laar, H.H. van, J. Goudriaan & H. van Keulen, 1992. *
*                Simulation of crop growth for potential and water-   *
*                limited production situations. Simulation Reports 27,*
*                CABO-TPE, Wageningen, The Netherlands, 72 pp.        *
*                                                                     *
*---------------------------------------------------------------------*

STORAGE RDTT(366),TMAXT(366),TMINT(366),HUAAT(366),WDST(366)
STORAGE RAINT(366),NTOTMT(15),DNOST(15),DNAPT(10)
FIXED I,IDOY,IDOYTR,NS,NA,SWIYR,SWILAI,SWINPR,SWINUP,SWISIN,SWIRES
FIXED SWINPH,SWIPAR,SWISAI,SWIMEA

*** 1.    Initial Conditions

          INITIAL

*         Initial leaf area index

          SLA    = SLAC*AFGEN(SLAFAC,DVS)
          LAII   = WLVGI*SLA
          LAIOLD= LAII
*         initial weight of the roots calculated with FRT/FSH
           WRTLI = (WSTSI+WLVGI)*0.5/0.5

*         Initial amounts nitrogen organs

          ANSTI = FNSTI * WSTSI
          ANLVI = FNLVI * WLVGI
          ANRTI = FNRTI * WRTLI
          ANTOTI= ANLVI+ANSTI+ANRTI

          DYNAMIC

*** 2.    Phenological Development

          DVS    = INTGRL(DVSI,DVR)

PROCEDURE DVR,DRR,TSHCKD,TSTR= PRODVR (DVS,DVRV,HU,TSI,DVRR,SHCKD,...
                                       IDOY,IDOYTR)
            IF (DVS.LT.1.) THEN
               DVR    = DVRV * HU
               IF (IDOY.EQ.IDOYTR) TSTR = TSI
               TSHCKD = SHCKD * TSTR
               IF (IDOY.GT.IDOYTR.AND.(TS+TSI).LT.(TSTR+TSHCKD)) DVR=0.
            ELSE
               DVR    = DVRR * HU
               DRR    = DVR
            ENDIF
ENDPROCEDURE


*** 3.    Daily Dry Matter Production

*** 3.1   Daily Gross Canopy CO2 Assimilation

          AMAX0,DTGA=TOTASN(DOY, LAT, RDT,SCP,EFF,KDF,LAI,...
                           KDIFN, ANLVPH, ALPHAN, NB, REDFT)

          EFF    = AFGEN(EFFTB,TAVD)

PROCEDURE KDF    = PROKDF (LAI,DVS)
          KDF    = 0.6
          IF (LAI.LT.1.5 .AND. DVS.LT.1.) KDF=0.4
ENDPRO

          KDIFN = SWINPR*KDIFNP
          REDFT = AFGEN(REDFTT,TAVD)
          PCGT   = INTGRL(0.,DTGA)
          ANLVPH= INSW(0.5-SWINPH,ANLV,XXNLV)


*** 3.2   Maintenance Respiration

*         respiration, adapted for N content

          RMCR = SWIRES*(RMLV+RMST+RMSO+RMRT+RMMA)
*         in CH2O!
          RMLV   = WLVG*MAINLV*(1.+ACTLV)/2.*TEFF
          RMST   = WSTS*MAINST*(1.+ACTST)/2.*TEFF
          RMRT   = WRTL*MAINRT*(1.+ACTRT)/2.*TEFF
          RMSO   = WSO *MAINSO*TEFF
          RMMA   = 0.20*DTGA*0.5*30./44.

          TEFF   = Q10**((TAV-TREF)/10.)
          ACTLV  = (FNLV-RFNLV)/(NMAXLX-RFNLV)
          ACTST  = (FNST-RFNST)/(NMAXSX-RFNST)
          ACTRT  = (FNRT-RFNRT)/(NMAXRX-RFNRT)

          RCRT   = INTGRL(0.,RMCR+RGCR)
          CELV   = DTGA-RMCR
          CELVN  = INTGRL(0.,INSW(CELV,1.,-CELVN/DELT))


*** 3.3   Daily Dry Matter Growth Rates of the Crop

          CRGCR  = FSH*(CRGST*FST*(1.-FSTR)+CRGSTR*FSTR*FST+...
```

```
                    CRGLV*FLV+CRGSO*FSO)+CRGRT*FRT

          GCR    =((DTGA*30./44.)-RMCR+(LSTR*FCSTR*30./12.))/CRGCR


*** 3.4   Dry Matter Partitioning

PROCEDURE FSH,FLV,FST=PARPRO(SWIPAR,DVS,DAT)
              IF (SWIPAR.EQ.0) THEN
                  FSH    = AFGEN(FSHT,DVS)
                  FLV    = AFGEN(FLVT,DVS)
                  FST    = AFGEN(FSTT,DVS)
                  FSO    = AFGEN(FSOT,DVS)
              ELSE
                  FSH    = AFGEN(FSHT,DAT)
                  FLV    = AFGEN(FLVT,DAT)
                  FST    = AFGEN(FSTT,DAT)
                  FSO    = AFGEN(FSOT,DAT)
              ENDIF
ENDPRO

*          FSO    = AMAX1(0.,1.-FLV-FST)
          FRT    = AMAX1(0.,1.-FSH)


*** 3.5   Growth Rates of Plant Organs

          GRT    = GCR*FRT
          GLV    = GCR*FSH*FLV
          GSTS   = GCR*FSH*FST*(1.-FSTR)
          GSH    = GCR*FSH
          GSTR   = GCR*FSH*FST*FSTR+...
                   INSW((FSO*GSH)-GSOM,0.,(FSO*GSH)-GSOM)
          GSO    = AMIN1(FSO*GSH,GSOM)

*         Loss Rates Leaves and Roots
          LLV    = INSW(DVS-DVSG2, 0., WLVG*RLRLV)
          LRT    = INSW(DVS-DVSG2, 0., WRTL*RLRRT)
          LSTR   = INSW(FST-0.01,WSTR/TCLSTR,0.)
          RLRLV,RLRRT = SLLOSS(FNLV,NMINL,RDR,LAI,LAIREF)


*** 3.6   Dry Matter Production

          WLVG   = INTGRL(WLVGI,GLV-LLV)
          WLVD   = INTGRL(0.,LLV)
          WSTS   = INTGRL(WSTSI,GSTS)
          WSTR   = INTGRL(0.,GSTR-LSTR)
          WSTT   = WSTS+WSTR
          WSO    = INTGRL(0.,GSO)
          WSHG   = WLVG+WSTS+WSO+WSTR
          WSHT   = WLVG+WLVD+WSTS+WSO+WSTR
          WRTL   = INTGRL(WRTLI, GRT-LRT)
          WRTD   = INTGRL(0.,LRT)
          WCR    = WSHG+WRTL
          WRR    = WSO*0.90/0.86
          HI     = WRR/WSHT


*** 3.7   Carbon Balance Check

          CKCRD = FUCCHK(CKCIN,CKCFL,TIME)
          CKCIN = (WLVG+WLVD-WLVGI)*FCLV + (WSTS-WSTSI)*FCST+...
                  WSTR*FCSTR + (WRTL+WRTD-WRTLI)*FCRT + WSO*FCSO
          CKCFL = TNASS* (12./44.)
          TNASS = INTGRL(0.,DTGA-RMCCO2-RGCR)
          RGCR  = GRT*CO2RT + GLV*CO2LV + GSTS*CO2ST + GSO*CO2SO...
                   + GSTR*CO2STR
          RMCCO2= 44./30.*RMCR
          CO2RT = 44./12. * (CRGRT *12./30. - FCRT)
          CO2LV = 44./12. * (CRGLV *12./30. - FCLV)
          CO2ST = 44./12. * (CRGST *12./30. - FCST)
          CO2STR= 44./12. * (CRGSTR*12./30. - FCSTR)
          CO2SO = 44./12. * (CRGSO *12./30. - FCSO)
          CKCDIF= ABS((CKCIN-CKCFL)/(NOT(CKCIN)+CKCIN))

          FCCR  = FSH*(FLV*FCLV+FST*(1.-FSTR)*FCST+FSO*FCSO+...
                  FCSTR*FST*FSTR)+FRT*FCRT


*** 4.    Leaf Area Development

*         Leaf area formulation JG-HTB, 18 aug 92
*         Leaf area is integral no longer;now derived from other states
*         User must choose from four options, by setting SWILAI.

PROCEDURE LAI,SLA=PRLAI(SWILAI,SWISAI,SSA,SLAC,WSTS,WLVG,TSLV,...
                            XXWLVG,DVS,LAII)
             IF (SWILAI.EQ.1) THEN
*         option 1: use of tabulated (measured) SLA/SLAC ratio vd DVS

                SLA    = SLAC*AFGEN(SLAFAC,DVS)
                LAI    = INSW(TSLV-89.7,LAII,WLVG*SLA)

             ELSEIF (SWILAI.EQ.2) THEN
*         option 2: use of tabulated (measured) ln(LAI) vs temp sum

                LAI    = AMAX1(LAII,EXP(AFGEN(LAILNT,TSLV)))

             ELSEIF (SWILAI.EQ.3) THEN
*         option 3: use of param (measured) RGRL for sink lim (=exp) stage,
*                   and tabulated (measured) SLA for source limited stage

                IF (DVS.LT.0.3.AND.LAIOLD.LT.1.5) THEN
                   WLVEXP= WLVG
                   LAIEXP= LAII*AMAX1(1.,EXP(RGRL*(TSLV-89.7)))
*         temperature response and transplanting shock according
*         to Kropff
                   LAI    = LAIEXP+0.5*WSTS*SSA
                ELSE
                   SLA    = SLAC*AFGEN(SLAFAC,DVS)
                   LAI    = AMAX1(0.,LAIEXP)+0.5*WSTS*SSA+ ...
                            (WLVG-AMAX1(0.,WLVEXP))*SLA
                ENDIF

                LAIOLD= LAI

             ELSEIF (SWILAI.EQ.4) THEN
*         option 4:use of measured leaf mass and calc SLA

               SLA    = SLAC*AFGEN(SLAFAC,DVS)
               LAI    = INSW(TSLV-89.7,LAII,XXWLVG*SLA)

             ELSEIF (SWILAI.EQ.5) THEN
*         option 5:use of measured leaf area

               LAI = AFGEN(XLAITB,DOY)

             ENDIF

             SSGA = AFGEN(SSGATB, DVS)
             SAI  = SSGA * WSTS
             IF (SWISAI.EQ.1) THEN
                LAI = LAI + 0.5*SAI
             ENDIF


ENDPROCEDURE
```

```
*** 5.     Daily Nitrogen Assimilation

*** 5.1    Nitrogen Uptake Rate

PROCEDURE F1,NUPT,DNAP,DNOS,NTOTM,DATEX=UPPRO(SWIYR,DOY,...
            DOYS,ANLCR,SWINUP,NS,NA,NTOTMT,DNOST,DNAPT,...
            CRDN,NDEMV)

            IF (SWINUP.EQ.1) THEN
*         N uptake measured forcing function; model maintains
*         total N (kg/ha) in crop as measured;
               F1,NUPT,DNAP,DNOS,NTOTM,DATEX=SUNUPT(SWIYR,...
               DOY,DOYS,ANLCR,NS,NA,NTOTMT,DNOST,DNAPT,CRDN)
            ELSEIF (SWINUP.EQ.2) THEN
*         for potential production,model maintains max concentration in
*         organs, corresponding to development stage;
               NUPT=NDEMV+GLV*NMAXL+GSTS*NMAXS+GRT*NMAXR
            ENDIF
ENDPROCEDURE

          NUPTP=NDEMV+GLV*NMAXL+GSTS*NMAXS*GRT*NMAXR

*** 5.2   Total Nitrogen Uptake

          NUPTOT= INTGRL(0.,NUPT)
          ANTOT = INTGRL(ANTOTI,NUPT)
          NUPNEG= INTGRL(0.,AMIN1(0.,NUPT))
*         nupneg only to keep track of negative uptake; by adaptation
*         of death rate of leaves and roots should this value be brought
*         to zero throughout season.

*** 5.3   Nitrogen Allocation and Loss Rates

*         max N fractions in plant organs
          NMAXL = AFGEN(NMAXLT,DVS)
          NMAXS = AFGEN(NMAXST,DVS)
          NMAXR = AFGEN(NMAXRT,DVS)

*         min N fractions in plant organs
          NMINL = AFGEN(NMINLT,DVS)
          NMINS = AFGEN(NMINST,DVS)
          NMINR = AFGEN(NMINRT,DVS)

                  .

*         N demand by crop and organs
          NDEML,NDEMS,NDEMR,NDEMG,NDEMV,NDEMT=SNDEM(ANLV,ANST,ANRT,...
                 ANSO,NMAXL,NMAXS,NMAXR,NMAXSO,TCNA,WLVG,WSTS,WRTL,WSO)

*         and N allocation rates to different organs
          NALV,NAST,NART=SNALLC(SWINUP,ANLV,ANST,ANRT,ANSO,WLVG,...
                 WSTT,WRTL,WSO,NDEMV,NDEML,NDEMS,NDEMR,NUPT,GLV,...
                 GSTS,GRT,NMAXL,NMAXS,NMAXR)

*         N translocation rates from different organs,N supply
*         rate to grains
          NTLV,NTST,NTRT,NSUPG=SNSUPG(ANLV,ANST,ANRT,WLVG,WSTS,WRTL,...
                        WSO,RFNLV,RFNST,RFNRT,TCNT,LLV,FNLV,TEFG,NDEMG)

*         N loss rate by dying of leaves and roots
          NLDLV = LLV*AMAX1(RFNLV,0.5*ANLV/WLVG)
          NLDRT = LRT*RFNRT
          NLSINT= INTGRL(0.,NLDLV+NLDRT)


*** 5.4   Nitrogen in Biomass

          ANSO  = INTGRL(0.,NSUPG)
          ANLV  = INTGRL(ANLVI,NALV-NTLV-NLDLV)
          ANLD  = INTGRL(0.,NLDLV)
          ANST  = INTGRL(ANSTI,NAST-NTST)
          ANRT  = INTGRL(ANRTI,NART-NTRT-NLDRT)
          ANRD  = INTGRL(0.,NLDRT)
          ANCR  = ANSO+ANLV+ANLD+ANST+ANRT+ANRD
          ANLCR = ANCR-ANLD-ANRD

          FNLV   = ANLV/(WLVG+TINY)
          FNST   = ANST/(WSTS+TINY)
          FNRT   = ANRT/(WRTL+TINY)
          FNSO   = ANSO/(WSO+TINY)


*** 5.5   Nitrogen Balance Check

          CKNIN = ANLV-ANLVI+ANST-ANSTI+ANRT-ANRTI+ANSO
          CKNFL = NUPTCT - NLSINT
          CKNRD = FUNCHK(CKNIN,CKNFL,TIME)


*** 6.    Tiller and Grain Development

          NTI    = INTGRL(PLNUM,GNTI-LNTI)
          GNTI   = DVSTF*AMAX1(0.,(NTIP-NTI)/TCFT)
          LNTI   = DVSTD*AMAX1(0.,(NTI-NTIP)/TCDT)
          DVSTF  = NOR(DVST1-DVS,DVS-DVST2)
          DVSTD  = NOR(DVST1-DVS,DVS-(DVST2+0.15))
          CNTI   = AFGEN(CNTIT,DVS)

          NGR    = INTGRL(0.,GNGR)
          GNGR   = DVSGR*AMAX1(0.,AMIN1(NGRP-NGR,NGRMX-NGR)/TCFG)
          NGRP   = GCR*CRGCR/GGRMN
          NGRMX  = NTI*100.
          DVSGR  = NOR(DVSG1-DVS,DVS-DVSG2)
          GGRMX  = GGRMN*2.
          GGRMN  = WGRMX/GFP
          GFP    = 1./(1.33*(NOT(DRR)+DRR))
          WGR    = WSO/(AMAX1(1.*NGR,1000.))
          GSOM   = INSW(1.5-1.0*SWISIN, NGR*GGRMX*TEFG, 1000.)

*         temperature function TEFG was not defined in TIL
*         check TILMX for your variety
*         morphogenetic parameters for sink size calculation
*         potential number of tillers, related to rel tillering rate
          NTIP   = AMIN1(GCR*CRGCR/CNTI,PLNUM*TIL)
          TIL    = TILMX*AFGEN (RTILT,FNLV)

*         temperature dependent relative translocation TEFG used in
*         translocation calculation,but also in GSOM calculation (main)
          TEFG   = AFGEN(GGRT,TAV)


*** 7.    Reading of Measured Data

PROCEDURE XXWLVG, XXNLV = READMD(DOY, DAT)

          IF (SWIMEA.EQ.0) THEN

             XXWLVG= AFGEN(XWLVGT,DOY)
             XXWSTS= AFGEN(XWSTTB,DOY)
             XXWRTL= AFGEN(XWRTLT,DOY)
             XXWSO = AFGEN(XWSOTB,DOY)
*             XXLAI = AFGEN(XLAITB,DOY)
             XXNLV = (AFGEN(XNLV,DOY)/100)*XXWLVG
             XXNST = (AFGEN(XNST,DOY)/100)*XXWSTS
             XXNRT = (AFGEN(XNRT,DOY)/100)*XXWRTL
             XXNSO = (AFGEN(XNSO,DOY)/100)*XXWSO
```

```
         ELSE

           XXWLVG= AFGEN(XWLVGT,DAT)
           XXWSTS= AFGEN(XWSTTB,DAT)
           XXWRTL= AFGEN(XWRTLT,DAT)
           XXWSO = AFGEN(XWSOTB,DAT)
*           XXLAI = AFGEN(XLAITB,DAT)
           XXNLV = (AFGEN(XNLV,DAT)/100)*XXWLVG
           XXNST = (AFGEN(XNST,DAT)/100)*XXWSTS
           XXNRT = (AFGEN(XNRT,DAT)/100)*XXWRTL
           XXNSO = (AFGEN(XNSO,DAT)/100)*XXWSO

         ENDIF

ENDPROCEDURE


         XXWCR = XXWLVG+XXWSTS+XXWSO+XXWRTL

*        XXNSO is included from first grain harvest day (FGHDAY)
*        in Days after Transplanting (DAT) on
         XXNCR = XXNLV+XXNST+XXNRT+(XXNSO*(INSW(DAT-FGHDAY,0.,1.)))


*** 8.   Time and Environmental Variables

PROCEDURE DAT = TRANSP(TIME,IDOY,DOYS,IDOYTR,SWIYR)
         IF ((IDOY+(SWIYR*365.)).LT.IDOYTR) THEN
           DAT=0.
         ELSE
           TD  = IDOYTR-DOYS
           DAT = TIME-TD
         ENDIF
ENDPROCEDURE

         DOY  = AMOD(DOYS+TIME+364.,365.)+1.
         IDOY = DOY

*        if time proceeds into the next year; for SUNUPT
PROCEDURE SWIYR=YRSWIT(DOY,TIME)
           IF (ABS(DOY-1.).LT.0.1.AND.TIME.GT.1.) SWIYR=1
ENDPROCEDURE

*         RDT   = RDTC*(PARA+PARB*RDTT(IDOY)/DLA)
*         RDTC,DLA,DLP=SUASTR(DOY,LAT)
         RDT   = RDTT(IDOY)*1.E6
*         RTOT  = 1.E-6*INTGRL(0.,RDT)

         TAV   = (TMAXT(IDOY)+TMINT(IDOY))/2.
         TAVD  = (TMAXT(IDOY)+TAV)/2.

         HU    = AMIN1(TMD -TBD ,(AMAX1(0.,TAV-TBD)))
         HULV  = AMIN1(TMLV-TBLV,(AMAX1(0.,TAV-TBLV)))
         TS    = INTGRL(0.,HU)
         TSLV  = INTGRL(0.,HULV)


*** 9.   Run Control

         FINISH DVS =2.0, CELVN =10.0
         TIMER  TIME=0.0, DELT=1,PRDEL=10.,OUTDEL=10.,FINTIM=200.
         METHOD RECT

         PRINT   DOY,DVS,LAI,WLVG,XXWLVG,WSTT,XXWSTS,WRTL,XXWRTL,...
                 WSO,XXWSO,WCR,XXWCR,WSTR,ANLV,XXNLV,ANST,XXNST,...
                 ANRT,XXNRT,ANSO,XXNSO,ANLCR,XXNCR

         PREPARE DOY,DVS,LAI,WLVG,XXWLVG,WSTT,XXWSTS,WRTL,XXWRTL,...
                 WSO,XXWSO,WCR,XXWCR,WSTR,ANLV,XXNLV,ANST,XXNST,...
```

```
                 ANRT,XXNRT,ANSO,XXNSO,ANLCR,XXNCR

*********************************************************************
* PARAMETERS, FUNCTIONS, TABLES, ALL VALUES COMMON TO ALL EXPERIMENTS
* SO FAR USED IN L3C VALIDATION
*********************************************************************

         PARAM TINY  = 0.0001
         PARAM SCP   = 0.2

*** 2.   Phenological Development

         PARAM SHCKD = 0.4

*** 3.1  Daily Gross Canopy CO2 Assimilation

         FUNCTION EFFTB = 10.,0.54, 40.,0.36

*        minimum N conc 0.1 g/m2 leaf at AMAX=0; based on 0.5% MASS
*        minimum N conc and 200 kg/ha leaf
         PARAM NB     = 0.15

*        ALPHAN based on NB=0.10 and max N conc 2.4 g/m2 at AMAX=1.1*68
*        kg CO2 /ha/hr; own obs; and graph FPV,HVK,JCA; leaf 30 g m-2;
         PARAM ALPHAN= 33.

         FUNCTION REDFTT = -10.0,0., 10.,0., 20.,1. , 37.,1., 43.,0.0

         PARAM KDIFNP = 0.2


*** 3.2  Maintenance Respiration

*        residual N levels in organs; assumed variety independent
         PARAM TREF  = 25.0 , Q10   = 2.0
         PARAM RFNLV = 0.005, RFNST = 0.002, RFNRT = 0.002
         PARAM MAINLV= 0.020, MAINST= 0.015, MAINSO= 0.003, MAINRT=0.01

*** 3.3  Daily Dry Matter Growth Rates of the Crop

         PARAM CRGLV = 1.326, CRGST = 1.326, CRGRT = 1.326
         PARAM CRGSO = 1.462, CRGSTR= 1.111


*** 3.5  Growth Rates of Plant Organs

*        (N-dependent) Loss Rates Leaves and Roots
*        relative death rate leaf and root; used with N content
         PARAM RDR    =  0.01
         PARAM LAIREF=  5.
         PARAM TCLSTR= 10.


*** 3.7  Carbon Balance Check

         PARAM FCLV = 0.419, FCST = 0.444, FCSO = 0.487
         PARAM FCRT = 0.431, FCSTR= 0.444


*** 4.   Leaf Area Development

         PARAM TBLV  = 8.,      TBD = 8.
         PARAM RGRL  = 0.0085
         PARAM SLAC  = 0.002,   SSA = 0.001

*        SLAFAC calculated from data CVLINE IRRI--> Gon
         FUNCTION SLAFAC=(0.00,1.72),(0.21,1.72),(0.24,1.72),...
                         (0.33,1.32),(0.70,1.20),(1.01,1.00),...
```

```
                  (2.00,0.75),(2.10,0.75)

        FUNCTION LAILNT=(    0.,-1.61),(89.15,-1.61),( 157.,-1.01),...
                  ( 303.,-0.31),( 451., 0.45),( 589., 1.07),...
                  ( 734., 1.34),( 882., 1.46),(1020., 1.37),...
                  (1171., 1.24),(1324., 1.13),(1483., 1.04)
*       THIS TABLE WAS GENERATED WITH SWILAI=1 AND tmt WEATHER DATA

        FUNCTION SSGATB=(0.,0.0003),(0.9,0.0003),(2.1,0.)

*** 5.  Daily Nitrogen Assimilation

        PARAM CRDN = 5.

        PARAM NMAXLX = 0.06, NMAXSX = 0.03, NMAXRX = 0.034

*       max N levels in plant organs as functon of DVS
*       FUNCTION NMAXLT= 0.00,0.060, 0.4,0.050, 0.7,0.045, ...
*                        1.00,0.030, 1.5,0.025, 2.0,0.010, 2.1,0.010
*       NOTE changed at DVS=1.
        FUNCTION NMAXLT= 0.00,0.060, 0.4,0.050, 0.7,0.045,...
                         1.00,0.045, 1.5,0.025, 2.0,0.010, 2.1,0.010
        FUNCTION NMAXST= 0.00,0.025, 0.4,0.030, 0.7,0.030,...
                         1.00,0.020, 1.5,0.015, 2.0,0.010, 2.1,0.010
        FUNCTION NMAXRT= 0.00,0.034, 0.4,0.013, 0.6,0.017,...
                         0.85,0.017, 1.1,0.014, 2.0,0.011, 2.1,0.010

        FUNCTION NMINLT= 0.,0.025, 1.0,0.012, 2.1,0.007
        FUNCTION NMINST= 0.,0.017, 1.0,0.007, 2.1,0.004
        FUNCTION NMINRT= 0.,0.005, 1.0,0.008, 2.1,0.006

*       time coefficients for translocation, and acquisition
        PARAM TCNT = 10., TCNA = 1.

*       max and min values of N fraction in grains
*       may be changed according to your data; use min value to check
*       prediction with data
        PARAM NMAXSO = 0.0175, NMINSO = 0.010


*** 6.  Tiller and Grain Development

        PARAM TCFT  = 15., TCDT = 10.0, TCFG = 3.
        PARAM WGRMX = 23.5E-6
        PARAM DVST1 = 0.30, DVSG1 = 0.95
        PARAM DVST2 = 0.75, DVSG2 = 1.15
        PARAM PLNUM = 500000.

        FUNCTION CNTIT = 0.0, 5.E-6, 0.3, 5.E-6, 0.75,25.E-6, ...
                         1.0,75.E-6, 2.1,75.E-6
        FUNCTION GGRT  = 10.,0.0, 15.,0.0, 18.,0.75,...
                         23.,1.0, 27.,0.9, 40.,0.0

        FUNCTION RTILT = 0.00,0.0, 0.02,0.2, 0.04,0.6,...
                         0.05,0.8, 0.06,1.0, 0.08,1.0

*       max tiller number; check for your varieties; this is the
*       tiller number at excess N levels, e.g. 300-400 kg/ha; do
*       not simply take your highest observed value if that was
*       measured at lower N levels
        PARAM TILMX = 50.

*** 8.  Time and Environmental Variables

        PARAM TMD  =  30.0 , TMLV = 26.0
        PARAM TBD  =   8.0 , TBLV =  8.0
        PARAM PAFA =   0.25
        PARAM PAFB =   0.45
        PARAM ZREF =   2.0
```

```
        PARAM CO2E = 330.  , FRCO2=  0.7

*********************************************************************
* EXTRA INFORMATION ON L3C INPUT
*********************************************************************
*
*
*** SWITCHES
*
*   SWIMEA =0: measured data versus day of year (DOY)
*          =1: measured data versus days after transplanting (DAT)
*
*   SWIPAR =0: partitioning table versus development stage
*          =1: partitioning table versus days after transplanting, DAT
*
*   SWILAI =1: use of tabulated (measured) SLA/SLAC ratio vs DVS
*          =2: use of tabulated (measured) ln(LAI) vs temperature sum
*          =3: use of param (measured) relative growth rate for leaf
*              area, RGRL for sink lim (=exp) stage, and tabulated
*              (measured) SLA for source limited stage
*          =4: use of measured leaf mass and calculated SLA
*          =5: use of measured leaf area
*
*   SWINUP =1: nitrogen limited production; uptake forcing function
*          =2: potential production; uptake equals demand
*
*   SWISIN =1: no sink limitation; no maximum grain filling rate GSOM
*          =2: sink limitation; use of GSOM, calculated from tiller and
*              grain number
*
*   SWIYR  =0: time switch for experiment across january 1; should be
*           set to zero for every run
*
*   SWINPH =0: use measured amount of nitrogen in leaves for
*              photosynthesis calculation
*          =1: use simulated  amount of nitrogen in leaves for
*              photosynthesis calculation
*
*   SWIRES =0: excluding respiration
*          =1: including respiration
*
*   SWINPR =0: no nitrogen profile in canopy; homogenous distribution
*          =1: with nitrogen profile in canopy; with extinction
*              coefficient
*   SWISAI =0: stem area is NOT included in leaf area
*          =1: stem area is included in leaf area
*
*** EXPERIMENTAL DATA ON NITROGEN SAMPLING AND MANAGEMENT
*   PARAM NS      number of sampling dates for N in crop
*   TABLE DNOST   julian dates (DOY) at which NTOTMT was measured the
*                 last figure in the table should be the harvest date
*                 or just after. For seasons across January 1st , day
*                 numbers proceed as 365., 366., 367., 368. etc. untill
*                 the end of the season.
*   TABLE NTOTMT total nitrogen in crop (cumulative uptake),in kg N/ha,
*                 at the julian days specified in DNOST; NTOTMT should
*                 include the total amount at harvest as the last figure
*
*** NITROGEN APPLICATION SCHEME
*   PARAM NA      the number of nitrogen application dates, including
*                 basal dressing at planting/seeding, and including one
*                 dummy date after harvest
*   DNAPT         julian dates (DOY) at which nitrogen was applied;
*                 first figure is equal to DOYB also in absence of basal
*                 dressing; the last figure should be any date after
*                 harvest! For seasons across January 1st , see DNOST
*
*   CRDN          critical day number which affects the rate at which
```

```
*               uptake declines after fertilizer N application;
*               see function F1 in subroutine SUNUPT
*
*** MEASURED DATA
*   FGHDAY      first grain harvest day, expressed in days after
*               transplanting.
*
*****************************************************************
* PARAMETERS, FUNCTIONS, TABLES VALUES SPECIFIC PER EXPERIMENT SO FAR
* USED IN L3C VALIDATION
*****************************************************************
*****************************************************************
* PARAMETERS, FUNCTIONS, TABLES VALUES SPECIFIC PER EXPERIMENT SO FAR
* USED IN L3C VALIDATION
*****************************************************************

TITLE Aduthurai 1988-89 (Thyagarajan)
* weather data table contain:
*   January 1 to March 31,1989 (1-90)
*   March 31 to December 31, 1988 (90-366)

PARAM LAT=11.00
PARAM ELV=19.50

* maximum temperature in degrees Celsius
TABLE TMAXT(1-366)= ...
  28.5,  28.3,  29.0,  29.8,  27.7,  28.5,  27.7,  28.1,  28.3,...
  28.0,  28.1,  20.6,  27.6,  28.7,  28.0,  26.8,  28.4,  28.4,...
  28.3,  28.3,  28.3,  28.5,  29.1,  30.1,  30.8,  29.7,  28.8,...
  29.0,  28.8,  30.0,  29.7,  29.1,  29.6,  29.0,  30.0,  31.3,...
  30.8,  30.4,  30.3,  30.3,  30.2,  30.4,  30.8,  30.6,  30.2,...
  31.0,  31.5,  32.2,  32.5,  31.5,  32.8,  31.0,  31.0,  32.0,...
  31.6,  31.2,  31.2,  32.1,  31.0,  31.6,  33.5,  32.0,  33.6,...
  33.5,  32.5,  31.8,  32.5,  32.8,  32.5,  32.5,  32.0,  34.4,...
  32.5,  32.0,  32.8,  32.0,  33.0,  33.5,  35.5,  35.5,  36.0,...
  36.8,  36.5,  36.4,  35.5,  35.5,  35.5,  34.0,  32.8,  33.2,...
  37.6,  36.2,  36.5,  36.0,  34.2,  33.4,  33.7,  36.4,  34.6,...
  35.6,  35.2,  33.9,  34.6,  31.1,  34.2,  35.3,  36.0,  34.2,...
  34.0,  32.7,  34.5,  35.1,  35.5,  34.6,  35.0,  35.6,  32.3,...
  34.0,  34.3,  35.2,  34.9,  36.3,  35.3,  37.3,  36.8,  36.5,...
  36.7,  36.6,  37.8,  38.2,  38.3,  39.1,  38.9,  39.4,  39.0,...
  40.5,  37.0,  38.5,  38.2,  39.3,  36.0,  38.5,  38.5,  39.6,...
  39.2,  38.6,  39.5,  39.2,  39.0,  37.4,  37.7,  36.0,  32.5,...
  36.6,  32.5,  36.4,  35.2,  36.3,  36.1,  36.4,  36.8,  35.2,...
  36.8,  38.5,  37.7,  37.9,  38.3,  38.6,  37.8,  37.5,  37.7,...
  38.5,  38.2,  38.7,  36.6,  38.3,  38.0,  37.8,  37.2,  37.5,...
  39.0,  37.8,  37.8,  38.7,  37.8,  37.5,  37.0,  37.6,  35.8,...
  35.0,  35.3,  35.4,  33.3,  36.3,  33.8,  35.8,  34.6,  33.4,...
  32.7,  32.9,  34.6,  37.1,  37.0,  31.9,  30.8,  35.6,  34.6,...
  35.7,  34.0,  32.5,  34.0,  35.4,  35.3,  35.5,  35.4,  35.4,...
  36.2,  35.7,  37.2,  36.1,  35.8,  34.3,  35.6,  35.5,  31.8,...
  26.8,  32.5,  34.7,  35.5,  31.8,  31.0,  33.0,  34.1,  35.6,...
  37.0,  32.6,  31.6,  33.5,  33.7,  33.0,  33.5,  33.4,  30.8,...
  32.1,  33.2,  33.6,  33.6,  33.0,  34.7,  34.7,  33.5,  34.1,...
  33.9,  33.0,  30.1,  32.8,  33.9,  31.8,  33.1,  32.7,  32.6,...
  32.6,  32.1,  32.0,  33.4,  33.4,  33.8,  33.8,  32.9,  30.6,...
  31.2,  33.0,  31.0,  32.6,  32.7,  33.1,  33.8,  35.0,  34.2,...
  33.7,  34.0,  32.8,  30.4,  29.5,  32.0,  32.3,  33.1,  33.4,...
  33.5,  34.4,  34.0,  34.1,  34.0,  34.2,  33.5,  33.5,  33.4,...
  33.4,  32.1,  31.0,  31.5,  31.6,  31.8,  31.3,  31.8,  32.0,...
  32.6,  30.6,  29.3,  28.7,  24.4,  24.4,  25.9,  23.5,  28.0,...
  28.2,  25.2,  28.8,  29.9,  29.5,  30.3,  29.0,  30.5,  30.3,...
  29.7,  29.9,  29.8,  29.6,  30.2,  29.9,  29.7,  29.4,  29.3,...
  30.9,  29.1,  29.0,  28.6,  28.8,  29.4,  28.5,  28.0,  29.2,...
  29.4,  30.0,  29.5,  29.1,  31.3,  30.1,  30.5,  29.2,  28.5,...
  28.5,  28.0,  27.3,  28.1,  28.2,  28.5,  28.0,  28.0,  28.2,...
  28.7,  28.1,  28.5,  28.1,  28.6,  28.5

* minimum temperature in degrees Celsius
TABLE TMINT(1-366)= ...
  20.0,  21.1,  21.8,  22.5,  22.0,  18.5,  19.2,  19.5,  20.2,...
  18.6,  19.6,  18.2,  18.6,  20.5,  20.0,  21.5,  21.4,  21.5,...
  20.2,  17.6,  19.4,  18.5,  19.0,  19.8,  20.0,  20.0,  18.5,...
  21.3,  19.8,  19.8,  19.0,  18.1,  16.8,  16.0,  15.5,     15.0,...
  15.0,  14.7,  16.1,  19.0,  18.2,  17.6,  17.0,  16.8,  16.4,...
  18.0,  18.9,  18.8,  19.0,  16.1,  17.8,  19.6,  18.4,  18.7,...
  20.2,  20.6,  20.2,  19.7,  19.6,  16.3,  16.3,  17.4,  16.8,...
  17.9,  19.0,  21.1,  21.8,  23.2,  23.4,  23.9,  24.4,  21.7,...
  18.9,  20.1,  19.6,  19.4,  18.7,  18.7,  21.1,  23.4,    24.0,...
  24.3,  24.1,  22.9,  21.5,  21.7,  23.4,  22.9,  23.4,  22.1,...
  25.0,  26.0,  25.2,  22.4,  23.2,  24.2,  25.5,  25.6,  25.2,...
  25.1,  24.9,  25.5,  25.5,  25.8,  25.4,  25.7,  27.2,  26.8,...
  21.7,  23.7,  24.6,  25.6,  23.4,  24.8,  23.5,  22.7,  24.5,...
  25.7,  25.8,  25.0,  25.7,  26.0,  26.2,  27.7,  26.7,  27.0,...
  28.1,  26.4,  26.5,  26.5,  28.0,  25.8,  27.5,  26.3,  28.0,...
  24.8,  25.5,  28.5,  28.8,  26.5,  27.6,  28.5,  28.0,  26.7,...
  27.2,  28.2,  26.4,  27.8,  25.3,  29.2,  27.7,  28.4,  26.5,...
  24.6,  25.5,  25.8,  25.8,  26.9,  27.0,  27.0,  26.5,  26.7,...
  28.2,  25.5,  26.1,  25.5,  26.2,  27.2,  26.5,  26.8,  26.3,...
  26.5,  26.7,  25.1,  26.5,  27.2,  27.0,  27.2,  27.3,  25.7,...
  26.0,  25.5,  26.2,  27.1,  26.4,  26.5,  27.1,  24.0,  24.2,...
  24.6,  23.8,  24.3,  25.5,  24.3,  25.9,  25.5,  26.5,  27.0,...
  24.7,  26.1,  26.0,  27.4,  26.0,  24.7,  24.2,  24.2,  25.5,...
  26.0,  26.2,  25.8,  26.0,  25.8,  26.2,  26.0,  26.0,  27.2,...
  26.8,  26.0,  25.0,  24.5,  25.8,  25.8,  26.0,  23.5,  23.0,...
  24.8,  25.8,  25.7,  26.2,  25.5,  25.7,  25.6,  26.0,  25.3,...
  26.2,  23.6,  23.2,  24.5,  24.8,  24.6,  23.8,  22.8,  24.0,...
  25.0,  25.5,  25.1,  25.0,  26.0,  25.3,  22.4,  24.9,  24.4,...
  25.1,  22.0,  24.4,  24.6,  25.0,  25.0,  24.6,  25.0,  25.1,...
  24.5,  25.0,  25.4,  24.9,  24.6,  24.6,  25.5,  23.0,  22.7,...
  24.1,  24.3,  23.8,  24.5,  24.8,  26.0,  26.1,  25.3,  25.1,...
  25.7,  24.9,  22.6,  24.5,  23.6,  23.0,  24.7,  25.0,  23.2,...
  25.5,  25.7,  24.5,  24.5,  25.0,  22.6,  24.8,  25.3,  25.1,...
  25.0,  24.5,  24.6,  24.0,  22.5,  23.1,  23.1,  23.6,  24.0,...
  24.4,  22.7,  23.5,  23.5,  22.3,  22.6,  21.5,  22.0,  23.0,...
  23.5,  22.7,  22.9,  21.6,  23.5,  24.0,  22.2,  22.5,  22.8,...
  21.6,  20.5,  20.5,  20.0,  20.8,  21.2,  20.5,  19.5,  17.7,...
  19.6,  19.0,  17.7,  18.3,  22.5,  22.3,  23.5,  22.2,  22.3,...
  22.0,  21.5,  22.5,  21.2,  23.0,  22.4,  23.3,  22.6,  22.0,...
  20.8,  20.0,  21.2,  21.5,  21.6,  20.0,  19.5,  19.9,  18.5,...
  20.6,  20.6,  19.6,  19.0,  19.1,  19.5
* radiation in hours sunshine per day

TABLE RDTT(1-366)=...
   7.3,   8.8,   6.0,   2.7,   7.2,   9.0,   6.9,   7.8,   5.7,...
   5.9,   9.5,   5.9,   7.2,   5.0,   3.9,   7.1,   7.5,   5.7,...
   7.9,   9.6,   5.0,   7.3,   7.4,  10.0,   9.3,  10.4,  10.3,...
   9.8,   7.6,  10.9,  10.7,  10.9,  10.8,  11.2,  10.5,  10.7,...
  10.3,  10.1,   9.7,  10.0,  10.4,  10.5,  10.2,   9.3,  10.7,...
  10.6,  10.5,  10.5,   9.4,  10.7,  10.5,  10.6,  10.5,  10.0,...
  10.5,   7.9,   9.4,   9.1,   9.0,  10.7,  10.1,   9.8,  10.5,...
  10.6,  10.5,  10.6,   9.3,  10.1,  10.4,   6.4,   9.9,  10.4,...
  10.7,  10.4,  10.7,  10.5,  10.2,  10.5,  10.5,  10.6,  10.0,...
  10.0,  10.5,  10.5,  10.0,    .0,   9.9,  10.7,  10.5,  10.9,...
   9.0,   9.5,   7.9,  10.3,  10.5,   9.9,   5.7,   9.8,   4.7,...
  10.5,   9.1,   7.1,   5.7,   2.7,   9.6,   8.3,   9.9,   7.2,...
   5.3,   7.2,  10.8,  10.9,  10.6,   8.0,  10.8,   8.9,   8.4,...
  10.7,   5.9,  10.9,  10.5,   9.4,   6.2,  10.0,   8.6,   8.8,...
   8.1,  10.4,  10.0,   8.6,   9.5,   9.4,   9.1,   9.4,   8.8,...
   7.0,   4.7,   5.7,   6.1,   8.2,    .8,   5.1,   7.0,  10.4,...
   9.4,  10.7,   9.0,   9.0,   8.5,   4.5,   3.5,   1.5,    .0,...
   6.0,   3.4,  10.4,   9.4,   6.0,   6.2,  10.3,   8.5,   3.2,...
   8.8,   7.8,  10.5,   4.9,  11.2,  10.6,  10.2,   9.4,  11.2,...
```

```
10.0,  9.7,  9.0,  6.9, 11.3, 11.3, 10.4,  9.6,  9.2,...
11.0, 10.9,  8.8,  9.1,  9.0, 10.3,  7.8,  9.5, 10.2,...
 7.1,  8.6, 11.0,  8.6,  8.6,  2.9,  8.8,  1.2,  1.1,...
  .4,  2.6,  3.9,  4.2,  8.3,   .0,   .0,  8.9,  9.5,...
10.1,  2.0,   .4,  4.2,  9.9,  7.9, 11.0,  8.5,  6.5,...
 9.0,  7.1,  9.2,  8.4, 10.8,  4.0, 10.1,  9.3,  2.3,...
  .0,  1.0,  9.9, 10.0,   .0,   .0,  2.5,  6.8,  8.7,...
 9.0,  6.3,  4.0,  5.6,  6.1,  7.7,  7.0,  7.3,   .5,...
 3.6,  5.4,  9.4, 10.4,  7.8, 10.9,  6.9, 10.6,  8.1,...
 8.9,  5.8,  2.5,  6.8,  7.9,  7.6, 10.1, 10.4, 10.3,...
 4.8,  1.5,  7.2,  9.2,  9.7,  8.5,  7.3,  3.2,  2.2,...
 4.3,  9.8,  1.6,  9.4,  8.3,  5.4,  5.5, 10.4, 10.3,...
 8.0,  9.8,  4.6,   .2,  2.4,  5.3,  7.2, 10.0,  7.6,...
 9.6,  9.9,  8.3,  8.9, 10.0,  9.5, 10.3,  9.3,  9.4,...
 7.4, 10.5,  7.0,  6.6, 10.3, 10.0, 10.1,  9.6, 10.2,...
10.1,  8.8,  1.3,  1.0,   .0,   .0,   .0,   .0,   .6,...
  .2,   .0,  4.6,  9.9,  7.6,  9.8,   .2, 10.2,  6.6,...
 5.4, 10.6, 10.5, 10.5, 10.5, 10.6,  9.1, 10.2,  5.8,...
 8.6,  7.4, 10.5, 10.4, 10.1,  7.5,  4.8,  2.0,  9.6,...
 9.1,  9.9,  9.7,  9.2,  9.7,  7.8, 10.3,  8.4,  7.5,...
 9.7, 10.2,  6.6,  6.7, 10.0, 10.1,  9.9, 10.3,  9.4,...
 9.6, 10.0, 10.2,  9.9, 10.2, 10.0

*********************************************************
* Thiyagarajan, Tamil Nadu, India
* 1988-1989
* variety:   ADT 39
* treatment: 0 KG/HA
*********************************************************
TITLE THIYAGARAJAN, 0 KG N/HA

PARAM SWIPAR = 0
PARAM SWILAI = 4
PARAM SWINUP = 1
PARAM SWISIN = 1
PARAM SWINPH = 0
PARAM SWINPR = 1
PARAM SWIRES = 1
PARAM SWIMEA = 1

PARAM DOYS   = 344.0
PARAM IDOYTR = 344
PARAM FGHDAY = 63.0

INCON WLVGI  = 47.0
INCON WSTSI  = 38.0
INCON WRTLI  = 19.0

PARAM FNSTI  = 0.0168
PARAM FNLVI  = 0.0315
PARAM FNRTI  = 0.0034

PARAM DVSI   = 0.531
PARAM TSI    = 676.9

PARAM FSTR   = 0.39
PARAM DVRV   = 0.000784
PARAM DVRR   = 0.001674

PARAM NA = 5
TABLE DNAPT(1- 5)  = 344.,370.,392.,406.,600.
PARAM NS = 11
TABLE DNOST(1-11)  = 344.,362.,369.,376.,383.,390.,397.,407.,425.,...
                     433.,441.
TABLE NTOTMT(1-11) = 2.18,13.90,16.98,28.14,37.87,41.69,...
                     43.51,41.78,52.48,54.87,54.87

* NOTE first value of NSO is dummy
*      first two values of WSO are dummy's
*      last value of W/NLV, W/NST, W/NRT, W/NSO are dummy's
FUNCTION XWSTS =( 0,  38),(18, 420),(25, 715),(32,1165),(39,1673),...
                (46,2115),(53,2630),(63,2146),(81,1883),(89,1615)
FUNCTION XWLVGT=( 0,  47),(18, 286),(25, 469),(32, 715),(39, 828),...
                (46, 943),(53, 936),(63, 840),(81, 792),(89, 767)
FUNCTION XWRTLT=( 0,  19),(18, 260),(25, 326),(32, 370),(39, 421),...
                (46, 463),(53, 482),(63, 537),(81, 530),(89, 530)
FUNCTION XWSOTB=( 0,   0),(43,   0),(63,1317),(81,2803),(89,3456)

FUNCTION XNST  =( 0,1.68),(18,1.38),(25,0.83),(32,0.97),(39,1.03 ),...
                (46,0.94),(53,0.99),(63,0.64),(81,0.53),(89,0.48)
FUNCTION XNLV  =( 0,3.25),(18,2.35),(25,2.00),(32,2.07),(39,2.07),...
                (46,1.93),(53,1.45),(63,1.10),(81,0.97),(89,0.70)
FUNCTION XNRT  =( 0,0.34),(18,0.53),(25,0.51),(32,0.55),(39,0.83),...
                (46,0.78),(53,0.81),(63,0.78),(81,0.70),(89,0.64)
FUNCTION XNSO  =( 0,1.11),(97,1.11)

* value at 2.0 is dummy
FUNCTION FSTT =(0.,0.62),...
               (0.50,0.62),(0.65,0.62),(0.73,0.65),(0.81,0.82),...
               (0.89,0.79),(1.00,0.00),(1.14,0.00),...
               (1.52,0.00),(1.90,0.00),(2.1,0.)
FUNCTION FLVT =(0.,0.38),...
               (0.50,0.38),(0.65,0.38),(0.73,0.35),(0.81,0.18),...
               (0.89,0.21),(1.00,0.00),(1.14,0.00),...
               (1.52,0.00),(1.90,0.00),(2.1,0.)
FUNCTION FSOT =(0.,0.00),...
               (0.50,0.00),(0.65,0.00),(0.73,0.00),(0.81,0.00),...
               (0.89,0.00),(1.00,1.00),(1.14,1.00),(1.52,1.00),...
               (1.90,1.00),(2.1,1. )
FUNCTION FSHT =(0.,0.72),...
               (0.50,0.72),(0.65,0.88),(0.73,0.94),(0.81,0.92),...
               (0.89,0.93),(0.97,0.96),(1.14,0.93),(1.52,1.00),...
               (1.90,1.00),(2.1,0.)

END

*********************************************************
* Thiyagarajan, Tamil Nadu, India
* 1988-1989
* variety:   ADT 39
* treatment: 400 KG/HA
*********************************************************
TITLE THIYAGARAJAN, 400 KG N/HA


PARAM FSTR  =0.30

PARAM DVRV  = 0.000716
PARAM DVRR  = 0.001582

PARAM DVSI  = 0.485

PARAM NS = 10
TABLE DNCST(1-10) =344.,362.,369.,376.,383.,390.,397.,407.,425.,441.
TABLE NTOTMT(1-10)=2.18,49.64,110.56,159.91,201.37,212.66,246.23,...
                   303.82,277.76,212.78

FUNCTION XWSTTB=( 0,  38),(18, 718),(25,1612),(32,2650),(39,3855),...
                (46,4627),(53,5736),(63,6619),(81,5021),(97,4556)
FUNCTION XWLVGT=( 0,  47),(18, 652),(25,1438),(32,2500),(39,3325),...
                (46,4009),(53,4707),(63,5624),(81,4285),(97,3208)
FUNCTION XWRTLT=( 0,  19),(18, 521),(25, 775),(32,1030),(39,1250),...
                (46,1525),(53,1750),(63,2003),(81,1968),(97,1968)
FUNCTION XWSOTB=( 0,   0),(51,   0),(63,1426),(81,5365),(97,6337)

FUNCTION XNST  =( 0,1.68),(18,2.41),(25,2.67),(32,2.07),(39,1.76),...
                (46,1.62),(53,1.60),(63,1.48),(81,1.29),(97,1.06)
FUNCTION XNLV  =( 0,3.15),(18,4.00),(25,4.16),(32,3.65),(39,3.38),...
```

```
                 (46,2.83),(53,2.72),(63,2.72),(81,2.24),(97,0.98)
FUNCTION XNRT  =( 0,0.34),(18,1.20),(25,1.03),(32,1.34),(39,1.68),...
                 (46,1.59),(53,1.51),(63,1.38),(81,1.12),(97,1.06)
FUNCTION XNSO  =( 0,1.77),(97,1.77)

* NOTE the first values of the functions are dummy's
*      the values at 2.1 are dummy's
FUNCTION FSTT  =(0.,0.53),...
                 (0.46,0.53),(0.60,0.53),(0.68,0.49),(0.75,0.59),...
                 (0.82,0.53),(0.89,0.61),(1.00,0.00),...
                 (1.30,0.00),(1.77,0.00),(2.10,0.00)
FUNCTION FLVT  =(0.,0.47),...
                 (0.46,0.47),(0.60,0.47),(0.68,0.51),(0.75,0.41),...
                 (0.82,0.47),(0.89,0.39),(1.00,0.00),(1.30,0.00),...
                 (1.77,0.00),(2.10,0.00)
FUNCTION FSOTB =(0.,0.00),...
                 (0.46,0.00),(0.60,0.00),(0.68,0.00),(0.75,0.00),...
                 (0.82,0.00),(0.89,0.00),(1.00,1.00),(1.30,1.00),...
                 (1.77,1.00),(2.10,1.00)
FUNCTION FSHT  =(0.,0.72),...
                 (0.46,0.72),(0.60,0.87),(0.68,0.89),(0.75,0.90),...
                 (0.82,0.84),(0.89,0.89),(0.98,0.93),(1.30,1.00),...
                 (1.77,1.00),(2.10,0.00)

END

STOP
```

```
*--------------------------------------------------------------------*
* SUBROUTINE SNDEM                                                   *
*                                                                    *
* Authors:
* Date   :
* Version:
*                                                                    *
* Purpose: This subroutine calculates the nitrogen demand of the     *
*          leaves, stems, roots and grains                           *
*                                                                    *
* FORMAL PARAMETERS:(I=input,O=output,C=control,IN=init,T=time)      *
* name   type meaning                                  units  class *
* ----   ---- -------                                  -----  ----- *
* ANLV    R4  Amount of N (nitrogen) in the leaves     kg/ha    I   *
* ANST    R4  Amount of N (nitrogen) in the stems      kg/ha    I   *
* ANRT    R4  Amount of N (nitrogen) in the roots      kg/ha    I   *
* ANSO    R4  Amount of N (nitrogen) in the grains     kg/ha    I   *
* NMAXL   R4  Maximum N (nitrogen) concentration                    *
*             in leaves                                kg/kg    I   *
* NMAXS   R4  Maximum N (nitrogen) concentration                    *
*             in stems                                 kg/kg    I   *
* NMAXR   R4  Maximum N (nitrogen) concentration                    *
*             in roots                                 kg/kg    I   *
* NMAXSO  R4  Maximum N (nitrogen) concentration                    *
*             in storage organs                        kg/kg    I   *
* TCNA    R4  Time coefficient for N acquisition         d      I   *
* WLVG    R4  Weight of the leaves                     kg/ha    I   *
* WSTS    R4  Weight of the stems                      kg/ha    I   *
* WRTL    R4  Weight of the roots                      kg/ha    I   *
* WSO     R4  Weight of the storage organs             kg/ha    I   *
* NDEML   R4  N (nitrogen) demand of leaves            kg/ha/d  O   *
* NDEMS   R4  N (nitrogen) demand of stems             kg/ha/d  O   *
* NDEMR   R4  N (nitrogen) demand of roots             kg/ha/d  O   *
* NDEMG   R4  N (nitrogen) demand of grains            kg/ha/d  O   *
* NDEMV   R4  N (nitrogen) demandof leaves plus                     *
*             stems and roots                          kg/ha/d  O   *
* NDEMT   R4  Total N (nitrogen) demand of crop        kg/ha/d  O   *
*                                                                    *
* SUBROUTINES called : none                                          *
*                                                                    *
* FUNCTIONS   called : none                                          *
*                                                                    *
* FILE usage         : none                                          *
*--------------------------------------------------------------------*

      SUBROUTINE SNDEM(ANLV,ANST,ANRT,ANSO,NMAXL,NMAXS,NMAXR,NMAXSO,
     $                 TCNA,WLVG,WSTS,WRTL,WSO,
     $                 NDEML,NDEMS,NDEMR,NDEMG,NDEMV,NDEMT)

      IMPLICIT REAL(A-Z)

*** N-demand of various organs

      NDEML  = (NMAXL*WLVG - ANLV)/TCNA
      NDEMS  = (NMAXS*WSTS - ANST)/TCNA
      NDEMR  = (NMAXR*WRTL - ANRT)/TCNA

      IF(WSO.LT.10.) THEN
         NDEMG=0.
      ELSE
         NDEMG=AMAX1(0.,(NMAXSO*WSO-ANSO)/TCNA)
      ENDIF
      NDEMV  = NDEML + NDEMS + NDEMR
      NDEMT  = NDEMV + NDEMG

      RETURN
      END
```

```
*--------------------------------------------------------------------*
* SUBROUTINE SNALLC                                                  *
*                                                                    *
* Authors:
* Date   :
* Version:
*                                                                    *
* Purpose: This subroutine calculates:                               *
*          1. the fraction of nitrogen in leaf, stem, root and       *
*             storage organs                                         *
*          2. the N (nitrogen) acquisition rate by plant organs      *
*                                                                    *
* FORMAL PARAMETERS:(I=input,O=output,C=control,IN=init,T=time)      *
* name   type meaning                                  units  class *
* ----   ---- -------                                  -----  ----- *
* SWINUP  R4  Switch for choosing N (nitrogen) input      -     I   *
* ANLV    R4  Amount of N (nitrogen) in the leaves     kg/ha    I   *
* ANST    R4  Amount of N (nitrogen) in the stems      kg/ha    I   *
* ANRT    R4  Amount of N (nitrogen) in the roots      kg/ha    I   *
* ANSO    R4  Amount of N (nitrogen) in the grains     kg/ha    I   *
* WLVG    R4  Weight of the leaves                     kg/ha    I   *
* WSTT    R4  Weight of the stemsplus shielded reserves kg/ha   I   *
* WRTL    R4  Weight of the roots                      kg/ha    I   *
* WSO     R4  Weight of the storage organs             kg/ha    I   *
* NDEMV   R4  N (nitrogen) demandof leaves plus                     *
*             stems and roots                          kg/ha/d  I   *
* NDEML   R4  N (nitrogen) demand of leaves            kg/ha/d  I   *
* NDEMS   R4  N (nitrogen) demand of stems             kg/ha/d  I   *
* NDEMR   R4  N (nitrogen) demand of roots             kg/ha/d  I   *
* NUPT    R4  N (nitrogen) uptake rate by crop         kg/ha/d  I   *
* GLV     R4  Growth rate (dry matter) of the leaves   kg/ha/d  I   *
* GSTS    R4  Growth rate (dry matter) of the stems    kg/ha/d  I   *
* GRT     R4  Growth rate (dry matter) of the roots    kg/ha/d  I   *
* NMAXL   R4  Maximum N concentration in leaves        kg/kg    I   *
* NMAXS   R4  Maximum N concentration in stems         kg/kg    I   *
* NMAXR   R4  Maximum N concentration in roots         kg/kg    I   *
* NALV    R4  N (nitrogen) acquisition by leaves       kg/ha/d  O   *
* NAST    R4  N (nitrogen) acquisition by stems        kg/ha/d  O   *
* NART    R4  N (nitrogen) acquisition by roots        kg/ha/d  O   *
*                                                                    *
```

```
*  SUBROUTINES called : none                                      *
*                                                                 *
*  FUNCTIONS   called : none                                      *
*                                                                 *
*  FILE usage         : none                                      *
*-----------------------------------------------------------------*

      SUBROUTINE SNALLC(SWINUP,ANLV,ANST,ANRT,ANSO,WLVG,WSTT,WRTL,WSO,
     $                  NDEMV,NDEML,NDEMS,NDEMR,NUPT,
     $                  GLV,GSTS,GRT,NMAXL,NMAXS,NMAXR,
     $                  NALV,NAST,NART)
      IMPLICIT REAL(A-Z)
      INTEGER SWINUP
      DATA TINY/1.E-10/

*     N contents live plant organs
      FNLV   = ANLV/(WLVG+TINY)
      FNST   = ANST/(WSTT+TINY)
      FNRT   = ANRT/(WRTL+TINY)
      FNSO   = ANSO/(WSO+TINY)

*     N acquisition rate by plant organs
      IF(SWINUP.EQ.1) THEN
*      uptake is a measured forcing function
       POSDEM=AMAX1(0.,NDEML)+AMAX1(0.,NDEMR)+AMAX1(0.,NDEMS)
       NEGDEM=-(AMIN1(0.,NDEML)+AMIN1(0.,NDEMR)+AMIN1(0.,NDEMS))
*      avail is the net pool of N available for allocation on each day
       AVAIL = NEGDEM+NUPT
       IF(NUPT.GE.0.) THEN
*         note: any of the organ demands can be pos or neg
*         total crop uptake was not demand related but forced
          IF(NDEMR.GT.0.) NART=AMIN1(NDEMR,AVAIL*(NDEMR/(POSDEM+TINY)))
          IF(NDEMR.LE.0.) NART=NDEMR
          IF(NDEMS.GT.0.) NAST=AMIN1(NDEMS,AVAIL*(NDEMS/(POSDEM+TINY)))
          IF(NDEMS.LE.0.) NAST=NDEMS
*         excess stored in leaf mass only:
          NALV=NUPT-NART-NAST
       ELSE
*         nitrogen extraction by forced negative uptake
*         this has signal function only; death rate of leaves and roots
*         should be increased
          NALV= ANLV/(ANLV+ANST+ANRT)*NUPT
          NAST= ANST/(ANLV+ANST+ANRT)*NUPT
          NART= ANRT/(ANLV+ANST+ANRT)*NUPT
          IF(NALV.LT.-ANLV) STOP
          IF(NAST.LT.-ANST) STOP
          IF(NART.LT.-ANRT) STOP
       ENDIF

      ELSEIF(SWINUP.EQ.2) THEN
*       pot. prod.;
       NALV  = NDEML+GLV*NMAXL
       NART  = NDEMR+GRT*NMAXR
       NAST  = NDEMS+GSTS*NMAXS
      ENDIF


      RETURN
      END


*-----------------------------------------------------------------*
*  SUBROUTINE SNSUPG                                              *
*                                                                 *
*  Authors:
*  Date   :
*  Version:
*                                                                 *
*  Purpose: This subroutine calculates N (nitrogen) supply to the *
*           grains based upon the amount of translocatable N(nitrogen)*
*           from the leaves, stems and roots.                     *
*                                                                 *
*  FORMAL PARAMETERS:(I=input,O=output,C=control,IN=init,T=time)  *
*  name   type meaning                                units  class *
*  ----   ---- -------                                -----  ----- *
*  ANLV    R4  Amount of N (nitrogen) in the leaves    kg/ha    I   *
*  ANST    R4  Amount of N (nitrogen) in the stems     kg/ha    I   *
*  ANRT    R4  Amount of N (nitrogen) in the roots     kg/ha    I   *
*  WLVG    R4  Weight of the leaves                    kg/ha    I   *
*  WSTS    R4  Weight of the stems                     kg/ha    I   *
*  WRTL    R4  Weight of the roots                     kg/ha    I   *
*  WSO     R4  Weight of the storage organs            kg/ha    I   *
*  RFNLV   R4  Residual N (nitrogen) fraction of leaves kg/kg   I   *
*  RFNST   R4  Residual N (nitrogen) fraction of stems  kg/kg   I   *
*  RFNRT   R4  Residual N (nitrogen) fraction of roots  kg/kg   I   *
*  TCNT    R4  Time coefficient for N (nitrogen)                    *
*              translocation                               d    I   *
*  LLV     R4  Rate of loss of leaf weight (dry matter) kg/ha/d I   *
*  FNLV    R4  Fraction of N (nitrogen) in leaves          -    I   *
*  TEFG    R4  Relation of temperature to growth rate               *
*              of grains                                   -    I   *
*  NDEMG   R4  N (nitrogen) demand of grains           kg/ha/d  I   *
*  DVS     R4  Phenological development stage crop         -    I   *
*  NTLV    R4  N (nitrogen) translocated from leaves   kg/ha/d  O   *
*  NTST    R4  N (nitrogen) translocated from stems    kg/ha/d  O   *
*  NTRT    R4  N (nitrogen) translocated from roots    kg/ha/d  O   *
*  NSUPG   R4  Rate of N (nitrogen) supply to grains   kg/ha/d  O   *
*                                                                 *
*  SUBROUTINES called : none                                      *
*                                                                 *
*  FUNCTIONS   called : none                                      *
*                                                                 *
*  FILE usage         : none                                      *
*-----------------------------------------------------------------*

      SUBROUTINE SNSUPG(ANLV,ANST,ANRT,WLVG,WSTS,WRTL,WSO,RFNLV,RFNST,
     $                  RFNRT,TCNT,LLV,FNLV,TEFG,NDEMG,
     $                  NTLV,NTST,NTRT,NSUPG)
      IMPLICIT REAL(A-Z)

*     N supply to grains based upon the amount of translocatable N

*     rate of translocation from dead leaves, in kg/ha/d
*     old L3c by Mishra contained different set of assumptions on N
*     mobilization from dead leaves

*     potential rate (temperature-corrected) of N translocation
*     from organs, in kg/ha/d

      ATNLV  = AMAX1(0.,TEFG*(ANLV - WLVG*RFNLV)/TCNT)
      ATNST  = AMAX1(0.,TEFG*(ANST - WSTS*RFNST)/TCNT)
      ATNRT  = AMAX1(0.,TEFG*(ANRT - WRTL*RFNRT)/TCNT)
      ATN    = ATNLV+ATNST+ATNRT

*     actual N supply rates by plant organs, in kg/ha/d

      IF (WSO.LT.10.) THEN
         NTLV=0.
         NTST=0.
         NTRT=0.
      ELSEIF(ATN.GE.NDEMG) THEN
*        conversion potential to actual translocation
         NTLV  = NDEMG*ATNLV/ATN
         NTST  = NDEMG*ATNST/ATN
         NTRT  = NDEMG*ATNRT/ATN
      ELSE
         NTLV  = ATNLV
```

```
      NTST  = ATNST
      NTRT  = ATNRT
   ENDIF

*  actual N supply to grains by translocation
   NSUPG=NTLV+NTST+NTRT
   RETURN
   END


*----------------------------------------------------------------*
* SUBROUTINE SUNUPT                                              *
*                                                                *
* Authors:
* Date   :
* Version:
*                                                                *
* Purpose: This subroutine calculates the daily N (nitrogen) uptake *
*          from an observation set given in kg N/ha in live biomass *
*          at sampling dates.                                    *
*                                                                *
* FORMAL PARAMETERS:(I=input,O=output,C=control,IN=init,T=time)  *
* name   type meaning                              units  class *
* ----   ---- -------                              -----  ----- *
* SWIYR  I4  Initialization time switch for experiment          *
*            across january 1                        -      I   *
* DOY    R4  Julian date                             d      I   *
* DOYB   R4  Julian date at beginning of simulation  d      I   *
* ANTOT  R4  Total amount of N (nitrogen) in the crop kg/ha I   *
* ANLCR  R4  Amount of N (nitrogen) in the crop (live) kg/ha I  *
* NS     I4  number of sampling dates for total                 *
*            N (nitrogen) in the crop                -      I   *
* NA     I4  Number of N (nitrogen) applications dates -    I   *
* NTOTMT R4  Tabulated total N (nitrogen) measured   kg/ha  I   *
* DNOST  R4  Table of julian dates at which NTOTMT              *
*            was measured                            -      I   *
* DNAPT  R4  Daynumberof N (nitrogen) applications   d      I   *
* CRDN   R4  Critical daynumber which affects the rate          *
*            at which uptake declines after                     *
*            N (nitrogen) application                -      I   *
* F1     R4  Leaf area fraction in 0-30 and 30-60               *
*            degree leaf angle classes for layes 1 to 5 -   O   *
* NUPT   R4  N (nitrogen) uptake rate by crop        kg/ha/d O  *
* DNAP   R4  Daynumber of nitrogen applications      -      O   *
* DNOS   R4  Daynumber of crop sampling for N(nitrogen) -   O   *
* NTOTM  R4  Total N (nitrogen) in crop measured     kg/ha  O   *
* DATEX  R4  Dummy for printing only                 -      O   *
*                                                                *
* SUBROUTINES called : none                                      *
*                                                                *
* FUNCTIONS   called : none                                      *
*                                                                *
* FILE usage         : none                                      *
*----------------------------------------------------------------*

      SUBROUTINE SUNUPT(SWIYR,DOY,DOYS,ANLCR,NS,NA,
     $                  NTOTMT,DNOST,DNAPT,CRDN,F1,NUPT,DNAP,
     $                  DNOS,NTOTM,DATEX)
*     subroutine calculates daily N uptake from observation set
*     given in kg N /ha in live biomass at sampling dates

      REAL DOY,NTOTMT(15),DNOST(15),DNAPT(5),CRDN,F1,NUPT
      REAL DSLA,NTOTM,ANLCR,DNOS,DNAP,NUPTX
      INTEGER NA,NS,I,SWIYR

*     identification of next target sampling date to match
*     'simulated' with measured uptake
      DATEX=DOY+SWIYR*365.
      DO 888 I=1,NS
         IF(DATEX.GE.DNOST(I)) THEN
            CONTINUE
         ELSE
            NTOTM=NTOTMT(I)
            DNOS=DNOST(I)
            GOTO 999
         ENDIF
888   CONTINUE
999   CONTINUE

      DO 222 I=1,NA
         IF(ABS(DATEX-DOYS).LT.0.1) THEN
            DNAP=DOYS
            DSLA=1.
            GOTO 333
         ELSEIF(DATEX.GT.DNAPT(I)) THEN
            CONTINUE
         ELSE
            DNAP=DNAPT(I-1)
            DSLA=DATEX-DNAP
            GOTO 333
         ENDIF
222   CONTINUE
333   CONTINUE

      IF(DSLA.LE.CRDN) THEN
         F1= 1.* SQRT(CRDN/AMIN1(1.,DSLA))
      ELSE
         F1=1.
      ENDIF

      IF(DATEX.GE.DNOST(NS)) THEN
        NUPT=0.
      ELSE
        IF(NTOTM.GT.ANLCR) NUPT=AMIN1(NTOTM-ANLCR,
     $                            F1*(NTOTM-ANLCR)/(DNOS-DATEX))
        IF(NTOTM.LE.ANLCR) NUPT=AMAX1(NTOTM-ANLCR,
     $                            (NTOTM-ANLCR)/(DNOS-DATEX))
      ENDIF
      RETURN
      END



      FUNCTION FUNCHK(CKNIN,CKNFL,TIME)
* check on crop nitrogen balance.
* ten Berge, August 1992
      FUNCHK=2.0*(CKNIN-CKNFL)/(CKNIN+CKNFL+1.E-10)
      IF(ABS(FUNCHK).GT.0.01) THEN
       WRITE(6,10) FUNCHK, CKNIN,CKNFL,TIME
10     FORMAT(/'*** ERROR IN NITROGEN BALANCE, PLS CHECK***',/,
     $ ' CKNRD=',F6.3,' CKNIN=',F8.2,' CKNFL=',F8.2,' AT TIME=',
     $ F6.1)
      ENDIF
      RETURN
      END

*----------------------------------------------------------------*
* SUBROUTINE ASTRO                                               *
* Purpose: This subroutine calculates astronomic daylength,      *
*          diurnal radiation characteristics such as the daily   *
*          integral of sine of solar elevation and solar constant. *
*                                                                *
* FORMAL PARAMETERS:  (I=input,O=output,C=control,IN=init,T=time) *
* name   type meaning                              units  class *
* ----   ---- -------                              -----  ----- *
* DOY    R4  Daynumber (Jan 1st = 1)                -      I    *
* LAT    R4  Latitude of the site                degrees   I    *
```

```
*  SC        R4  Solar constant                              J m-2 s-1 O  *
*  DS0       R4  Daily extraterrestrial radiation            J m-2 d-1 O  *
*  SINLD     R4  Seasonal offset of sine of solar height        -      O  *
*  COSLD     R4  Amplitude of sine of solar height              -      O  *
*  DAYL      R4  Astronomic daylength (base = 0 degrees)        h      O  *
*  DSINB     R4  Daily total of sine of solar height            s      O  *
*  DSINBE    R4  Daily total of effective solar height          s      O  *
*                                                                         *
*  FATAL ERROR CHECKS (execution terminated, message)                     *
*  condition: LAT > 67, LAT < -67                                         *
*                                                                         *
*  FILE usage : none                                                      *
*-------------------------------------------------------------------------*

      SUBROUTINE ASTRO (DOY, LAT,
     &                  SC , DS0, SINLD, COSLD, DAYL, DSINB, DSINBE)
      IMPLICIT REAL (A-Z)

*-----PI and conversion factor from degrees to radians
      PI    = 3.141592654
      RAD   = PI/180.

*-----check on input range of parameters
      IF (LAT.GT.67.)  STOP 'ERROR IN ASTRO: LAT> 67'
      IF (LAT.LT.-67.) STOP 'ERROR IN ASTRO: LAT>-67'

*-----declination of the sun as function of daynumber (DOY)
      DEC   = -ASIN (SIN (23.45*RAD)*COS (2.*PI*(DOY+10.)/365.))

*-----SINLD, COSLD and AOB are intermediate variables

      SINLD = SIN (RAD*LAT)*SIN (DEC)
      COSLD = COS (RAD*LAT)*COS (DEC)
      AOB   = SINLD/COSLD

*-----daylength (DAYL)
      DAYL   = 12.0*(1.+2.*ASIN (AOB)/PI)

      DSINB  = 3600.*(DAYL*SINLD+24.*COSLD*SQRT (1.-AOB*AOB)/PI)
      DSINBE = 3600.*(DAYL*(SINLD+0.4*(SINLD*SINLD+COSLD*COSLD*0.5))+
     &         12.0*COSLD*(2.0+3.0*0.4*SINLD)*SQRT (1.-AOB*AOB)/PI)

*-----solar constant (SC) and daily extraterrestrial radiation (DS0)
      SC  = 1370.*(1.+0.033*COS (2.*PI*DOY/365.))
      DS0 = SC*DSINB

      RETURN
      END


*-------------------------------------------------------------------------*
*  SUBROUTINE TOTASN                                                      *
*  Purpose: This subroutine calculates daily total gross                  *
*           assimilation (DTGA) by performing a Gaussian integration      *
*           over time. At three different times of the day,               *
*           radiation is computed and used to determine assimilation      *
*           whereafter integration takes place.                           *
*                                                                         *
*  FORMAL PARAMETERS:  (I=input,O=output,C=control,IN=init,T=time)        *
*  name   type meaning                                      units  class  *
*  ----   ---- -------                                      -----  -----  *
*  DOY     R4  Daynumber (January 1 = 1)                       -      I   *
*  LAT     R4  Latitude of the site                         degrees   I   *
*  DTR     R4  Daily total of global radiation              J/m2/d    I   *
*  SCP     R4  Scattering coefficient of leaves for visible               *
*              radiation (PAR)                                 -      I   *
*  EFF     R4  Initial light use efficiency                 kg CO2/J/ I   *
*                                                           ha/h m2 s     *
*  KDF     R4  Extinction coefficient for diffuse light               I   *
*  LAI     R4  Leaf area index                                ha/ha   I   *
*  KDIFN   R4  Extinction coefficient for N in canopy           -     I   *
*  ANLV    R4  Amount of N in the leaves                      kg/ha   I   *
*  ALPHAN  R4  Slope of AMAX versus NPA                   kg CO2/ha/h I   *
*  NB      R4  Min N concentration leaf at AMAX=0              g/m2   I   *
*  REDFT   R4  Temperature correction for AMAX                  -     I   *
*  AMAX0   R4  Maximum rate of photosynthesis of single  kg/          I   *
*              leaves at top of canopy                   ha leaf/h        *
*  DTGA    R4  Daily total gross Assimilation            kg CO2/ha/d O    *
*                                                                         *
*                                                                         *
*  SUBROUTINES and FUNCTIONS called : ASTRO, ASSIM                        *
*  FILE usage : none                                                      *
*-------------------------------------------------------------------------*

      SUBROUTINE TOTASN (DOY,  LAT , DTR, SCP, EFF, KDF, LAI,
     &                   KDIFN, ANLV, ALPHAN, NB, REDFT,
     &                   AMAX0, DTGA)
      IMPLICIT REAL(A-Z)
      REAL XGAUSS(3), WGAUSS(3)
      INTEGER I1, IGAUSS

      DATA IGAUSS /3/, TINY /0.01/
      DATA XGAUSS /0.112702, 0.500000, 0.887298/
      DATA WGAUSS /0.277778, 0.444444, 0.277778/

      PI   = 3.141592654

      CALL ASTRO(DOY,LAT,SC,DS0,SINLD,COSLD,DAYL,DSINB,DSINBE)

*-----assimilation set to zero and three different times of the day (HOUR)
      DTGA = 0.

***---L3C specifiek

      NT=(ANLV)*1000./10000.
      IF (KDIFN.GT.TINY) THEN
         AMAX01=ALPHAN*KDIFN*(NT-NB*LAI)/(1.-EXP(-KDIFN*LAI))
      ELSE
         AMAX01=ALPHAN*(NT/LAI-NB)
      ENDIF

      AMAX0=AMAX1(AMIN1(70.,REDFT*AMAX01),1.)


      LAIL  =AMIN1(10.,LAI)

***---einde L3C specifiek

      DO 10 I1=1,IGAUSS

*---------at the specified HOUR, radiation is computed and used to compute
*         assimilation
          HOUR = 12.0+DAYL*0.5*XGAUSS(I1)

*---------sine of solar elevation
          SINB  = AMAX1 (0., SINLD+COSLD*COS (2.*PI*(HOUR+12.)/24.))

*---------diffuse light fraction (FRDF) from atmospheric
*         transmission (ATMTR)
          PAR   = 0.5*DTR*SINB*(1.+0.4*SINB)/DSINBE
          ATMTR = PAR/(0.5*SC*SINB)

          IF (ATMTR.LE.0.22) THEN
             FRDF = 1.
          ELSE IF (ATMTR.GT.0.22 .AND. ATMTR.LE.0.35) THEN
             FRDF = 1.-6.4*(ATMTR-0.22)**2
          ELSE
             FRDF = 1.47-1.66*ATMTR
```

```
      END IF

      FRDF = AMAX1 (FRDF, 0.15+0.85*(1.-EXP (-0.1/SINB)))

*--------diffuse PAR (PARDF) and direct PAR (PARDR)
      PARDF = PAR * FRDF
      PARDR = PAR - PARDF


      CALL ASSIM (SCP, EFF, KDF, LAI, SINB, PARDR, PARDF, KDIFN,
     &            AMAX0, LAIL, FGROS)

*--------integration of assimilation rate to a daily total (DTGA)
      DTGA = DTGA+FGROS*WGAUSS(I1)

10    CONTINUE

      DTGA = DTGA * DAYL

      RETURN
      END


*----------------------------------------------------------------------*
* SUBROUTINE ASSIM                                                     *
* Purpose: This subroutine performs a Gaussian integration over        *
*          depth of canopy by selecting three different LAI's and      *
*          computing assimilation at these LAI levels. The             *
*          integrated variable is FGROS.                               *
*                                                                      *
* FORMAL PARAMETERS:  (I=input,O=output,C=control,IN=init,T=time)      *
* name   type meaning                                    units  class *
* ----   ---- -------                                    -----  ----- *
* SCP     R4  Scattering coefficient of leaves for visible            *
*             radiation (PAR)                              -       I  *
* EFF     R4  Initial light use efficiency          kg CO2/J/     I  *
*                                                    ha/h m2 s       *
* KDF     R4  Extinction coefficient for diffuse light             I  *
* LAI     R4  Leaf area index                          ha/ha      I  *
* SINB    R4  Sine of solar height                       -        I  *
* PARDR   R4  Instantaneous flux of direct radiation (PAR) W/m2   I  *
* PARDF   R4  Instantaneous flux of diffuse radiation(PAR) W/m2   I  *
* KDIFN   R4  Extinction coefficient for N in canopy     -        I  *
* AMAX0   R4  Maximum rate of photosynthesis of single  kg/       I  *
*             leaves at top of canopy                ha leaf/h        *
* LAIL    R4  Leaf area index, with maximum of 10       ha/ha     I  *
* FGROS   R4  Instantaneous assimilation rate of        kg CO2/   O  *
*             whole canopy                           ha soil/h        *
*                                                                      *
* SUBROUTINES and FUNCTIONS called : none                              *
* FILE usage : none                                                    *
*----------------------------------------------------------------------*

      SUBROUTINE ASSIM (SCP, EFF, KDF, LAI, SINB, PARDR, PARDF, KDIFN,
     &                  AMAX0, LAIL, FGROS)
      IMPLICIT REAL(A-Z)
      REAL XGAUSS(3), WGAUSS(3)
      INTEGER I1, I2, IGAUSS

*-----Gauss weights for three point Gauss
      DATA IGAUSS /3/
      DATA XGAUSS /0.112702, 0.500000, 0.887298/
      DATA WGAUSS /0.277778, 0.444444, 0.277778/

*-----reflection of horizontal and spherical leaf angle distribution
      SQV  = SQRT(1.-SCP)
      REFH = (1.-SQV)/(1.+SQV)
      REFS = REFH*2./(1.+2.*SINB)

*-----extinction coefficient for direct radiation and total direct flux
      CLUSTF = KDF / (0.8*SQV)
      KBL    = (0.5/SINB) * CLUSTF
      KDRT   = KBL * SQV

*-----selection of depth of canopy, canopy assimilation is set to zero
      FGROS = 0.

      DO 10 I1=1,IGAUSS

***---LJC specifiek
        LAIC = LAI * XGAUSS(I1)
        AMAX = AMAX0*EXP(-KDIFN*LAIC)

*--------absorbed fluxes per unit leaf area: diffuse flux, total direct
*        flux, direct component of direct flux.
         VISDF = (1.-REFH)*PARDF*KDF  *EXP (-KDF  *LAIC)
         VIST  = (1.-REFS)*PARDR*KDRT *EXP (-KDRT *LAIC)
         VISD  = (1.-SCP) *PARDR*KBL  *EXP (-KBL  *LAIC)

*--------absorbed flux (J/M2 leaf/s) for shaded leaves and assimilation of
*        shaded leaves
         VISSHD = VISDF + VIST - VISD
         IF (AMAX.GT.0.) THEN
           FGRSH  = AMAX * (1.-EXP(-VISSHD*EFF/AMAX))
         ELSE
           FGRSH = 0.
         END IF

*--------direct flux absorbed by leaves perpendicular on direct beam and
*        assimilation of sunlit leaf area

         VISPP  = (1.-SCP) * PARDR / SINB
         FGRSUN = 0.
         DO 20 I2=1,IGAUSS
           VISSUN = VISSHD + VISPP * XGAUSS(I2)
           IF (AMAX.GT.0.) THEN
             FGRS = AMAX * (1.-EXP(-VISSUN*EFF/AMAX))
           ELSE
             FGRS = 0.
           END IF
           FGRSUN = FGRSUN + FGRS * WGAUSS(I2)
20       CONTINUE

*--------fraction sunlit leaf area (FSLLA) and local assimilation
*        rate (FGL)
         FSLLA = CLUSTF * EXP(-KBL*LAIC)
         FGL   = FSLLA  * FGRSUN + (1.-FSLLA) * FGRSH

*--------integration of local assimilation rate to canopy
*        assimilation (FGROS)
         FGROS = FGROS + FGL * WGAUSS(I1)

10    CONTINUE
      FGROS = FGROS * LAI

      RETURN
      END


*----------------------------------------------------------------------*
* SUBROUTINE SLLOSS                                                    *
*                                                                      *
* Authors:
```

```
* Date    :
* Version:
*                                                                    *
* Purpose: This subroutine computes the relative death rates of      *
*          leaves and roots depending on N (nitrogen) concentration  *
*          in the leaves and leaf area.                              *
*                                                                    *
* FORMAL PARAMETERS:(I=input,O=output,C=control,IN=init,T=time)      *
* name    type meaning                                 units  class *
* ----    ---- -------                                 -----  ----- *
* FNLV    R4   Fraction of N (nitrogen) in leaves        -      I   *
* NMINL   R4   Maximum N (nitrogen) in leaves          kg/kg    I   *
* RDR     R4   Relative death rate root and leaf        1/d     I   *
* LAI     R4   Leaf area index                           -      I   *
* LAIREF  R4   Leaf area index reference                 -      I   *
* RLRLV   R4   Relative loss of leaf weight (dry matter) 1/d    O   *
* RLRRT   R4   Relative loss of root weight (dry matter) 1/d    O   *
*                                                                    *
* SUBROUTINES called : none                                          *
*                                                                    *
* FUNCTIONS   called : none                                          *
*                                                                    *
* FILE usage         : none                                          *
*--------------------------------------------------------------------*

      SUBROUTINE SLLOSS(FNLV,NMINL,RDR,LAI,LAIREF,RLRLV,RLRRT)

C computes the relative death rates of leaves and roots,
c depending on N concentration in the leaves and leaf area

      IMPLICIT REAL(A-Z)
      IF (FNLV.LT.1.1*NMINL) THEN
          RDRL = RDR * 5.
        ELSEIF (FNLV.GT.1.5*NMINL) THEN
          RDRL = RDR
        ELSE
          RDRL = (5.-(FNLV-1.1*NMINL)/(0.4*NMINL)*4.)*RDR
      ENDIF
      RLRLV   = (LAI/LAIREF)*RDRL
*      RDRLV=0.
      RLRRT   = RLRLV
      RETURN
      END

ENDJOB
```

Appendix II:
Acronymns used in the ORYZA_N model

Acronym	Explanation	unit
ACTLV	activity coefficient of leaves based on N content	-
ACTRT	activity coefficient of roots based on N content	-
ACTST	activity coefficient of stems based on N content	-
ALPHAN	slope of AMAX versus NPA	kg CO_2 ha^{-1} hr^{-1} (gN m^{-2})
AMAXT	maximum rate of photosynthesis of single leaves (CO_2) at top of canopy	kg $ha^{-1}h^{-1}$
ANCR	amount of N in the crop (live and dead material)	kg ha^{-1}
ANLCR	amount of N in the crop (live material)	kg ha^{-1}
ANLD	amount of N in the dead leaves	kg ha^{-1}
ANLV(I)	amount of N in the leaves (initial)	kg ha^{-1}
ANLVPH	amount of N in the leaves (measured or simulated) used for calculation of the photosynthesis in SUNPHO	kg ha^{-1}
ANRD	amount of N in the dead roots	kg ha^{-1}
ANRT(I)	amount of N in the roots (initial)	kg ha^{-1}
ANSO	amount of N in the storage organs	kg ha^{-1}
ANST(I)	amount of N in the stems (initial)	kg ha^{-1}
ANTOT(I)	total amount of N in the crop (live and dead material) (initial)	kg ha^{-1}
CBCHK	function for carbon balance check	-
CELV	carbohydrate export (glucose, 24 h total) from leaves plus stems, excluding remobilization	kg $ha^{-1}d^{-1}$
CELVN	number of days that CELV is negative	d
CELVNR	rate of change of CELVN	d^{-1}
CKCDIF	difference between carbon added to the crop since initialization and the net total of integrated carbon fluxes, relative to their sum	-
CKCFL	sum of integrated carbon fluxes into and out of the crop	kg ha^{-1}
CKCIN	carbon in the crop accumulated since simulation started	kg ha^{-1}
CKCRD	difference between carbon added to the crop since initialization and the net total of integrated carbon fluxes, relative to their sum	-
CKNFL	sum of integrated N fluxes into and out of the crop	kg ha^{-1}
CKNIN	N in crop accumulated since simulation started	kg ha^{-1}
CKNRD	difference between N added to the crop since initialization and the net total of integrated N fluxes, relative to their sum	-
CNTI	carbohydrates needed to initiate and maintain 1 tiller	kg $ha^{-1}d^{-1}$
CNTIT	relation of CNTI to DVS	-
CO2E	CO_2 concentration ambient air	vppm
CO2LV	growth respiration of leaves	kg CO_2 kg^{-1}DM
CO2RT	growth respiration of roots	kg CO_2 kg^{-1}DM
CO2SO	growth respiration of storage organs	kg CO_2 kg^{-1}DM
CO2ST	growth respiration of stems	kg CO_2 kg^{-1}DM

Acronym	Explanation	unit
CO2STR	growth respiration of shielded reserves	kg CO_2 kg^{-1}DM
CRDN	critical daynumber which affects the rate at which N uptake declines after fertilizer N-application	-
CRG(LV,RT,SO,ST,STR,CR)	weight of carbohydrates required for dry matter growth of leaves (LV), roots (RT), storage organs (SO), stems (STS), shielded reserves (STR), crop (CR)	kg kg^{-1}
DAT	days after transplanting	d
DATEX	dummy for printing	d
DELT	CSMP time period for integration	d
DLA	daylength, astronomical	h
DLP	daylength effective for photoperiodism	h
DNAP	daynumber of nitrogen applications	d
DNAPT	table of nitrogen application dates	-
DNOS	daynumber of crop sampling for nitrogen	
DNOST	table of daynumbers (DOY) at which NTOTMT was measured	-
DOY(S)	day of year=Julian date (at beginning of simulation)	d
DRR	development rate crop in reproductive (R) phase	d^{-1}
DTGA	photosynthesis canopy, gross, in current weather and physiological state, in CO_2	kg $ha^{-1}d^{-1}$
DVR	development rate crop in vegetative (V) phase	d^{-1}
DVRR	development rate crop in reproductive (R) phase	°C d
DVRV	development rate crop in vegetative (V) phase	°C d
DVS(I)	phenological development stage crop (initial)	-
DVSG1,2	DVS when grain formation starts (1), ends (2)	-
DVSGR	variable with value 1.0 during grain formation, else 0.0	-
DVST(1,2)	DVS when tiller formation starts (1), ends (2)	-
DVSTD	switch active during tiller formation	
DVSTF	switch active during tiller formation, and 0.15 DVS units beyond	
EFF	initial light use efficiency for individual leaves	kg CO_2 ha^{-1} h^{-1}(J m^{-2} s^{-1})$^{-1}$
EFFTB	table of EFF as a function of temperature	EFF,°C
ELV	elevation of growth site above sea level	m
F1	leaf area fraction in 0-30 and 30-60 degree leaf angle classes for layers 1 to 5	-
FC(CR,LV,RT,SO,ST,STR)	fraction carbon of total dry mass in the crop (CR), leaves (LV), roots (RT), storage organs (SO) and stems (ST), shielded reserves (STR)	kg kg^{-1}
FGHDAY	first sampling day of storage organs, expressed in days after transplanting	d
FLV	fraction of daily shoot dry matter increment allocated to leaves	-
FLVTB	tabulated FLV as function of DVS or DAT	-
FNLV(I)	fraction of N in leaves (initial)	-
FNRT(I)	fraction of N in roots (initial)	-
FNSO	fraction of N in storage organs	-
FNST(I)	fraction of N in stems (initial)	-
FRT	fraction of daily dry matter increment allocated to roots	-
FSH	fraction of daily dry matter increment allocated to shoots	-

Acronym	Explanation	unit
FSHTB	tabulated FSH as function of DVS or DAT	-
FSO	fraction of daily shoot dry matter increment allocated to storage organs	-
FSOTB	tablulated FSO as function of DVS or DAT	-
FST	fraction of daily shoot dry matter increment allocated to stems including leaf sheaths	-
FSTR	fraction of stem weight at flowering that is remobilizable (shielded reserves)	kg kg^{-1}
FSTTB	tabulated FST as function of DVS or DAT	-
G(CR,LV,RT,SO,STR,STS,SH)	growth rate (dry matter) of the whole crop (CR), leaves (LV), roots (RT), storage organs (SO), shielded reserves (STR, starch), stems (ST) and shoot (SH)	kg $ha^{-1}d^{-1}$
GFP	grain filling period	d
GGRMN	minimal growth rate of one grain	kg d^{-1}
GGRMX	maximal growth rate of one grain	kg d^{-1}
GGRT	tabulated TEFG as function of TPAV	-
GN(GR,TI)	growth of number of florets, grains, tillers	$ha^{-1}d^{-1}$
GSOM	maximum growth rate storage organs	kg $ha^{-1}d^{-1}$
GSTREX	extra growth rate shielded reserves (STR, starch) from	
HI	harvest index (based on above ground dry matter)	kg kg^{-1}
HU	daily heat unit for plant development	(°C d) d^{-1}
HULV	daily heat unit for leaf development	(°C d) d^{-1}
IDOY	integer value of DOY	d
IDOYS	integer value of DOYS	d
IDOYTR	integer value of transplanting day of year	d
KDF	extinction coefficient for diffuse light	-
KDIFN	extinction coefficient for N in canopy	-
KDIFNP	dummy for KDIFN	-
KDIFT	tabulated KDIF as function of ALV	-
LAI(I)	leaf area index (initial)	-
LAIEXP	ALV in exponential growth phase	-
LAILN(T)	tabulated ln(ALV) vs TSLV	-
LAIOLD	leaf area at previous time step	-
LAIREF	Leaf area index reference	-
LAT	latitude (south of equator negative values)	degree
LLV	rate of loss of leaf weight (dry matter)	kg $ha^{-1}d^{-1}$
LNTI	loss of number of tillers	$ha^{-1}d^{-1}$
LRT	rate of loss of root weight (dry matter)	kg $ha^{-1}d^{-1}$
LSTR	loss rate of stem reserves (starch)	kg $ha^{-1}d^{-1}$
MAINLV	maintenance respiration coefficient of leaves	kg CH_2O kg^{-1} DM d^{-1}
MAINRT	maintenance respiration coefficient of roots	kg CH_2O kg^{-1} DM d^{-1}
MAINSO	maintenance respiration coefficient of storage organs	kg CH_2O kg^{-1} DM d^{-1}
MAINST	maintenance respiration coefficient of stems	kg CH_2O kg^{-1} DM d^{-1}
NA	number of N application dates	
NA(LV,RT,ST)	N acquisition by leaves (LV), roots (RT), stem (ST)	kg ha^{-1} d^{-1}
NB	min N concentration leaf at AMAX=0	g m^{-2}

Acronym	Explanation	unit
NBCHK	function for crop N balance check	-
NDEM(G,L,R,S)	N demand of grains (G), leaves (LV)	kg ha^{-1} d^{-1}
NDEMT	total N demand of crop	kg ha^{-1} d^{-1}
NDEMV	N demand of leaves plus stems and roots	kg ha^{-1} d^{-1}
NGR(MX,P)	number of grains (maximum, potential) (module TIL)	ha^{-1}
NLD(LV,RT)	N loss due to death of leaves (LV) and roots (RT)	kg $ha^{-1}d^{-1}$
NLSINT	nitrogen removal translocated from dead leaves and roots	kg ha^{-1}
NMAX(L,R,S,SO)	maximum N fraction in leaves (L), roots (RT), stems (S), storage organs (SO) at given DVS	kg kg^{-1}
NMAX(LT,RT,ST)	relation of NMAX(L,R,S) to DVS	kg kg^{-1}
NMAX(LX,RX,SX)	absolute maximum of NMAX(LT,RT,ST) over whole season	kg kg^{-1}
NMIN(L,R,S,SO)	minimum N concentration in leaves (L), roots (R), stems (S), storage organs (SO) at given DVS	kg kg^{-1}
NMIN(LT,RT.ST)	relation of NMIN(L,R,S) to DVS	
NS	number of sampling dates for total N in the crop	-
NSUPG	rate of N supply to grains	kg ha^{-1} d^{-1}
NT(LV,RT,ST)	N translocated from leaves (LV), roots (RT) and stems (ST)	kg ha^{-1} d^{-1}
NTI	number of tillers, including number of main stems (NTII)	ha^{-1}
NTIP	potential number of tillers (limited by carbohydrates)	ha^{-1}
NTOTM	total N in crop measured (cumulative uptake), forcing function	kg ha^{-1}
NTOTMT	tabulated NTOTM	kg ha^{-1}
NUPNEG	'negative nitrogen uptake' counter	kg ha^{-1} d^{-1}
NUPT	N uptake rate by crop	kg ha^{-1} d^{-1}
NUPTOT	total N uptake, cumulative since initial	kg ha^{-1}
NUPTX	potential N uptake rate as not constrained by demand	kg ha^{-1} d^{-1}
PARA	first coëfficient of Angström formula, to calculate from sunshine hours to Joules	-
PARB	second coëfficient of Angström formula, to calculate from sunshine hours to Joules	-
PCGT	PCGC totaled since start of simulation	kg ha^{-1}
PLNUM	number of plants	ha^{-1}
Q10	Q10 of maintenance respiration sensitivity to temperature	-
RCRT	respiration crop, totaled (in CO_2)	kg ha^{-1}
RDR	relative death rate root and leaf	d^{-1}
RDT	radiation, daily total global, measured (400-400 nm)	J $m^{-2}d^{-1}$
RDTC	radiation daily total global above atmosphere (400-400 nm)	$Jm^{-2}d^{-1}$
RDTT	table of measured daily total global radiation during year	-
REDFT	factor accounting for effect of temperature on AMAX	-
REDFTT	table of REDFT as function of temperature	-
RFNLV	residual N fraction of leaves	kg kg^{-1}
RFNRT	residual N fraction of roots	kg kg^{-1}
RFNST	residual N fraction of stems	kg kg^{-1}
RGCR	respiration (in CO_2) due to growth of the whole crop (CR)	kg $ha^{-1}d^{-1}$
RGRL	relative growth rate of leaf area	d^{-1}
RLRLV	relative loss of leaf weight (dry matter)	d^{-1}
RLRRT	relative loss of root weight (dry matter)	d^{-1}

Acronym	Explanation	unit
RM(CR,LV,RT,SO,ST)	maintenance respiration (CH_2O) of whole crop (CR), leaves (LV), roots (RT), storage organs (SO), stems (ST)	kg $ha^{-1}d^{-1}$
RMCCO2	maintenance respiration (CO_2) of whole crop	kg $ha^{-1}d^{-1}$
RMMA	maintenance respiration due to metabolic activity (CH_2O)	kg $ha^{-1}d^{-1}$
RTILT	relation of relative tillering capacity to N content of leaves	
RTOT	total radiation (cumulative)	J m^{-2}
SAI	stem area index	ha ha^{-1}
SCP	scattering coefficient of leaves for PAR	J m^{-2} s^{-1}
SHCKD	parameter indicating relation between seedling age and delay in phenological development	(°C d) °C d^{-1}
SLA	specific leaf area	ha kg^{-1}
SLAC	specific leaf area constant	ha kg^{-1}
SLAFAC	tabulated relation of SLA to DVS	-
SLATB	table of SLA as function of day of year	-
SSA	specific stem area	ha kg^{-1}
SSGA	specific green stem area	ha kg^{-1}
SSGATB	table of SSGA as function of DVS	-
STTIME	starting time of simulation (day of year)	d
SWILAI	switch for choosing calculation of leaf area	-
SWIMEA	switch for reading measured data	-
SWINPH	switch for choosing measured or simulated amount of N in the leaves for calculation of photosynthesis	-
SWINPR	switch for choosing nitrogen profile in canopy	-
SWINUP	switch for choosing nitrogen input option	-
SWIPAR	switch for reading the dry matter partioning table	-
SWIRES	switch to include or exclude respiration	
SWISAI	switch to include or exclude stem area in leaf area	-
SWISIN	switch for choosing sink limitation	
SWIYR	initialization time switch for experiment across January 1	-
TAV(D)	actual air temperature at each DTIME (A), in daytime (D) and 24h average (V)	°C
TBD	base temperature for plant development	°C
TBLV	base temperature for leaf development	°C
TCDT	time coefficient for loss of tillers	d
TCFG	time coefficient for formation of grains	d
TCFT	time coefficient for formation of tillers	d
TCLSTR	time coefficient for loss of stem reserves	d^{-1}
TCNA	time coefficient for N acquisition	d
TCNT	time coefficient for N translocation	d
TD	time difference between day of seeding and day of transplanting	d
TEFF	temperature effect on maintenance respiration	-
TEFG	relation of temperature to growth rate of grains	
TIL	maximum number of tillers per plant at given leaf N content	-
TILMX	maximum number of tillers per plant	-
TMAXT	table of maximum day temperatures during a year	°C
TMD	maximum temperature for phenological development	°C

Acronym	Explanation	unit
TMINT	table of minimum night temperatures during a year	°C
TMLV	maximum temperature for leaf area development	°C
TMN	minimum night temperature	°C
TMX	maximum day temperature	°C
TNASS	net canopy photosynthesis totaled since start simulation	kg ha^{-1}
TREF	reference temperature for maintenance respiration	°C
TS(I)	temperature sum for plant development(initial)	°C d
TSHCKD	transplanting shock for phenological development	°C d
TSLV	temperature sum for leaf development	°C d
TSTR	temperature sum for phenological development at transplanting	°C d
WCR	weight crop (shoot plus storage organs, roots)	kg ha^{-1}
WGR(MX)	average weight of a grain, filled plus unfilled (maximum)	kg
WLVD	weight dead leaves	kg ha^{-1}
WLVEXP	WLV during exponential phase of leaf area development	kg ha^{-1}
WLVG(I)	weight green leaves (initial)	kg ha^{-1}
WRR	weight rough rice (14% moisture content)	kg ha^{-1}
WRTD	weight dead roots	kg ha^{-1}
WRTL(I)	weight kive roots (initial)	kg ha^{-1}
WSHG	sum of WLVG, WSTS, WSTR and WSO (live shoot)	kg ha^{-1}
WSHT	sum of WLVG, WLVD, WST, WSTR and WSO (total shoot)	kg ha^{-1}
WSO	weight storage organs	kg ha^{-1}
WSTR	weight of shielded reserves (starch) in stem	kg ha^{-1}
WSTS(I)	weight stems (initial) minus WSTR contained in it	kg ha^{-1}
WSTT	weight stem plus shielded reserves	kg ha^{-1}
XLAITB	table of XLAI as function of day of year	-
XNLV	tabulated measured N content in leaves	%
XNRT	tabulated measured N content in roots	%
XNSO	tabulated measured N content in storage organs	%
XNST	tabulated measured N content in stems	%
XSLA	measured specific leaf area	ha kg^{-1}
XSLATB	tabulated measured SLA as function of day of year	-
XWLVDT	tabulated measured weight of dead leaves	kg ha^{-1}
XWLVGT	tabulated measured weight of leaves	kg ha^{-1}
XWRTLT	tabulated measured weight of roots	kg ha^{-1}
XWSOTB	tabulated measured weight of storage organs	kg ha^{-1}
XWSTTB	tabulated measured weight of stems	kg ha^{-1}
XWTDMT	tabulated measured weight of total dry matter	kg ha^{-1}
XXLAI	measured LAI	ha ha^{-1}
XXNCR	measured N content in crop	kg ha^{-1}
XXNFLV	measured nitrogen fraction in the leaves	gr m^{-2}
XXNLV	measured N content in the leaves	kg ha^{-1}
XXNRT	measured N content in the roots	kg ha^{-1}
XXNSO	measured N content in the storage organs	kg ha^{-1}
XXNST	measured N content in the stems	kg ha^{-1}
XXWCR	measured weight of crop	kg ha^{-1}
XXWLVD	measured weight of dead leaves	kg ha^{-1}

Acronym	Explanation	unit
XXWLVG	measured weight of leaves	kg ha^{-1}
XXWRTL	measured weight of roots	kg ha^{-1}
XXWSO	measured weight of storage organs	kg ha^{-1}
XXWSTS	measured weight of stems	kg ha^{-1}
XXWTDM	measured total weight of the crop	kg ha^{-1}

Appendix III:

Parameters, switches, functions and tables needed as input for ORYZA_N.CSM

Acronym		Explanation	
WEATHER DATA (All as in L1D)			
PARAM LAT		latitude	degree
PARAM ELV		elevation of growth site above sea level	m
TABLE TMAXT		table of maximum day temperatures during a year	°C
TABLE TMINT		table of minimum night temperatures during a year	°C
TABLE RDTT		table of measured daily total global radiation during year	sunshine h
SWITCHES			
SWILAI	= 1:	use of simulated leaf mass and SLA	-
	= 2:	use of tabulated (measured) ln(LAI) vs temperature sum	-
	= 3:	use of relative growth rate for leaf area, RGRL, during exponential stage, and SLA afterwards	-
	= 4:	use of measured leaf mass and SLA	-
	= 5:	use of measured LAI	-
SWIMEA	= 0:	measured data versus day of year (DOY)	
	= 1:	measured data versus days after transplanting (DAT)	
SWINPH	= 0:	use of measured amount of nitrogen in leaves for photosynthesis calculation	-
	= 1:	use of simulated amount of nitrogen in leaves for photosynthesis calculation	-
SWINPR	= 0:	no nitrogen profile in canopy; uniform distribution	-
	= 1:	nitrogen profile in canopy; with extinction coefficient KDIFN	-
SWINUP	= 1:	nitrogen limited production; N uptake as forcing function	-
	= 2:	potential production; N uptake equals demand	-
SWIPAR	= 0:	table of biomass partitioning versus development stage is used	-
	= 1:	table of biomass partitioning versus days after transplanting (DAT) is used	-

Acronym		Explanation	unit
SWISAI	= 0:	stem area is NOT included in leaf area	-
	= 1:	stem area is included in leaf area	-
SWISIN	= 1:	no sink limitation; no GSOM	-
	= 2:	sink limitation; GSOM is calculated from tiller and grain number	-

INITIAL VALUES

PARAM DOYS	doy of year = julian date, at beginning of simulation (real value)	d
PARAM IDOYTR	integer value of transplanting day of year	d
PARAM FGHDAY	first sampling day of storage organs, expressed in days after transplanting (real value)	d
INCON WLVGI	initial weight of green leaves	kg ha $^{-1}$
INCON WRTLI	initial weight of roots	kg ha $^{-1}$
INCON WSTSI	initial weight of stems	kg ha $^{-1}$
PARAM FNLVI	initial fraction of N in leaves(mass basis)	-
PARAM FNRTI	initial fraction of N in roots (mass basis)	-
PARAM FNSTI	initial fraction of N in stems (mass basis)	-
PARAM DVSI	initial phenological development stage (see Appendix IV)	-
PARAM TSI	initial temperature sum for plant development, starting from seeding onwards (see Appendix IV)	

GENERAL CROP PARAMETERS

See Appendix IV for calculation methods.

PARAM FSTR	fraction of stem weight at flowering that is remobilizable	kg kg $^{-1}$
PARAM DVRV	development rate crop in the vegetative stage	d^{-1}
PARAM DVRR	development rate crop in the reproductive stage	d^{-1}
FUNCTION FLVTB	tabulated FLV as function of DVS or DAT	-
FUNCTION FSHTB	tabulated FSH as function of DVS or DAT	-
FUNCTION FSTTB	tabulated FST as function of DVS or DAT	-
FUNCTION FSOTB	tabulated FSO as function of DVS or DAT	-
SLAC	specific leaf area constant	ha kg^{-1}
SLAFAC	tabulated relation of SLA/SLAC ratio to DVS	-

Acronym	Explanation	unit

EXPERIMENTAL DATA ON NITROGEN SAMPLING AND MANAGEMENT

See Appendix IV for calculation methods.

PARAM NS	number of sampling dates for total N in the crop	-
TABLE DNOST	table of daynumbers (DOY) at which NTOTMT was measured	d
TABLE NTOTMT	total amount of N measured in crop biomass (including roots) (cumulative uptake)	kg ha^{-1}
PARAM NA	the number of nitrogen application dates	-
TABLE DNAPT	daynumber of nitrogen applications	d

MEASURED DATA FOR VALIDATION OR FOR USE AS FORCING FUNCTION

FUNCTION XWLVGT	tabulated measured weight of the leaves	kg ha^{-1}
FUNCTION XWRTLT	tabulated measured weight of the roots	kg ha^{-1}
FUNCTION XWSOT	tabulated measured weight of the storage organs (appendix IV)	kg ha^{-1}
FUNCTION XWSTTB	tabulated measured weight of the stems	kg ha^{-1}
FUNCTION XNLV	tabulated measured N content in leaves	%
FUNCTION XNRT	tabulated measured N content in roots	%
FUNCTION XNSO	tabulated measured N content in storage organs	%
FUNCTION XNST	tabulated measured N content in stems	%

Appendix IV:
Determination of parameters, functions and tables

DVSI & TSI
If simulation starts at transplanting date the DVSI and TSI are needed. Both can be calculated with the programs DR1.CSM and DR2.CSM in CSMP.

FSTR
The fraction of stem weight at flowering, that is remolizable, can be calculated as follows:

$$FSTR = \frac{\text{(maximum measured weight of the stems - weight of the stems at harvest)}}{\text{maximum measured weight of the stems}}$$

example:

DAT	WSTS
40	3000
50	4000
60	5000
70	4500
80	3500

FSTR =(5000 - 3500) / 5000 = 0.3

DVRV & DVRR
The development rates in the vegetative and reproductive stages can be calculated with the programs DR1.CSM and DR2.CSM in CSMP.

SLAC & SLAFAC
If leaf area is measured the SLAC and SLAFAC can be calculated. Otherwise the standard SLAC and SLAFAC is used.

SLAC
Specific leaf area constant is the specific leaf area at flowering, calculated as follows:

$$SLAC = LAI_{\mathbf{flowering}} / XXWLVG_{\mathbf{flowering}}$$

SLAFAC

The relation of the specific leaf area to development stage is expressed in the SLAFAC. The SLAFAC is the SLA at time t divided by the SLA at flowering.

$$SLAFAC = (LAI_t / XXWLVG_t) / SLAC_{flowering}$$

Write these values in the SLAFAC table:

FUNCTION SLAFAC = (0.0, 1.72), (0.30, 1.60),.............,(2.0,0.75)

PARTITIONING: FLVTB, FSTTB, FSOTB, FSHTB

A procedure to calculate the partitioning tables:

1. Calculate DVS for sampling dates with the programs DR1.CSM and DR2.CSM in CSMP.
2. Make a table including sampling date, development stage (DVS), weight of leaves (WLVG), stems (WSTS), storage organs (WSO), totals and the difference in weights between two harvests (see for example Table III.2.1).

Table III.2.1 Example of partitioning calculation.

sampling date (d)	mean date	DVS	mean DVS	WLV (kg/ha)	increase WLV	WSTS (kg/ha)	increase WSTS	WSO (kg/ha)	increase WSO	WSHG (kg/ha)	increase WSHG
100		0.8		2000		4000		0		6000	
	110		*0.9*		*400*		*2000*		*0*		*3400*
120		1.0		2400		6000		1000		9400	
	130		*1.1*		*0*		*0*		*1000*		*1000*
140		1.2		2400		6000		2000		10400	
	150		*1.3*	(1800)	*0*	(5000)	*0*		*2000*		*2000*
160		1.4		2400 (1000)		6000 (4000)		4000		12400	

In this example, after flowering (DVS=1) there is no increase in leaves and stems.

3. Calculate the mean DVS for the period between two harvests and divide the individual increase in weight per organ by the total increase in weight (WSHG).

DVS	FLV	FST	FSO
0.9	400/3400 = 0.11	2000/3400 = 0.59	1000/3400 = 0.30
1.1	0/1000 = 0.00	0/1000 = 0.00	1000/1000 = 1.00
1.3	0/2000 = 0.00	0/1000 = 0.00	1000/1000 = 1.00

4. Write these fractions in the partitioning tables, either as a function of DVS (SWIPAR = 0):
   FUNCTION FLVTB = (0.90,0.11) , (1.10,0.00) ,..............., (2.10,0.00)
   FUNCTION FSTTB = (0.90,0.59) , (1.10,0.00) ,..............., (2.10,0.00)
   FUNCTION FSOTB = (0.90,0.00) , (1.10,1.00) ,..............., (2.10,1.00)

   or, as a function of DAT (SWIPAR = 1):
   FUNCTION FLVTB = (40.0,0.11) , (60.0,0.00) ,..............., (80.0,0.00)
   FUNCTION FSTTB = (40.0,0.59) , (60.0,0.00) ,..............., (80.0,0.00)
   FUNCTION FSOTB = (40.0,0.00) , (60.0,1.00) ,..............., (80.0,1.00)

5 If root mass is measured, FSH can be calculated:
- Include in table III.2.1 a column with the weights of the roots.
- Calculate the total weight of dry mass (including the root mass) WCR.
- Calculate the increase in weight of the total dry mass (WCR).
- Divide the increase in shoot weight (WSHG = WSTS +WLVG+WSO) by the increase in weight of total dry mass (WCR).

6 Grain filling starts at 10 days before flowering, therefore the FSO remains zero until 10 days before flowering. For this dummy value is included in the FUNCTION FSO at 10 days before flowering.

NS
The number of sampling dates for total N in the crop.

DNOST
Table of daynumbers (DOY) at which NTOTMT was measured. The last figure in the table should be the harvest date or just after. For seasons across January 1st, day numbers proceed as 365., 366., 367., 368. etc. untill the end of the season.

NTOTMT
The total N in crop measured (cumulative uptake), at the days specified in DNOST. The last figure of the table NTOTMT should be the total amount of N in the crop at harvest.

NA
The number of nitrogen application dates, includes basal dressing at planting/seeding, and one dummy date after harvest.

DNAPT
The daynumbers (DOY) of nitrogen application are specified in table DNAPT. The first figure in the table is equal to DOYS; also in absence of basal dressing. The last figure should be any date after harvest! For seasons across January 1st, day numbers proceed as 365., 366., 367., 368. etc. untill the end of the season.

XXWSOT
Approximately 10 to 15 days before flowering the panicle initiation starts. To establish this within the interpolation of the measured weights of the storage organs a dummy value of zero at 10 days before flowering should be included in the FUNCTION XXWSOT.

Appendix V:

Complete sets of data used for validation

TNAU-TNRRI, Tamil Nadu, India, 1988-1989

```
*****************************************************************
Weather data used:
Aduthurai, India, 1988-1989

PARAM LAT=11.00
PARAM ELV=19.50
*******************************************************

*******************************************************
* Thiyagarajan, Tamil Nadu, India
* 1988-1989
* variety:   ADT 39
* treatment: 0 KG/HA
*******************************************************
TITLE THIYAGARAJAN, 0 KG N/HA

PARAM SWIPAR = 0
PARAM SWILAI = 4
PARAM SWINUP = 1
PARAM SWISIN = 1
PARAM SWINPH = 0
PARAM SWINPR = 1
PARAM SWIRES = 1
PARAM SWISAI = 0
PARAM SWIMEA = 1

PARAM DOYS   = 344.0
PARAM IDOYTR = 344
PARAM FGHDAY = 63.0

INCON WLVGI  = 47.0
INCON WSTSI  = 38.0
INCON WRTLI  = 19.0

PARAM FNSTI  = 0.0168
PARAM FNLVI  = 0.0315
PARAM FNRTI  = 0.0034

PARAM DVSI   = 0.531
PARAM TSI    = 676.9

PARAM FSTR   = 0.39
PARAM DVRV   = 0.000784
PARAM DVRR   = 0.001674

PARAM NA = 5
TABLE DNAPT(1- 5)  = 344.,370.,392.,406.,600.
PARAM NS = 11
TABLE DNOST(1-11)  = 344.,362.,369.,376.,383.,390.,397.,407.,425.,...
                     433.,441.
TABLE NTOTMT(1-11) = 2.18,13.90,16.98,28.14,37.87,41.69,...
                     43.51,41.78,52.48,54.87,54.87

* NOTE first value of NSO is dummy
```

```
*      first two values of WSO are dummy's
*      last value of W/NLV, W/NST, W/NRT, W/NSO are dummy's
FUNCTION XWSTS =( 0,  38),(18, 420),(25, 715),(32,1165),(39,1673),...
                 (46,2115),(53,2630),(63,2146),(81,1883),(89,1615)
FUNCTION XWLVGT=( 0,  47),(18, 286),(25, 469),(32, 715),(39, 828),...
                 (46, 943),(53, 936),(63, 840),(81, 792),(89, 767)
FUNCTION XWRTLT=( 0,  19),(18, 260),(25, 326),(32, 370),(39, 421),...
                 (46, 463),(53, 482),(63, 537),(81, 530),(89, 530)
FUNCTION XWSOTB=( 0,   0),(43,   0),(63,1317),(81,2803),(89,3456)

FUNCTION XNST  =( 0,1.68),(18,1.38),(25,0.83),(32,0.97),(39,1.03 ),...
                 (46,0.94),(53,0.99),(63,0.64),(81,0.53),(89,0.48)
FUNCTION XNLV  =( 0,3.15),(18,2.35),(25,2.00),(32,2.07),(39,2.07),...
                 (46,1.93),(53,1.45),(63,1.10),(81,0.97),(89,0.70)
FUNCTION XNRT  =( 0,0.34),(18,0.53),(25,0.51),(32,0.55),(39,0.83),...
                 (46,0.78),(53,0.81),(63,0.78),(81,0.70),(89,0.64)
FUNCTION XNSO  =( 0,1.11),(97,1.11)

* value at 2.0 is dummy
FUNCTION FSTT =(0.,0.62),...
                (0.50,0.62),(0.65,0.62),(0.73,0.65),(0.81,0.82),...
                (0.89,0.79),(1.00,0.00),(1.14,0.00),...
                (1.52,0.00),(1.90,0.00),(2.1,0.)
FUNCTION FLVT =(0.,0.38),...
                (0.50,0.38),(0.65,0.38),(0.73,0.35),(0.81,0.18),...
                (0.89,0.21),(1.00,0.00),(1.14,0.00),...
                (1.52,0.00),(1.90,0.00),(2.1,0.)
FUNCTION FSOT =(0.,0.00),...
                (0.50,0.00),(0.65,0.00),(0.73,0.00),(0.81,0.00),...
                (0.89,0.00),(1.00,1.00),(1.14,1.00),(1.52,1.00),...
                (1.90,1.00),(2.1,1. )
FUNCTION FSHT =(0.,0.72),...
                (0.50,0.72),(0.65,0.88),(0.73,0.94),(0.81,0.92),...
                (0.89,0.93),(0.97,0.96),(1.14,0.93),(1.52,1.00),...
                (1.90,1.00),(2.1,0.)

END

*******************************************************
* Thiyagarajan, Tamil Nadu, India
* 1988-1989
* variety:   ADT 39
* treatment: 100 kg N/ha
*******************************************************
TITLE THIYAGARAJAN, 100 KG N/HA


PARAM FSTR  = 0.29

TABLE NTOTMT(1-11)= 2.18,22.9,38.46,53.71,60.67,71.05,88.00,96.03,...
                    108.03,104.48,104.48

FUNCTION XWSTTB=( 0,38.),(18, 522),(25,1028),(32,1710),(39,2312),...
                (46,2974),(53,3904),(63,4505),(81,3691),(89,3216)
```

```
FUNCTION XWLVGT=( 0,  47),(18, 394),(25, 717),(32,1047),(39,1281),...
                (46,1448),(53,1628),(63,1765),(81,1680),(89,1616)
FUNCTION XWRTLT=( 0,  19),(18, 377),(25, 494),(32, 590),(39, 672),...
                (46, 734),(53, 848),(63, 836),(81, 836),(89, 836)
FUNCTION XWSOTB=( 0,   0),(43,   0),(63,1536),(81,4520),(89,5525)

FUNCTION XNST  =( 0,1.68),(18,1.76),(25,1.52),(32,1.24),(39,1.03),...
                (46,1.13),(53,1.15),(63,0.84),(81,0.69),(89,0.53)
FUNCTION XNLV  =( 0,3.15),(18,2.62),(25,2.62),(32,2.62),(39,2.40),...
                (46,2.16),(53,2.21),(63,1.82),(81,1.20),(89,0.84)
FUNCTION XNRT  =( 0,0.34),(18,0.90),(25,0.82),(32,0.86),(39,0.91),...
                (46,0.84),(53,0.84),(63,0.84),(81,0.76),(89,0.64)
FUNCTION XNSO  =( 0,1.24),(97,1.24)

* NOTE the first values are dummy's
FUNCTION FSTT  =(0.00,0.58),...
                (0.50,0.58),(0.65,0.61),(0.73,0.67),(0.81,0.72),...
                (0.89,0.80),(1.14,0.26),(1.52,0.00),(1.90,0.00),...
                (2.10,0.00)
FUNCTION FLVT  =(0.00,0.42),...
                (0.50,0.42),(0.65,0.39),(0.73,0.33),(0.81,0.28),...
                (0.89,0.20),(1.14,0.06),(1.52,0.00),(1.90,0.00),...
                (2.10,0.00)
FUNCTION FSOT  =(0.00,0.00),...
                (0.50,0.00),(0.65,0.00),(0.73,0.00),(0.81,0.00),...
                (0.89,0.00),(1.14,0.00),(1.52,1.00),(1.90,1.00),...
                (2.10,1.00)
FUNCTION FSHT  =(0.00,0.70),...
                (0.50,0.70),(0.65,0.88),(0.73,0.91),(0.81,0.91),...
                (0.89,0.93),(0.97,0.91),(1.14,1.00),(1.52,1.00),...
                (1.90,1.00),(2.10,0.00)

END

*********************************************************
* Thiyagarajan, Tamil Nadu, India
* 1988-1989
* variety:   ADT 39
* treatment: 200 kg N/ha
*********************************************************
TITLE THIYAGARAJAN, 200 KG N/HA


PARAM FSTR  = 0.43

PARAM DVRV  = 0.000740
PARAM DVRR  = 0.001606

PARAM DVSI  = 0.501

TABLE NTOTMT(1-11)=2.18,27.80,64.75,81.85,96.98,108.91,130.08,...
                   165.60,166.76,144.08,144.08

FUNCTION XWSTTB=( 0,  38),(18, 555),(25,1238),(32,2253),(39,3143),...
                (46,3992),(53,5029),(63,5338),(81,4139),(94,3067)
FUNCTION XWLVGT=( 0,  47),(18, 429),(25,1103),(32,1590),(39,1868),...
                (46,2140),(53,2361),(63,2759),(81,2304),(94,1530)
FUNCTION XWRTLT=( 0,  19),(18, 491),(25, 620),(32, 764),(39, 880),...
                (46, 930),(53,1120),(63,1183),(81, 997),(94, 950)
FUNCTION XWSOTB=( 0,   0),(50,   0),(63,1712),(81,5413),(94,6706)

FUNCTION XNST  =( 0,1.68),(18,1.90),(25,1.97),(32,1.38),(39,1.24),...
                (46,1.25),(53,1.24),(63,1.24),(81,1.03),(94,0.62)
FUNCTION XNLV  =( 0,3.15),(18,2.90),(25,3.17),(32,2.76),(39,2.62),...
                (46,2.31),(53,2.41),(63,2.21),(81,1.38),(94,0.94)
FUNCTION XNRT  =( 0,0.34),(18,0.98),(25,0.87),(32,0.90),(39,1.03),...
                (46,1.03),(53,1.03),(63,1.02),(81,0.90),(94,0.78)
FUNCTION XNSO  =( 0,1.54),(97,1.54)
```

```
* NOTE the first values of the functions are dummy's
*       the values at 2.1 are dummy's
FUNCTION FSTT  =(0.00,0.58),...
                (0.48,0.58),(0.62,0.50),(0.69,0.68),(0.77,0.76),...
                (0.84,0.76),(0.92,0.82),(1.00,0.13),(1.38,0.00),...
                (1.74,0.00),(2.10,0.00)
FUNCTION FLVT  =(0.00,0.42),...
                (0.48,0.42),(0.62,0.50),(0.69,0.32),(0.77,0.24),...
                (0.84,0.24),(0.92,0.18),(1.00,0.16),(1.38,0.00),...
                (1.74,0.00),(2.10,0.00)
FUNCTION FSOT  =(0.00,0.00),...
                (48,0.00),(0.62,0.00),(0.69,0.00),(0.77,0.00),...
                (0.84,0.00),(0.92,0.00),(1.00,0.71),(1.38,1.00),...
                (1.74,1.00),(2.10,1.00)
FUNCTION FSHT  =(0.00,0.66),...
                (0.48,0.66),(0.62,0.91),(0.69,0.91),(0.77,0.91),...
                (0.84,0.96),(0.92,0.87),(1.00,0.97),(1.38,1.00),...
                (1.74,1.00),(2.10,0.00)

END

*********************************************************
* Thiyagarajan, Tamil Nadu, India
* 1988-1989
* variety:   ADT 39
* treatment: 300 kg N/ha
*********************************************************
TITLE THIYAGARAJAN, 300 KG N/HA


PARAM FSTR  = 0.37

TABLE NTOTMT(1-11)=2.18,38.24,91.48,128.14,155.89,171.09,182.60,...
                   240.41,217.71,181.80,181.80

FUNCTION XWSTTB=( 0,  38),(18, 640),(25,1438),(32,2385),(39,3257),...
                (46,4221),(53,5500),(63,6073),(81,5136),(94,3828)
FUNCTION XWLVGT=( 0,  47),(18, 571),(25,1300),(32,2080),(39,2695),...
                (46,3150),(53,3486),(63,3899),(81,3761),(94,2808)
FUNCTION XWRTLT=( 0,  19),(18, 500),(25, 710),(32, 925),(39,1150),...
                (46,1324),(53,1502),(63,1790),(81,1507),(94,1507)
FUNCTION XWSOTB=( 0,   0),(50,   0),(63,2542),(81,4763),(94,6450)

FUNCTION XNST  =( 0,1.68),(18,2.21),(25,2.34),(32,1.79),(39,1.65),...
                (46,1.57),(53,1.31),(63,1.31),(81,1.11),(94,0.80)
FUNCTION XNLV  =( 0,3.15),(18,3.24),(25,3.93),(32,3.65),(39,3.24),...
                (46,2.84),(53,2.68),(63,2.49),(81,1.69),(94,0.95)
FUNCTION XNRT  =( 0,0.34),(18,1.12),(25,0.95),(32,1.03),(39,1.29),...
                (46,1.16),(53,1.14),(63,1.12),(81,1.01),(94,0.90)
FUNCTION XNSO  =( 0,1.72),(97,1.72)

* NOTE the first values of the functions are dummy's
*       the values at 2.1 are dummy's
FUNCTION FSTT  =(0.00,0.53),...
                (0.48,0.53),(0.62,0.52),(0.69,0.55),(0.77,0.59),...
                (0.84,0.68),(0.92,0.79),(1.00,0.16),(1.38,0.00),...
                (1.82,0.00),(2.10,0.00)
FUNCTION FLVT  =(0.00,0.47),...
                (0.48,0.47),(0.62,0.48),(0.69,0.45),(0.77,0.41),...
                (0.84,0.32),(0.92,0.21),(1.00,0.12),(1.38,0.00),...
                (1.82,0.00),(2.10,0.00)
FUNCTION FSOT  =(0.00,0.00),...
                (0.48,0.00),(0.62,0.00),(0.69,0.00),(0.77,0.00),...
                (0.84,0.00),(0.92,0.00),(1.00,0.72),(1.38,1.00),...
                (1.82,1.00),(2.10,1.00)
FUNCTION FSHT  =(0.00,0.70),...
                (0.48,0.70),(0.62,0.88),(0.69,0.89),(0.77,0.87),...
                (0.84,0.89),(0.92,0.90),(1.00,0.92),(1.38,1.00),...
                (1.82,1.00),(2.10,0.00)
```

```
END

*********************************************************
* Thiyagarajan, Tamil Nadu, India
* 1988-1989
* variety:   ADT 39
* treatment: 400 KG/HA
*********************************************************
TITLE THIYAGARAJAN, 400 KG N/HA


PARAM FSTR  =0.30

PARAM DVRV  = 0.000716
PARAM DVRR  = 0.001582

PARAM DVSI  = 0.485

PARAM NS = 10
TABLE DNOST(1-10) =344.,362.,369.,376.,383.,390.,397.,407.,425.,441.
TABLE NTOTMT(1-10)=2.18,49.64,110.56,159.91,201.37,212.66,246.23,...
                   303.82,277.76,212.78

FUNCTION XWSTTB=( 0,  38),(18, 718),(25,1612),(32,2650),(39,3855),...
                (46,4627),(53,5736),(63,6619),(81,5021),(97,4558)
FUNCTION XWLVGT=( 0,  47),(18, 652),(25,1438),(32,2500),(39,3329),...
                (46,4009),(53,4707),(63,5624),(81,4285),(97,3208)
FUNCTION XWRTLT=( 0,  19),(18, 521),(25, 775),(32,1030),(39,1250),...
                (46,1525),(53,1750),(63,2003),(81,1968),(97,1968)
FUNCTION XWSOTB=( 0,   0),(51,   0),(63,1426),(81,5365),(97,6337)

FUNCTION XNST  =( 0,1.68),(18,2.41),(25,2.67),(32,2.07),(39,1.76),...
                (46,1.62),(53,1.60),(63,1.48),(81,1.29),(97,1.06)
FUNCTION XNLV  =( 0,3.15),(18,4.00),(25,4.14),(32,3.65),(39,3.38),...
                (46,2.83),(53,2.72),(63,2.72),(81,2.24),(97,0.98)
FUNCTION XNRT  =( 0,0.34),(18,1.20),(25,1.03),(32,1.34),(39,1.68),...
                (46,1.59),(53,1.51),(63,1.38),(81,1.12),(97,1.06)
FUNCTION XNSO  =( 0,1.77),(97,1.77)

* NOTE the first values of the functions are dummy's
*      the values at 2.1 are dummy's
FUNCTION FSTT  =(0.,0.53),...
                (0.46,0.53),(0.60,0.53),(0.68,0.49),(0.75,0.59),...
                (0.82,0.53),(0.89,0.61),(1.00,0.00),...
                (1.30,0.00),(1.77,0.00),(2.10,0.00)
FUNCTION FLVT  =(0.,0.47),...
                (0.46,0.47),(0.60,0.47),(0.68,0.51),(0.75,0.41),...
                (0.82,0.47),(0.89,0.39),(1.00,0.00),(1.30,0.00),...
                (1.77,0.00),(2.10,0.00)
FUNCTION FSOTB =(0.,0.00),...
                (0.46,0.00),(0.60,0.00),(0.68,0.00),(0.75,0.00),...
                (0.82,0.00),(0.89,0.00),(1.00,1.00),(1.30,1.00),...
                (1.77,1.00),(2.10,1.00)
FUNCTION FSHT  =(0.,0.72),...
                (0.46,0.72),(0.60,0.87),(0.68,0.89),(0.75,0.90),...
                (0.82,0.84),(0.89,0.89),(0.98,0.93),(1.30,1.00),...
                (1.77,1.00),(2.10,0.00)

END

STOP
```

CRRI, Cuttack, India, 1990

```
*************************************************************************
Weather data used:
CRRI, CUTTACK, INDIA, 1990

PARAM LAT=20.
PARAM ELV=23.
***************************************************************

***************************************************************
* Rao/Dash, Cuttack, India
* dry season 1990
* variety: IR 36
* 0 kg N/ha
***************************************************************
TITLE RAO & DASH, 0 KG N/HA

PARAM SWIPAR = 0
PARAM SWIALV = 1
PARAM SWINUP = 2
PARAM SWISIN = 1
PARAM SWINLV = 1
PARAM SWINPR = 1
PARAM SWIRES = 1
PARAM SWISAI = 0
PARAM SWIMEA = 1

PARAM DOYS   = 25.0
PARAM IDOYTR = 25
PARAM FGHDAY = 70.0

INCON WLVI   = 32.0
INCON WSTI   = 48.0
INCON WRTI   = 44.0

PARAM FNSTI  = 0.020
PARAM FNLVI  = 0.025
PARAM FNRTI  = 0.010

PARAM DSI    = 0.32
PARAM TSI    = 497.5

PARAM FSTR   = 0.411
PARAM DVRV   = 6.2E-04
PARAM DVRR   = 2.4E-03

PARAM NA = 4
TABLE DNAPT (1-4) = 25.,45.,78.,365.
PARAM NS = 6
TABLE DNOST(1-6)  = 45.,75.,95.,105.,117.,125.
TABLE NTOTMT(1-6) = 21.98,57.88,60.46,60.74,73.38,73.38

*NOTE: first value of NSO is dummy
*       first two values of WSO are dummy's
*       last value of W/NLV,W/NST,W/NRT,W/NSO are dummy's

FUNCTION XWLVGT=( 0, 32.),(20,272.),(30.440.),(40,679.),...
                (50,872.),(70,754.),(80,761.),(92,776.),(95,776.)
FUNCTION XWSTTB=( 0,  48.),(20, 267.),(30, 745.),(40,1441.),...
                (50,2420.),(70,3779.),(80,2101.),(92,2225.),(95,2225.)
FUNCTION XWRTLT=( 0, 44.),(20,223.),(30,323.),(40,605.),...
                (50,602.),(70,535.),(80,500.),(92,500.),(95,500.)
FUNCTION XWSOT =( 0,   0.),(64,0.),(70,443.),(80,2783.),(92.4246.),...
                (95,4246.)

FUNCTION XNST  =( 0,2.00),(20,1.89),(50,1.31),(70,0.91),(80,0.69),...
                (92,0.69),(95,0.69)
FUNCTION XNLV  =( 0.2.50),(20,4.88),(50,2.25),(70.1.79),(80,1.42),...
                (92,1.42),(95,1.42)
FUNCTION XNRT  =( 0,1.00),(20,1.64),(50,1.09),(70,0.91),(80,0.91),...
                (92,0.91),(95,0.91)
FUNCTION XNSO  =( 0,1.74),(70,1.74),(80,1.11),(92.1.00),(95,1.00)

* NOTE first and last values are dummy's
FUNCTION FSHT  =(0.00,0.70),...
                (0.36,0.72),(0.51,0.87),(0.61,0.77),(0.71,1.00),...
                (0.86,1.00),(1.06,1.00),(1.64,1.00),(2.10,1.00)
FUNCTION FLVT  =(0.00,0.52),...
                (0.36,0.52),(0.51,0.26),(0.61,0.26),(0.71,0.16),...
                (0.81,0.16),(0.86,0.00),(1.0,0.0),(1.06,0.00),...
                (1.64,0.01),(2.10,0.01)
FUNCTION FSOTB =(0.00,0.00),...
                (0.36,0.00),(0.51,0.00),(0.61,0.00),(0.71,0.00),...
                (0.81,0.00),(0.86,0.32),(1.0,1.0),(1.06,1.00),...
                (1.64,0.91),(2.10,0.91)
FUNCTION FSTT  =(0.00,0.48),...
                (0.36,0.48),(0.51,0.74),(0.61,0.74),(0.71,0.84),...
                (0.81,0.84),(0.86,0.68),(1.0,0.0),(1.06,0.00),...
                (1.64,0.08),(2.10,0.08)

END
```

```
***************************************************************
* Rao/Dash, Cuttack, India
* dry season 1990
* variety: IR 36
* 50 kg N/ha
***************************************************************
TITLE RAO & DASH, 50 KG N/HA


PARAM FSTR  = 0.34

TABLE NTOTMT(1-6)= 20.33,83.97,90.12,91.06,112.06.112.06

* NOTE first value of NSO is dummy
*       first two values of WSO are dummy's
*       last value of W/NLV, W/NST, W/NRT, W/NSO are dummy's
FUNCTION XWLVGT=(0,32.),(20,270.),(30.528.).(40,888.),...
                (50,1202.),(70,998.),(80,1058.),(92,1064.),(95,1064.)
FUNCTION XWSTTB=(0,48.),(20,289.),(30,809.),(40.1766.),...
                (50,3088.),(70,4682.),(80,2708.),(92,3075.),(95,3075.)
FUNCTION XWRTLT=(0,44.),(20,237.),(30,523.),(40,743.),...
                (50,905.),(70,704.),(80,861.),(92.820.),(95,820.)
FUNCTION XWSOT =(0,0.),(64,0.),(70,741.),(80.4194.),(92,6095.),...
                (95.6095.)

FUNCTION XNST  =(0,2.0),(20,1.60),(50,1.31),(70,1.02),(80,0.62),...
                (92,0.62),(95,0.62)
FUNCTION XNLV  =(0,2.5),(20,4.22),(50.2.80),(70,2.15),(80,1.71),...
                (92,1.71),(95,1.71)
FUNCTION XNRT  =(0,1.0),(20,1.82),(50.1.09),(70,0.98),(80,1.02),...
                (92,1.02),(95,1.02)
FUNCTION XNSO  =(0,1.89),(70,1.89),(80.1.13),(92,1.09),(95,1.09)

* NOTE first and last values are dummy's
FUNCTION FSHT  =(0.00,0.71),...
                (0.36,0.71),(0.51,0.73),(0.61,0.86),(0.71,0.91),...
                (0.86,1.00),(1.06,0.96),(1.64,1.00),(2.10,1.00)
FUNCTION FLVT  =(0.00,0.50),...
                (0.36,0.50),(0.51,0.33),(0.61,0.27),(0.71,0.19),...
                (0.81,0.19),(0.86,0.00),(1.0,0.0),(1.06,0.02),...
                (1.64,0.00),(2.10,0.00)
FUNCTION FSOTB =(0.00,0.00),...
                (0.36,0.00),(0.51,0.00),(0.61,0.00),(0.71,0.00),...
```

```
                (0.81,0.00),(0.86,0.32),(1.00,1.00),(1.06,0.98),...
                (1.64,0.84),(2.10,0.84)
FUNCTION FSTT  =(0.00,0.50),...
                (0.36,0.50),(0.51,0.67),(0.61,0.73),(0.71,0.81),...
                (0.81,0.81),(0.86,0.68),(1.0,0.0),(1.06,0.00),...
                (1.64,0.16),(2.10,0.16)

END

*******************************************************
* Rao/Dash, Cuttack, India
* dry season 1990
* variety: IR 36
* 100 kg N/ha
*******************************************************
TITLE RAO & DASH, 100 KG N/HA

PARAM FSTR  = 0.41

TABLE NTOTMT(1-6)= 25.95,119.92,120.10,121.67,140.0,140.0

* NOTE first value of NSO is dummy
*      first two values of WSO are dummy's
*      last value of W/NLV, W/NST, W/NRT, W/NSO are dummy's
FUNCTION XWLVGT=(0,32.),(20,333.),(30,726.),(40,1292.),...
                (50,1537.),(70,1340.),(80,1555.),(92,1191.),(95,1191.)
FUNCTION XWSTTB=(0,48.),(20,338.),(30,1042.),(40,2431.),...
                (50,3985.),(70,5590.),(80,3320.),(92,3314.),(95,3314.)
FUNCTION XWRTLT=(0,44.),(20,286.),(30,539.),(40,979.),...
                (50,1116.),(70,803.),(80,952.),(92,858.),(95,858.)
FUNCTION XWSOT =(0,0.),(64,0.),(70,1187.),(80,5145.),(92,6915.),...
                (95,6915.)

FUNCTION XNST  =(0,2.0),(20,1.82),(50,1.64),(70,1.10),(80,0.69),...
                (92,0.69),(95,0.69)
FUNCTION XNLV  =(0,2.5),(20,4.51),(50,2.73),(70,2.11),(80,1.71),...
                (92,1.71),(95,1.71)
FUNCTION XNRT  =(0,1.0),(20,1.67),(50,1.13),(70,0.94),(80,0.88),...
                (92,0.88),(95,0.88)
FUNCTION XNSO  =(0,1.92),(70,1.92),(80,1.24),(92,1.30),(95,1.30)

* NOTE first and last values are dummy's
FUNCTION FSHT  =(0.00,0.71),...
                (0.36,0.71),(0.51,0.81),(0.61,0.82),(0.71,0.93),...
                (0.86,1.00),(1.06,0.97),(1.64,1.00),(2.10,1.00)
FUNCTION FLVT  =(0.00,0.51),...
                (0.36,0.51),(0.51,0.36),(0.61,0.29),(0.71,0.14),...
                (0.81,0.14),(0.86,0.00),(1.0,0.0),(1.06,0.05),...
                (1.64,0.00),(2.10,0.00)
FUNCTION FSOTB =(0.00,0.00),...
                (0.36,0.00),(0.51,0.00),(0.61,0.00),(0.71,0.00),...
                (0.81,0.00),(0.86,0.43),(1.00,1.00),(1.06,0.95),...
                (1.64,1.00),(2.10,1.00)
FUNCTION FSTT  =(0.00,0.49),...
                (0.36,0.49),(0.51,0.64),(0.61,0.71),(0.71,0.86),...
                (0.81,0.86),(0.86,0.57),(1.0,0.0),(1.06,0.00),...
                (1.64,0.00),(2.10,0.00)

END

*******************************************************
* Rao/Dash, Cuttack, India
* dry season 1990
* variety: IR 36
* 150 kg N/ha
*******************************************************
TITLE RAO & DASH, 150 KG N/HA

PARAM FSTR  = 0.42
```

```
TABLE NTOTMT(1-6)= 30.10,157.54,160.79,160.81,181.41,181.41

* NOTE first value of NSO is dummy
*      first two values of WSO are dummy's
*      last value of W/NLV, W/NST, W/NRT, W/NSO are dummy's
FUNCTION XWLVGT=(0,32.),(20,366.),(30,872.),(40,1576.),...
                (50,1898.),(70,1789.),(80,1589.),(92,1485.),(95,1485.)
FUNCTION XWSTTB=(0,48.),(20,341.),(30,1023.),(40,2585.),...
                (50,4202.),(70,5702.),(80,3340.),(92,3303.),(95,3303.)
FUNCTION XWRTLT=(0,44.),(20,333.),(30,561.),(40,1078.),...
                (50,1317.),(70,825.),(80,932.),(92,899.),(95,899.)
FUNCTION XWSOT =(0,0.),(64,0.),(70,2467.),(80,5156.),(92,7326.),...
                (95,7326.)

FUNCTION XNST  =(0,2.0),(20,1.82),(50,1.79),(70,1.13),(80,0.91),...
                (92,0.91),(95,0.91)
FUNCTION XNLV  =(0,2.5),(20,5.10),(50,3.38),(70,2.19),(80,2.40),...
                 (92,2.40),(95,2.40)
FUNCTION XNRT  =(0,1.0),(20,1.57),(50,1.38),(70,0.98),(80,1.05),...
                (92,1.05),(95,1.05)
FUNCTION XNSO  =(0,1.99),(70,1.99),(80,1.60),(92,1.45),(95,1.45)

* NOTE first and last values are dummy's
FUNCTION FSHT  =(0.00,0.68),...
                (0.36,0.68),(0.51,0.84),(0.61,0.81),(0.71,0.89),...
                (0.86,1.00),(1.06,0.96),(1.64,1.00),(2.10,1.00)
FUNCTION FLVT  =(0.00,0.53),...
                (0.36,0.53),(0.51,0.43),(0.61,0.31),(0.71,0.17),...
                (0.81,0.17),(0.86,0.00),(1.0,0.0),(1.06,0.00),...
                (1.64,0.00),(2.10,0.00)
FUNCTION FSOTB =(0.00,0.00),...
                (0.36,0.00),(0.51,0.00),(0.61,0.00),(0.71,0.00),...
                (0.81,0.00),(0.86,0.62),(1.0,1.0),(1.06,1.00),...
                (1.64,1.00),(2.10,1.00)
FUNCTION FSTT  =(0.00,0.47),...
                (0.36,0.47),(0.51,0.57),(0.61,0.69),(0.71,0.83),...
                (0.81,0.83),(0.86,0.38),(1.0,0.0),(1.06,0.00),...
                (1.64,0.00),(2.10,0.00)

END
```

PUAT, Pantnagar, India, 1987

```
*********************************************************************
Weather data used:
Pantnagar, India, 1987

PARAM LAT =  29.
PARAM ELV = 243.84
PARAM RDUCF = 1.
**********************************************************

**********************************************************
* B. Mishra & B.P. Dhyani, Pantnagar, India
* 1987, wet season
* variety:   PD 4
* treatment: 0 KG N/HA
**********************************************************
TITLE MISHRA & DHYANI, 0 KG N/HA

PARAM SWIPAR = 1
PARAM SWILAI = 4
PARAM SWINUP = 1
PARAM SWISIN = 1
PARAM SWINPH = 0
PARAM SWINPR = 1
PARAM SWIRES = 1
PARAM SWISAI = 0
PARAM SWIMEA = 1

PARAM DOYS   = 190.0
PARAM IDOYTR = 190
PARAM FGHDAY = 108.0

INCON WLVGI  = 16.0
INCON WSTSI  = 16.0
INCON WRTLI  = 13.5

PARAM FNSTI  = 0.021
PARAM FNLVI  = 0.025
PARAM FNRTI  = 0.012

PARAM DVSI   = 0.329
PARAM TSI    = 622.2

PARAM FSTR   = 0.29
PARAM DVRV   = 0.000529
PARAM DVRR   = 0.001566

PARAM NA = 4
TABLE DNAPT(1-4) = 190.,216.,240.,300.
PARAM NS = 6
TABLE DNOST(1-6)  = 190.,215.,239.,262.,298.,300.
TABLE NTOTMT(1-6) = 0.45, 12.78, 25.47, 43.29, 54.65, 54.65

* NOTE: first 2 values of WSO are dummy
*       last value of WRTL is dummy
*       first and last value of XLAITB and XSLATB are dummy's
FUNCTION XWLVGT=(0.,16.),(25.,404.),(49.,935.),(72.,1351.),(108.,1263.)
FUNCTION XWSTTB=(0.,16.),(25.,449.),(49.,1664.),(72.,5151.),...
                (108.,3647.)
FUNCTION XWRTLT=(0.,13.5),(25.,317.),(49.,638.),(72.,1016.),(108.,762.)
FUNCTION XWSOTB=(0.,0.0),(62.,0.0 ),(108.,3896.)

FUNCTION XLAITB=(161.,0.0001),(215.,1.17),(239.,2.04),(262.,2.61),...
                (298.,2.61)
FUNCTION SLATB =(0.,0.0028),(25.,0.0028),(49.,0.0022),(72.,0.0020),...
                (108.,0.0020)

* NOTE: last value of NRT is dummy
*       first value of NSO is dummy
FUNCTION XNLV  =(0.,2.5),(25.,1.51),(49.,1.03),(72.,0.89),(108.,0.32)
FUNCTION XNST  =(0.,2.1),(25.,0.95),(49.,0.76),(72.,0.53),(108.,0.24)
FUNCTION XNRT  =(0.,1.2),(25.,0.76),(49.,0.50),(72.,0.39),(108.,0.24)
FUNCTION XNSO  =(0.,0.0),(108.,0.998)

* value at 0.0 , 72.0 and 110.0 are dummy's
FUNCTION FLVT  =( 0.,0.47),...
                (13.,0.47),(37.,0.30),(61.,0.11),(72.,0.00),...
                (90.,0.00),(110.,0.00)
FUNCTION FSTT  =( 0.,0.53),...
                (13.,0.53),(37.,0.70),(61.,0.89),(72.,0.00),...
                (90.,0.00),(110.,0.00)
FUNCTION FSHT  =( 0.,0.73),...
                (13.,0.73),(37.,0.84),(61.,0.91),(72.,1.00),(110.,1.00)
FUNCTION FSOT  =( 0.,0.00),(13.,0.00),(37.,0.00),(61.,0.00),...
                (72.,1.00),(90.,1.00),(110.,1.00)

END

**********************************************************
* B. Mishra & B.P. Dhyani, Pantnagar, India
* 1987, wet season
* variety:   PD 4
* treatment: 60 KG N/HA
**********************************************************
TITLE MISHRA & DHYANI, 60 KG N/HA

PARAM FSTR   = 0.32

TABLE NTOTMT(1-6) = 0.45, 19.07, 51.77, 76.06, 82.88,82.88

* NOTE: first 2 values of WSO are dummy
*       last value of WRTL is dummy
FUNCTION XWLVGT=(0.,16.),(25.,582.),(49.,1644.),(72.,2306.),...
                (108.,1840.)
FUNCTION XWSTTB=(0.,16.),(25.,605.),(49.,2651.),(72.,7264.),...
                (108.,4933.)
FUNCTION XWRTLT=(0.,13.5),(25.,349.),(49.,976.),(72.,1434.),...
                (108.,1075.)
FUNCTION XWSOTB=(0.,0.0),(62.,0.0 ),(108.,5562.)

* NOTE: last value of NRT is dummy
*       first value of NSO is dummy
*       first and last value of XLAITB and SLATB are dummy's
FUNCTION XNLV  =(0.,2.5),(25.,1.69),(49.,1.36),(72.,1.11),(108.,0.34)
FUNCTION XNST  =(0.,2.1),(25.,1.03),(49.,0.87),(72.,0.60),(108.,0.31)
FUNCTION XNRT  =(0.,1.2),(25.,0.86),(49.,0.65),(72.,0.48),(108.,0.31)
FUNCTION XNSO  =(0.,0.0),(108.,1.01)
FUNCTION XLAITB=(161.,0.0001),(215.,1.59),(239.,4.06),(262.,4.98),...
                (298.,4.98)
FUNCTION SLATB =(0.,0.0029),(25.,0.0029),(49.,0.0026),(72.,0.0021),...
                (108.,0.0021)

* value at 0., 72. and 110. are dummy's
FUNCTION FLVT  =(0.,0.49),...
                (13.,0.49),(37.,0.34),(61.,0.13),(72.,0.00),...
                (90.,0.00),(110.,0.00)
FUNCTION FSTT  =(0.,0.51),...
                (13.,0.51),(37.,0.66),(61.,0.87),(72.,0.00),...
                (90.,0.00),(110.,0.00)
FUNCTION FSHT  =(0.,0.77),...
                (13.,0.77),(37.,0.83),(61.,0.92),(72.,1.00),(110.,1.00)
FUNCTION FSOT  =( 0.,0.00),...
                (13.,0.00),(37.,0.00),(61.,0.00),(72.,1.00),...
                (90.,1.00),(110.,1.00)
```

```
END

**********************************************************
* B. Mishra & B.P. Dhyani, Pantnagar, India
* 1987, wet season
* variety:   PD 4
* treatment: 120 KG N/HA
**********************************************************
TITLE MISHRA & DHYANI, 120 KG N/HA


PARAM FSTR    = 0.30

TABLE NTOTMT(1-6) = 0.45, 25.34, 70.38, 100.07, 112.80,112.80

* NOTE: first 2 values of WSO are dummy
*        last value of WRTL is dummy
*        first and last value of XLAITB and SLATB are dummy's
FUNCTION XWLVGT=(0.,16.),(25.,721.),(49.,2247.),(72.,2715.),...
                (108.,2040.)
FUNCTION XWSTTB=(0.,16.),(25.,760.),(49.,3146.),(72.,8172.),...
                (108.,5701.)
FUNCTION XWRTLT=(0.,13.5),(25.,414.),(49.,1034.),(72.,1566.),...
                (108.,1175.)
FUNCTION XWSOTB =(0.,0.0),(62.,0.0 ),(108.,6418.)

FUNCTION XLAITB=(161.,0.0001),(215.,2.24),(239.,5.80),(262.,6.48),...
                (298.,6.48)
FUNCTION SLATB =(0.,0.0032),(25.,0.0032),(49.,0.0026),(72.,0.0024),...
                (108.,0.0024)

* NOTE: last value of NRT is dummy
*        first value of NSO is dummy
FUNCTION XNLV  =(0.,2.5),(25.,1.88),(49.,1.48),(72.,1.28),(108.,0.51)
FUNCTION XNST  =(0.,2.1),(25.,1.06),(49.,0.95),(72.,0.69),(108.,0.42)
FUNCTION XNRT  =(0.,1.2),(25.,0.90),(49.,0.70),(72.,0.57),(108.,0.42)
FUNCTION XNSO  =(0.,0.0),(108.,1.118)

* value at 0., 72. and 110. are dummy's
FUNCTION FLVT  =( 0.,0.49),...
                (13.,0.49),(37.,0.39),(61.,0.09),(72.,0.00),...
                (90.,0.00),(110.,0.00)
FUNCTION FSTT  =( 0.,0.51),...
                (13.,0.51),(37.,0.61),(61.,0.91),(72.,0.00),...
                (90.,0.00),(110.,0.00)
FUNCTION FSHT  =( 0.,0.78),...
                (13.,0.78),(37.,0.86),(61.,0.91),(72,1.00),(110.,1.00)
FUNCTION FSOT  =( 0.,0.00),...
                (13.,0.00),(37.,0.00),(61.,0.00),(72.,1.00),...
                (90.,1.00),(110.,1.00)

END

**********************************************************
* B. Mishra & B.P. Dhyani, Pantnagar, India
* 1987, wet season
* variety:   PD 4
* treatment: 180 KG N/HA
**********************************************************
TITLE MISHRA & DHYANI, 180 KG N/HA

PARAM FSTR    = 0.25

TABLE NTOTMT(1-6) = 0.45, 32.63, 98.43, 119.27, 132.53,132.53

* NOTE: first 2 values of WSO are dummy
*        last value of WRTL is dummy
*        first and last value of XLAITB and SLATB are dummy's
FUNCTION XWLVGT=(0.,16.),(25.,857.),(49.,2561.),(72.,3183.),...
                (108.,2641.)
FUNCTION XWSTTB=(0.,16.),(25.,940.),(49.,4252.),(72.,8539.),...
                (108.,6394.)
FUNCTION XWRTLT=(0.,13.5),(25.,479.),(49.,1276.),(72.,1806.),...
                (108.,1355.)
FUNCTION XWSOTB =(0.,0.0),(62.,0.0),(108.,6643.)

FUNCTION XLAITB =(161.,0.0001),(215.,2.90),(239.,6.36),(262.,7.52),...
                 (298.,7.52)
FUNCTION SLATB  =(0.,0.0034),(25.,0.0034),(49.,0.0025),(72.,0.0024),...
                 (108.,0.0024)

* NOTE: last value of NRT is dummy
*        first value of NSO is dummy
FUNCTION XNLV   =(0.,2.5),(25.,2.02),(49.,1.66),(72.,1.42),(108.,0.58)
FUNCTION XNST   =(0.,2.1),(25.,1.12),(49.,1.06),(72.,0.73),(108.,0.51)
FUNCTION XNRT   =(0.,1.2),(25.,1.00),(49.,0.85),(72.,0.65),(108.,0.51)
FUNCTION XNSO   =(0.,0.0),(108.,1.141)

* value at 0., 72. and 110. are dummy's
FUNCTION FLVT   =( 0.,0.48),...
                 (13.,0.48),(37.,0.34),(61.,0.13),(72.,0.00),...
                 (90.,0.00),(110.,0.00)
FUNCTION FSTT   =( 0.,0.52),...
                 (13.,0.52),(37.,0.66),(61.,0.87),(72.,0.00),...
                 (90.,0.00),(110.,0.00)
FUNCTION FSHT   =( 0.,0.79),...
                 (13.,0.79),(37.,0.66),(61.,0.90),(72,1.00),(110.,1.00)
FUNCTION FSOT   =( 0.,0.00),...
                 (13.,0.00),(37.,0.00),(61.,0.00),(72.,1.00),...
                 (90.,1.00),(110.,1.00)

END

**********************************************************
* B. Mishra & B.P. Dhyani, Pantnagar, India
* 1987, wet season
* variety:   PD 4
* treatment: 240 KG N/HA
**********************************************************
TITLE MISHRA & DHYANI, 240 KG N/HA

PARAM FSTR    = 0.21

TABLE NTOTMT(1-6) = 0.45, 41.12, 117.40, 131.08, 146.73,146.73

* NOTE: first 2 values of WSO are dummy
*        last value of WRTL is dummy
*        first and last value of XLAITB and SLATB are dummy's
FUNCTION XWLVGT=(0.,16.),(25.,990.),(49.,2669.),(72.,3399.),...
                (108.,2809.)
FUNCTION XWSTTB=(0.,16.),(25.,1053.),(49.,5105.),(72.,9086.),...
                (108.,7169.)
FUNCTION XWRTLT=(0.,13.5),(25.,520.),(49.,1500.),(72.,2041.),...
                (108.,1530.)
FUNCTION XWSOTB =(0.,0.0),(62.,0.0),(108.,6707.)
*FUNCTION XLAITB=(0.,0.0001),(25.,3.69),(49.,6.95),(72.,8.20),...
                 (108.,8.20)
FUNCTION XLAITB=(161.,0.0001),(215.,3.69),(239.,6.95),(262.,8.20),...
                (298.,8.20)
FUNCTION SLATB =(0.,0.0036),(25.,0.0036),(49.,0.0026),(72.,0.0024),...
                (108.,0.0024)

* NOTE: last value of NRT is dummy
*        first value of NSO is dummy
FUNCTION XNLV  =(0.,2.5),(25.,2.24),(49.,1.71),(72.,1.47),(108.,0.64)
FUNCTION XNST  =(0.,2.1),(25.,1.26),(49.,1.15),(72.,0.74),(108.,0.53)
FUNCTION XNRT  =(0.,1.2),(25.,1.09),(49.,0.87),(72.,0.68),(108.,0.53)
FUNCTION XNSO  =(0.,0.0),(108.,1.198)
```

```
* value at 0. ,72. and 110. are dummy's
FUNCTION FLVT  =( 0.,0.48),...
                 (13.,0.48),(37.,0.25),(61.,0.15),(72.,0.00),...
                 (90.,0.00),(110.,0.00)
FUNCTION FSTT  =( 0.,0.52),...
                 (13.,0.52),(37.,0.75),(61.,0.85),(72.,0.00),...
                 (90.,0.00),(110.,0.00)
FUNCTION FSHT  =( 0.,0.80),...
                 (13.,0.80),(37.,0.87),(61.,0.90),(72,1.00),(110.,1.00)
FUNCTION FSOT  =( 0.,0.00),...
                 (13.,0.00),(37.,0.00),(61.,0.00),(72.,1.00),...
                 (90.,1.00),(110.,1.00)

END
```

IRRI, Los Baños, Philippines, 1990-1991

```
*********************************************************
Weather data used:
Los Banos (IRRI), Philippines, wetland station, 1990-1991

PARAM RDUCF = 1.E6
PARAM ELV   = 21.0
PARAM LAT   = 14.17
PARAM ZREF  =  2.0
*********************************************************

*********************************************************
* L. Bastiaans, IRRI, Los Banos, Philippines
* 1990/1991, wetland site
* variety:   IR 50
* treatment: PLOT 1
*********************************************************
TITLE  BASTIAANS, PLOT 1

PARAM SWIPAR = 1
PARAM SWILAI = 1
PARAM SWINUP = 2
PARAM SWISIN = 1
PARAM SWINPH = 1
PARAM SWINPR = 1
PARAM SWIRES = 1
PARAM SWISAI = 0
PARAM SWIMEA = 1

PARAM DOYS   = 339.
PARAM IDOYTR = 339
PARAM FGHDAY = 63.0

INCON WLVGI  = 47.5
INCON WSTSI  = 30.8
INCON WRTLI  = 12.75

* based on the maximum values at DVS=0.4
PARAM FNSTI  = 0.03
PARAM FNLVI  = 0.05
PARAM FNRTI  = 0.013

PARAM DVSI   = 0.34
PARAM TSI    = 213.9

PARAM FSTR   = 0.25
* PARAM RGRL = 0.152
PARAM DVRV   = 0.000807
PARAM DVRR   = 0.001901

PARAM NA = 5
TABLE DNAPT(1-5)  = 339.,361.,388.,396.,432.
PARAM NS = 7
TABLE DNCST(1-7)  = 387.,394.,402.,411.,418.,425.,432.
TABLE NTCTMT(1-7) = 115.7,164.7,179.3,184.3,180.9,178.1,174.9

PARAM SLAC   = 0.0027
FUNCTION SLAFAC = 0.303,1.63,0.390,1.44,0.488,1.09,0.533,0.95,...
                  0.589,1.29,0.646,1.26,0.716,1.17,0.800,1.14,...
                  0.896,1.09,1.011,1.00,1.330,0.82,1.562,0.69,...
                  1.783,0.62,2.011,0.54

* based on green leaf
* based on green leaf
FUNCTION XWLVGT=(13.,  36.54),(19.,  88.00),(26., 391.05),...
                (29., 733.80),(33.,1042.84),(37.,1286.64),...
                (42.,1681.50),(48.,2170.50),(55.,2581.48),...
                (63.,2734.56),(72.,2582.72),(79.,2387.44),...
                (86.,2119.68),(93.,1904.25),(100.,1904.25)
FUNCTION XWSTTB=(13.,  26.46),(19.,  72.00),(26., 319.95),...
                (29., 489.20),(33., 755.16),(37.,1009.36),...
                (42.,1681.50),(48.,2170.50),(55.,3285.52),...
                (63.,4481.64),(72.,4058.56),(79.,3472.64),...
                (86.,3415.04),(93.,3427.65),(100.,3427.65)
FUNCTION XWSOTB=(13.,   0.00),(19.,   0.00),(26.,   0.00),...
                (29.,   0.00),(33.,   0.00),(37.,   0.00),...
                (42.,   0.00),(48.,   0.00),(55.,   0.00),...
                (63., 379.80),(72.,2582.72),(79.,4991.92),...
                (86.,6241.28),(93.,7363.10),(100.,7363.10)

FUNCTION LAILNT=(229.95,-1.82),(336.45,-1.06),(457.05,0.15),...
                (511.05, 0.64),(580.1 , 1.30),(650.75,1.49),...
                (737.00, 1.67),(841.40, 1.90),(960.75,2.04),...
                (1101.6, 2.01),(1261.6, 1.75),(1383.1,1.49),...
                (1499.3, 1.27),(1619.3  1.03),(1739.4,1.03)

FUNCTION XNLV  =(13.,5.30),(19.,5.60),(26.,5.25),(29.,5.16),...
                (33.,4.73),(37.,4.52),(42.,4.65),(48.,3.94),...
                (55.,4.31),(63.,3.96),(72.,3.60),(79.,3.31),...
                (86.,2.97),(93.,2.54),(100.,2.54)
* N amount in stems in kg/ha versus DAT
FUNCTION XNST  =( 0.0,33.0),...
                (48.0,33.0),(55.0,56.7),(63.0,65.9),(72.0,58.1),...
                (79.0,39.7),(86.0,33.8),(93.0,26.8),(100.0,26.8)
* N amount in storage organs in kg/ha versus DAT
FUNCTION XNSO  =( 0.0, 0.0),...
                (48.0, 0.0),(55.0, 0.0),(63.0,  5.8),( 72.0, 39.2),...
                (79.0,73.6),(86.0,95.1),(93.0,111.6),(100.0,111.6)

* first and last values are dummy's
FUNCTION FLVT  =(0.0,0.53),(13.,0.53),...
                (16.,0.53),(23.,0.55),(28.,0.67),(31.,0.54),...
                (35.,0.49),(40.,0.37),(45.,0.50),(52.,0.27),...
                (59.,0.09),(68.,0.00),(76.,0.00),(83.,0.00),...
                (90.,0.00),(97.,0.00),(100.,0.00)
FUNCTION FSTT  =(0.0,0.47),(13.,0.47),...
                (16.,0.47),(23.,0.45),(28.,0.33),(31.,0.46),...
                (35.,0.51),(40.,0.63),(45.,0.50),(52.,0.73),...
                (59.,0.69),(68.,0.00),(76.,0.00),(83.,0.00),...
                (90.,0.01),(97.,0.00),(100.,0.00)
FUNCTION FSOT  =(0.0,0.00),(13.,0.00),...
                (16.,0.00),(23.,0.00),(28.,0.00),(31.,0.00),...
                (35.,0.00),(40.,0.00),(45.,0.00),(52.,0.00),...
                (59.,0.22),(68.,1.00),(76.,1.00),(83.,1.00),...
                (90.,0.99),(97.,1.00),(100.,1.00)
* Penning de Vries et al, 1989
FUNCTION FSHT  =(0.0,0.86),(0.5,0.86),(0.6,0.86),(0.7,0.95),...
                (0.8,0.94),(1.0,0.89),(1.1,1.00),(2.5,1.00)

END

*********************************************************
* L. Bastiaans, IRRI, Los Banos, Philippines
* 1990/1991, wetland site
* variety:   IR 50
* treatment: PLOT 5
*********************************************************
TITLE  BASTIAANS, PLOT 5
```

```
PARAM FSTR  = 0.25
* PARAM RGRL  = 0.127

PARAM NA = 5
TABLE DNAPT(1-5)  = 339.,361.,388.,396.,432.
PARAM NS = 7
TABLE DNCST(1-7)  = 387.,394.,402.,411.,418.,425.,432.
TABLE NTOTWT(1-7) = 100.8,154.5,148.6,165.0,171.2,159.8,156.7


* based on green leaf
FUNCTION XWLVGT=(13.,  66.00),(19., 153.12),(26., 492.00),...
                (29., 798.56),(33., 976.64),(37.,1189.62),...
                (42.,1531.02),(48.,1986.22),(55.,2556.84),...
                (63.,2501.38),(72.,2389.14),(79.,2324.52),...
                (86.,2073.60),(93.,1946.72),(100.,1946.72)
FUNCTION XWSTTB=(13.,  44.00),(19., 110.88),(26., 328.00),...
                (29., 489.44),(33., 767.36),(37.,1013.38),...
                (42.,1470.98),(48.,2239.78),(55.,3254.16),...
                (63.,4267.06),(72.,4043.16),(79.,3803.76),...
                (86.,3456.00),(93.,3285.09),(100.,3285.09)
FUNCTION XWSOT =(13.,   0.00),(19.,   0.00),(26.,   0.00),...
                (29.,   0.00),(33.,   0.00),(37.,   0.00),...
                (42.,   0.00),(48.,   0.00),(55.,   0.00),...
                (63., 514.99),(72.,2848.59),(79.,4543.38),...
                (86.,5990.40),(93.,6935.19),(100.,6935.19)

* based on green leaf
FUNCTION LAILNT=(229.95,-1.15),(336.45,-0.64),(457.05,0.48),...
                (513.05, 0.68),(580.10, 1.21),(650.75,1.37),...
                (737.00, 1.54),(841.40, 1.72),(960.75,2.08),...
                (1101.6, 1.90),(1263.6, 1.63),(1383.1,1.39),...
                (1499.3, 1.19),(1619.3, 0.82),(1739.4,0.82)

FUNCTION XNLV  =(0.0,5.00),...
                (13.,5.19),(19.,5.46),(26.,5.21),(29.,4.99),...
                (33.,4.46),(37.,4.32),(42.,4.38),(48.,3.72),...
                (55.,4.16),(63.,3.48),(72.,3.45),(79.,3.27),...
                (86.,2.90),(93.,2.45),(100.,2.45)
* N amount in stems in kg/ha versus DAT
FUNCTION XNST  =( 0.0,31.0),...
                (48.0,31.0),(55.0,54.3),(63.0,57.4),(72.0,51.1),...
                (79.0,42.0),(86.0,28.3),(93.0,23.6),(100.0,23.6)
* N amount in storage organs in kg/ha versus DAT
FUNCTION XNSO  =( 0.0, 0.0),...
                (48.0, 0.0),(55.0, 0.0),(63.0,  7.4),( 72.0, 42.3),...
                (79.0,69.6),(86.0,88.6),(93.0,100.7),(100.0,100.7)


* first and last values are dummy's
FUNCTION FLVT  =(0.0,0.57),(13.,0.57),...
                (16.,0.57),(23.,0.61),(28.,0.66),(31.,0.39),...
                (35.,0.46),(40.,0.43),(45.,0.37),(52.,0.36),...
                (59.,0.00),(68.,0.00),(76.,0.00),(83.,0.00),...
                (90.,0.00),(97.,0.00),(100.,0.00)
FUNCTION FSTT  =(0.0,0.43),(13.,0.43),...
                (16.,0.43),(23.,0.39),(28.,0.34),(31.,0.61),...
                (35.,0.54),(40.,0.57),(45.,0.63),(52.,0.64),...
                (59.,0.66),(68.,0.00),(76.,0.00),(83.,0.00),...
                (90.,0.00),(97.,0.00),(100.,0.00)
FUNCTION FSOT  =(0.,0.00),(13.,0.00),...
                (16.,0.00),(23.,0.00),(28.,0.00),(31.,0.00),...
                (35.,0.00),(40.,0.00),(45.,0.00),(52.,0.00),...
                (59.,0.34),(68.,1.00),(76.,1.00),(83.,1.00),...
                (90.,1.00),(97.,1.00),(100.,1.00)

END
```

IRRI, Los Baños, Philippines, 1991

```
*******************************************************************
Weather data used:
IRRI, Los Banos, Philippines, 1991 wet season

PARAM LAT          = 14.18
*************************************************************

*************************************************************
* R. Torres et al., IRRI, The Philippines
* 1991, wet season
* variety:   LINE
* treatment: 0 KG/HA
*************************************************************

TITLE R. Torres et al. IRRI 1991 WS LINE-0N

PARAM SWIPAR = 0
PARAM SWILAI = 4
PARAM SWINUP = 1
PARAM SWISIN = 1
PARAM SWINPH = 0
PARAM SWINPR = 1
PARAM SWIRES = 1
PARAM SWISAI = 0
PARAM SWIMEA = 0

PARAM DOYS   = 194.
PARAM IDOYTR = 194
PARAM PGHDAY = 85.

INCON WLVGI  =  6.5
INCON WSTSI  =  7.5
INCON WRTLI  = 14.0

PARAM FNSTI  = 0.0176
PARAM FNLVI  = 0.0272
PARAM FNRTI  = 0.0176

PARAM DVSI   = 0.13410
PARAM TSI    = 242.1

PARAM FSTR   = 0.40
*PARAM RGRL  = 0.0060
PARAM DVRV   = 0.000554
PARAM DVRR   = 0.002278

PARAM NA = 3
TABLE DNAPT(1-3)  = 182.,193.,310.
PARAM NS = 9
TABLE DNOST(1-9)  = 194.,202.,211.,219.,249.,263.,279.,288.,302.
TABLE NTOTMT(1-9) = 0.31,1.96,4.34,14.16,30.89,40.35,46.84,47.04,52.71

* first and last values are dummy's
PARAM SLAC = 0.0016
FUNCTION SLAFAC=0.000,1.870,0.134,1.87,0.178,1.87,0.273,1.65,...
                0.359,1.840,0.678,1.37,0.835,1.40,1.008,1.00,...
                1.406,1.180,2.008,0.78,2.100,0.78

FUNCTION XWLVGT=(180.,    6.5),...
                (194.,    6.5),(202.,  29.3),(211.,  71.3),...
                (219.,  230.8),(249.,1099.8),(263.,1481.8),...
                (279.,1471.5),(288.,1237.5),(302., 564.5)
FUNCTION XWSTTB=(180.,    7.5),...
                (194.,    7.5),(202.,  20.0),(211.,  52.8),...
                (219.,  211.5),(249.,1210.8),(263.,2608.3),...
                (279.,4236.0),(288.,3475.0),(302.,2188.5)
FUNCTION XWSOTB=(180.,    0.0),...
                (194.,    0.0),(263.,    0.0),(279., 915.8),...
                (288.,2553.3),(302.,4608.3)
FUNCTION XWLVDT=(180.,    0.0),...
                (249.,    0.0),(263., 369.0),(279., 2962.),...
                (288.,1452.0),(302.,2657.0)
FUNCTION XWTDMT=(180.,   14.0),...
                (194.,   14.0),(202.,  49.3),(211., 124.0),...
                (219.,  442.3),(249.,2610.5),(263.,4459.0),...
                (279.,7585.3),(288.,8717.8),(302.,10018.3)
FUNCTION XWRTLT=(180.,    0.0),(302.,    0.0)

FUNCTION XLAITB=(180.,0.02),...
                (194.,0.02),(202.,0.09),(211.,0.17),(219.,0.70),...
                (249.,2.47),(263.,3.41),(279.,2.42),(288.,2.40),...
                (302.,0.72)
FUNCTION XNFLVT=(180.,0.804),...
                (194.,0.804),(202.,1.545),(211.,1.680),...
                (219.,1.368),(249.,0.903),(263.,0.708),...
                (279.,0.858),(288.,0.572),(302.,0.660)
FUNCTION SLATB =(180.,.0034),...
                (194.,.0036),(202.,.0030),(211.,.0024),...
                (219.,.0031),(249.,.0022),(263.,.0023),...
                (279.,.0016),(288.,.0019),(302.,.0013)

FUNCTION XNLV  =(  0.,2.72),( 8.,4.60),(17.,4.06),(25.,4.11),...
                ( 55.,2.03),(69.,1.63),(85.,1.41),(94.,1.26),...
                (108.,0.84)
FUNCTION XNST  =(  0.,1.76),( 8.,3.06),(17.,2.74),(25.,2.21),...
                ( 55.,0.71),(69.,0.62),(85.,0.41),(94.,0.35),...
                (108.,0.34)
FUNCTION XNSO  =(  0.,0.00),( 8.,0.00),(17.,0.00),(25.,0.00),...
                ( 55.,0.00),(69.,0.00),(85.,0.95),(94.,0.76),...
                (108.,0.88)
FUNCTION XNRT  =(  0.,0.00),(108.,0.00)

FUNCTION FSHT  =(0.0,0.5),(0.43,0.75),(1.0,1.0),(2.1,1.0)
FUNCTION FLVT  =(0.000,0.560),(0.156,0.645),(0.226,0.562), ...
                (0.316,0.501),(0.518,0.401),(0.756,0.258),...
                (0.922,0.000),(1.207,0.000),(1.707,0.000),(2.1,0.0)
FUNCTION FSTT  =(0.000,0.440),(0.156,0.355),(0.226,0.438), ...
                (0.316,0.499),(0.518,0.599),(0.756,0.742), ...
                (0.922,0.640),(1.207,0.000),(1.707,0.000),(2.1,0.0)
FUNCTION FSOT  =(0.000,0.000),(0.145,0.000),(0.756,0.000), ...
                (0.922,0.360),(1.207,1.000),(1.707,1.000),(2.1,1.0)

END

*************************************************************
* R. Torres et al., IRRI, The Philippines
* 1991 wet season
* variety:   LINE
* treatment: 80 KG/HA
*************************************************************

TITLE R. TORRES ET AL. IRRI 1991 WS    LINE-80N

* PARAM RGRL = 0.0090

PARAM NA = 3
TABLE DNAPT(1-3)  = 193.,224.,310.
PARAM NS = 9
TABLE DNOST(1-9)  = 194.,202.,211.,219.,249.,263.,279.,288.,302.
```

```
FUNCTION XWRTLT=(180.,   0.0),(288.,   0.0)

FUNCTION XLAITB=(180.,0.03),...
                (194.,0.03),(202.,0.19),(211.,0.33),(219.,1.05),...
                (240.,3.68),(254.,5.01),(261.,4.63),(273.,3.52),...
                (288.,1.94)
FUNCTION XNFLVT=(180.,0.917),...
                (194.,0.917),(202.,1.140),(211.,1.708),(219.,1.480),...
                (240.,1.341),(254.,0.918),(261.,0.878),(273.,0.681),...
                (288.,0.584)
FUNCTION SLATB =(180.,.0033),...
                (194.,.0033),(202.,.0041),(211.,.0023),(219.,.0029),...
                (240.,.0022),(254.,.0022),(261.,.0023),(273.,.0023),...
                (288.,.0019)

FUNCTION XNLV  =( 0.,3.02),( 8.,4.66),(17.,4.01),(25.,4.25),...
                (47.,2.93),(60.,2.03),(67.,2.01),(79.,1.62),...
                (94.,1.09)
FUNCTION XNST  =( 0.,1.89),( 8.,3.08),(17.,2.50),(25.,2.37),...
                (47.,1.13),(60.,0.66),(67.,0.59),(79.,0.47),...
                (94.,0.45)
FUNCTION XNSO  =( 0.,0.00),( 8.,0.00),(17.,0.00),(25.,0.00),...
                (47.,0.00),(60.,0.00),(67.,0.91),(79.,0.87),...
                (94.,0.99)
FUNCTION XNRT  =( 0.,0.00),(94.,0.00)


FUNCTION FLVT  =(0.000,0.560),(0.193,0.532),(0.281,0.658),...
                (0.393,0.529),(0.584,0.516),(0.817,0.210),...
                (0.962,0.000),(1.234,0.000),(1.730,0.000),(2.1,0.0)
FUNCTION FSTT  =(0.000,0.440),(0.193,0.468),(0.281,0.342),...
                (0.393,0.471),(0.584,0.484),(0.817,0.790),...
                (0.962,0.111),(1.234,0.000),(1.730,0.000),(2.1,0.0)
FUNCTION FSOT  =(0.000,0.000),(0.173,0.000),(0.817,0.000),...
                (0.962,0.889),(1.234,1.000),(1.730,1.000),(2.1,1.0)

END


**************************************************************
* R. Torres et al., IRRI, The Philippines
* 1991 wet season
* variety:   IR72
* treatment: 110 KG/HA
**************************************************************

TITLE R. TORRES ET AL.  IRRI 1991 WS   IR72-110N

* PARAM RGRL   = 0.0090

PARAM NA=5
TABLE DNAPT (1-5) = 193.,218.,244.,262.,296.
PARAM NS=9
TABLE DNOST(1-9) = 194.,202.,211.,219.,241.,254.,261.,273.,288.
TABLE WTOTMT(1-9)= 0.40,1.02,7.51,19.16,55.46,65.09,78.95,86.11,99.67

* first and last values are dummy's
PARAM SLAC = 0.0021
FUNCTION SLAFAC =0.000,1.67,0.167,1.67,0.340,1.02,0.446,1.30,...
                 0.735,0.94,0.913,1.04,1.011,1.00,1.457,1.03,...
                 2.011,0.96,2.100,0.96

FUNCTION XWLVGT=(180.,   8.5),...
                (194.,   8.5),(202.,  16.8),(211.,  133.8),...
                (219., 342.5),(240.,1503.3),(254.,1935.3),...
                (261.,2028.5),(273.,1564.8),(288., 892.8)
FUNCTION XWSTTB=(180.,   7.5),...
                (194.,   7.5),(202.,  10.0),(211.,  88.5),...
                (219., 275.8),(240.,1458.3),(254.,3208.5),...
                (261.,3856.3),(273.,2965.0),(288.,3119.8)
FUNCTION XWSOTB=(180.,   0.0),...
                (194.,   0.0),(254.,   0.0),(261.,1002.5),...
                (273.,3997.0),(288.,5674.0)
FUNCTION XWTDMT=(180.,  16.0),...
                (194.,  16.0),(202.,  26.8),(211.,  222.3),...
                (219., 618.3),(240.,2961.5),(254., 5439.0),...
                (261.,7503.0),(273.,9322.5),(288.,11534.5)
FUNCTION XWLVDT=(180.,   0.0),(240.,   0.0),(254.,  296.0),...
                (261., 616.0),(273., 796.0),( 288.,1848.0)
FUNCTION XWRTLT=(180.,   0.0),(288.,   0.0)


FUNCTION XLAITB=(180.,0.03),...
                (194.,0.03),(202.,0.15),(211.,0.29),(219.,0.94),...
                (240.,3.00),(254.,4.27),(261.,4.29),(273.,3.42),...
                (288.,1.81)
FUNCTION XNFLVT=(180.,0.917),...
                (194.,0.917),(211.,1.830),(219.,1.421),...
                (240.,1.344),(254.,0.947),(261.,0.986),...
                (273.,0.792),(288.,0.621)
FUNCTION SLATB =(180.,0.0033),...
                (194.,0.0033),(211.,.0022),(219.,.0028),...
                (254.,0.0022),(261.,.0021),(273.,.0022),(288.,.0020)

FUNCTION XNLV  =( 0.,3.02),( 8.,4.35),(17.,4.02),(25.,3.91),...
                (47.,2.69),(60.,2.09),(67.,2.09),(79.,1.79),...
                (94.,1.26)
FUNCTION XNST  =( 0.,1.89),( 8.,2.88),(17.,2.40),(25.,2.09),...
                (47.,1.04),(60.,0.77),(67.,0.68),(79.,0.57),...
                (94.,0.58)
FUNCTION XNSO  =( 0.,0.00),( 8.,0.00),(17.,0.00),(25.,0.00),...
                (47.,0.00),(60.,0.00),(67.,1.03),(79.,1.03),...
                (94.,1.24)
FUNCTION XNRT  =( 0.,0.00),(94.,0.00)

FUNCTION FLVT  =(0.000,0.560),(0.193,0.767),(0.281,0.598),...
                (0.393,0.527),(0.584,0.495),(0.817,0.198),...
                (0.962,0.053),(1.234,0.000),(1.730,0.000),...
                (2.100,0.000)
FUNCTION FSTT  =(0.000,0.440),(0.193,0.233),(0.281,0.402),...
                (0.393,0.473),(0.584,0.505),(0.817,0.802),...
                (0.962,0.372),(1.234,0.000),(1.730,0.000),...
                (2.100,0.000)
FUNCTION FSOT  =(0.000,0.000),(0.173,0.000),(0.817,0.000),...
                (0.962,0.575),(1.234,1.000),(1.730,1.000),
                (2.100,1.000)

END
```

IRRI, Los Baños, Philippines, 1992

```
************************************************************
* Weather data used:
* IRRI, Los Banos, Philippines, 1992 dry season


PARAM LAT         = 14.18
************************************************************

************************************************************
* R. Torres et al., IRRI, The Philippines
* 1992 dry season
* variety:   IR72
* treatment: 0 KG/HA
************************************************************

TITLE R. TORRES ET AL.  1992 DS       IR72 - 0N

PARAM DOYS   = 16.
PARAM IDOYTR = 16
PARAM FGHDAY = 68.0

INCON WLVGI  =  6.4
INCON WSTSI  =  5.1
INCON WRTLI  = 11.5

PARAM FNSTI = 0.0126
PARAM FNLVI = 0.0271
PARAM FNRTI = 0.0126

PARAM DVSI  = 0.152
PARAM TSI   = 202.6

PARAM FSTR  = 0.20
* PARAM RGRL  = 0.0060
PARAM DVRV  = 0.000751
PARAM DVRR  = 0.00168

PARAM NA=2
TABLE DNAPT (1-2) = 16.,120.
PARAM NS=6
TABLE DNOST (1-6)= 16.,33.,58.,68.,84.,114.
TABLE NTOTMT(1-6)= 0.24,8.30,22.33,37.41,51.03,58.84

* first and last values are dummy's
PARAM SLAC = 0.0013
FUNCTION SLAFAC=0.0,3.62,0.152,3.62,0.323,2.26,0.653,1.72,...
                0.787,1.01,1.011,1.00,1.464,1.26,2.011,1.03,2.1,1.03

FUNCTION XWLVGT =( 0.,   6.4),...
                 (16.,   6.4),(34., 116.3),(58.,693.2),...
                 (68.,1203.5),(84.,1523.5),(97.,926.7),(114.,545.2)...
FUNCTION XWLVDT =( 0.,  0.0),...
                 (16.,  0.0),(34.,    0.0),( 58.,  59.6),(68.,277.6),...
                 (84.,663.9),(97.,1094.4),(114.,1608.2
FUNCTION XWSTTB =( 0.,    5.1),...
                 (16.,    5.1),(34.,  90.2),( 58., 844.0),...
                 (68.,2133.1),(84.,3632.2),(97.,2619.3),(114.,2202.7)
FUNCTION XWSOTB =( 0.,  0.0),...
                 (16.,  0.0),(34.,    0.0),( 58.,    0.0),(68.,0.0),...
                 (84.,646.7),(97.,4003.5),(114.,5608.3)
FUNCTION XWTDMT =(0.,    11.5),...
                 (16.,  11.5),(34., 206.5),( 58.,1596.8),...
                 (68.,3614.2),(84.,6456.3),(97.,8640.9),(114.,9964.4)
FUNCTION XWRTLT =(0.,    0.0),(114.,  0.0)

FUNCTION XLAITB =(  0.,0.03),...
                 ( 16.,0.03),(34.,0.34),(58.,1.54),...
                 ( 68.,1.57),(84.,1.96),(97.,1.51),...
                 (114.,0.73)
FUNCTION XNFLVT =( 0.,0.578),(...
                 (16.,0.578),(34.,1.707),( 58.,1.056),...
                 (84.,1.274),(97.,0.806),(114.,0.713)
FUNCTION SLATB  =(  0.,0.0047),...
                 ( 16.,0.0047),(34.,0.0029),(58.,0.0022),...
                 ( 68.,0.0013),(84.,0.0013),(97.,0.0016),...
                 (114.,0.0013)

FUNCTION XNLV   =( 0.,2.71),(17.,4.99),(42.,2.35),(52.,1.98),...
                 (68.,1.65),(82.,1.31),(98.,0.96)
FUNCTION XNST   =( 0.,1.26),(17.,2.77),(42.,0.72),(52.,0.64),...
                 (68.,0.53),(82.,0.35),(98.,0.35)
FUNCTION XNSO   =( 0.,0.00),(17.,0.00),(42.,0.00),(52.,0.00),...
                 (68.,1.04),(98.,0.82)
FUNCTION XNRT   =( 0.,0.00),(98.,0.00)

FUNCTION FLVT   =(0.000,0.550),(0.244,0.563),(0.495,0.434),...
                 (0.720,0.284),(0.899,0.126),(1.221,0.000),...
                 (1.720,0.000),(2.100,0.000)
FUNCTION FSTT   =(0.000,0.450),(0.244,0.437),(0.495,0.566),...
                 (0.720,0.716),(0.899,0.610),(1.221,0.000),...
                 (1.720,0.000),(2.100,0.000)
FUNCTION FSOT   =(0.000,0.000),(0.244,0.000),(0.495,0.000),...
                 (0.720,0.000),(0.899,0.264),(1.221,1.000),...
                 (1.720,1.000),(2.100,1.000)

END


************************************************************
* R. Torres et al., IRRI, The Philippines
* 1992 dry season
* variety:   IR72
* treatment: 180 KG/HA
************************************************************

TITLE R. TORRES ET AL.  1992 DS  IR72-180N


* PARAM RGRL     = 0.0090

PARAM NA = 3
TABLE DNAPT(1-3)  = 16.,34.,120.
PARAM NS = 6
TABLE DNOST(1-6)  = 16.,33.,58.,68.,84.,114.
TABLE NTOTMT(1-6) = 0.24,11.20,93.73,135.45,135.10,137.00

* first and last values are dummy's
PARAM SLAC = 0.0019
FUNCTION SLAFAC=0.000,2.56,0.152,2.46,0.323,1.63,0.653,1.15,...
                0.787,1.11,1.011,1.00,1.464,0.92,2.011,0.83,2.1,0.83

FUNCTION XWLVGT=( 0.,    6.4),...
                (16.,   6.4),(34., 148.1),(58.,2011.7),...
                (68.,3024.3),(84.,3118.6),(97.,2430.7),(114.,1325.7)

FUNCTION XWLVDT=( 0.,  0.0),...
                (16.,  0.0),(34.,  0.0),(58.,  43.2),...
                (68.,247.3),(84.,717.3),(97.,1889.4),(114.,3004.0)
FUNCTION XWSTTB=( 0.,   5.1),...
                (16.,   5.1),(34., 112.1),( 58.,1720.2),...
                (68.,3317.4),(84.,4813.5),(97.,4307.5),(114.,3918.4)
```

```
FUNCTION XWRTLT=(180.,   0.0),(288.,   0.0)

FUNCTION XLAITB=(180.,0.03),...
                (194.,0.03),(202.,0.19),(211.,0.33),(219.,1.05),...
                (240.,3.68),(254.,5.01),(261.,4.63),(273.,3.52),...
                (288.,1.94)
FUNCTION XNFLVT=(180.,0.917),...
                (194.,0.917),(202.,1.140),(211.,1.708),(219.,1.480),...
                (240.,1.341),(254.,0.918),(261.,0.878),(273.,0.681),...
                (288.,0.584)
FUNCTION SLATB =(180.,.0033),...
                (194.,.0033),(202.,.0041),(211.,.0023),(219.,.0029),...
                (240.,.0022),(254.,.0022),(261.,.0023),(273.,.0023),...
                (288.,.0019)

FUNCTION XNLV  =( 0.,3.02),( 8.,4.66),(17.,4.01),(25.,4.25),...
                (47.,2.93),(60.,2.03),(67.,2.01),(79.,1.62),...
                (94.,1.09)
FUNCTION XNST  =( 0.,1.89),( 8.,3.08),(17.,2.50),(25.,2.37),...
                (47.,1.13),(60.,0.64),(67.,0.59),(79.,0.47),...
                (94.,0.45)
FUNCTION XNSO  =( 0.,0.00),( 8.,0.00),(17.,0.00),(25.,0.00),...
                (47.,0.00),(60.,0.00),(67.,0.91),(79.,0.87),...
                (94.,0.99)
FUNCTION XNRT  =( 0.,0.00),(94.,0.00)


FUNCTION FLVT  =(0.000,0.560),(0.193,0.532),(0.281,0.658),...
                (0.393,0.529),(0.584,0.516),(0.817,0.210),...
                (0.962,0.000),(1.234,0.000),(1.730,0.000),(2.1,0.0)
FUNCTION FSTT  =(0.000,0.440),(0.193,0.468),(0.281,0.342),...
                (0.393,0.471),(0.584,0.484),(0.817,0.790),...
                (0.962,0.111),(1.234,0.000),(1.730,0.000),(2.1,0.0)
FUNCTION FSOT  =(0.000,0.000),(0.173,0.000),(0.817,0.000),...
                (0.962,0.889),(1.234,1.000),(1.730,1.000),(2.1,1.0)

END


*****************************************************************
* R. Torres et al., IRRI, The Philippines
* 1991 wet season
* variety:   IR72
* treatment: 110 KG/HA
*****************************************************************

TITLE R. TORRES ET AL.  IRRI 1991 WS   IR72-110N

* PARAM RGRL   = 0.0090

PARAM NA=5
TABLE DRAPT (1-5) = 193.,218.,244.,262.,296.
PARAM MS=9
TABLE DMOST(1-9) = 194.,202.,211.,219.,241.,254.,261.,273.,288.
TABLE NTOTMT(1-9)= 0.40,1.02,7.51,19.16,55.46,65.09,78.95,86.11,99.67

* first and last values are dummy's
PARAM SLAC = 0.0021
FUNCTION SLAFAC =0.000,1.67,0.167,1.67,0.340,1.02,0.446,1.30,...
                 0.735,0.94,0.913,1.04,1.011,1.00,1.457,1.03,...
                 2.011,0.96,2.100,0.96

FUNCTION XWLVGT=(180.,   8.5),...
                (194.,   8.5),(202.,  16.8),(211., 133.8),...
                (219., 342.5),(240.,1503.3),(254.,1935.3),...
                (261.,2028.5),(273.,1564.8),(288., 892.8)
FUNCTION XWSTTB=(180.,   7.5),...
                (194.,   7.5),(202.,  10.0),(211.,  88.5),...
                (219., 275.8),(240.,1458.3),(254.,3208.5),...
                (261.,3856.3),(273.,2965.0),(288.,3119.8)
FUNCTION XWSOTB=(180.,   0.0),...
                (194.,   0.0),(254.,   0.0),(261.,1002.5),...
                (273.,3997.0),(288.,5674.0)
FUNCTION XWTDMT=(180.,  16.0),...
                (194.,  16.0),(202.,  26.8),(211.,  222.3),...
                (219., 618.3),(240.,2961.5),(254., 5439.0),...
                (261.,7503.0),(273.,9322.5),(288.,11534.5)
FUNCTION XWLVDT=(180.,   0.0),(240.,   0.0),(254.,  296.0),...
                (261., 616.0),(273., 796.0),( 288.,1848.0)
FUNCTION XWRTLT=(180.,   0.0),(288.,   0.0)

FUNCTION XLAITB=(180.,0.03),...
                (194.,0.03),(202.,0.15),(211.,0.29),(219.,0.94),...
                (240.,3.00),(254.,4.27),(261.,4.29),(273.,3.42),...
                (288.,1.81)
FUNCTION XNFLVT=(180.,0.917),...
                (194.,0.917),(211.,1.830),(219.,1.421),...
                (240.,1.344),(254.,0.947),(261.,0.986),...
                (273.,0.792),(288.,0.621)
FUNCTION SLATB =(180.,0.0033),...
                (194.,0.0033),(211.,.0022),(219.,.0028),...
                (254.,0.0022),(261.,.0021),(273.,.0022),(288.,.0020)

FUNCTION XNLV  =( 0.,3.02),( 8.,4.35),(17.,4.02),(25.,3.91),...
                (47.,2.69),(60.,2.09),(67.,2.09),(79.,1.79),...
                (94.,1.26)
FUNCTION XNST  =( 0.,1.89),( 8.,2.88),(17.,2.40),(25.,2.09),...
                (47.,1.04),(60.,0.77),(67.,0.68),(79.,0.57),...
                (94.,0.58)
FUNCTION XNSO  =( 0.,0.00),( 8.,0.00),(17.,0.00),(25.,0.00),...
                (47.,0.00),(60.,0.00),(67.,1.03),(79.,1.03),...
                (94.,1.24)
FUNCTION XNRT  =( 0.,0.00),(94.,0.00)

FUNCTION FLVT  =(0.000,0.560),(0.193,0.767),(0.281,0.598),...
                (0.393,0.527),(0.584,0.495),(0.817,0.198),...
                (0.962,0.053),(1.234,0.000),(1.730,0.000),...
                (2.100,0.000)
FUNCTION FSTT  =(0.000,0.440),(0.193,0.233),(0.281,0.402),...
                (0.393,0.473),(0.584,0.505),(0.817,0.802),...
                (0.962,0.372),(1.234,0.000),(1.730,0.000),...
                (2.100,0.000)
FUNCTION FSOT  =(0.000,0.000),(0.173,0.000),(0.817,0.000),...
                (0.962,0.575),(1.234,1.000),(1.730,1.000),
                (2.100,1.000)

END
```

IRRI, Los Baños, Philippines, 1992

```
************************************************************
* Weather data used:
* IRRI, Los Banos, Philippines, 1992 dry season


PARAM LAT          = 14.18
************************************************************

************************************************************
* R. Torres et al., IRRI, The Philippines
* 1992 dry season
* variety:   IR72
* treatment: 0 KG/HA
************************************************************

TITLE R. TORRES ET AL.  1992 DS       IR72 - ON

PARAM DOYS   = 16.
PARAM IDOYTR = 16
PARAM FGHDAY = 68.0

INCON WLVGI  =  6.4
INCON WSTSI  =  5.1
INCON WRTLI  = 11.5

PARAM FNSTI = 0.0126
PARAM FNLVI = 0.0271
PARAM FNRTI = 0.0126

PARAM DVSI  = 0.152
PARAM TSI   = 202.6

PARAM FSTR  = 0.20
* PARAM RGRL  = 0.0060
PARAM DVRV  = 0.000751
PARAM DVRR  = 0.00168

PARAM NA=2
TABLE DNAPT (1-2) = 16.,120.
PARAM NS=6
TABLE DNOST (1-6)= 16.,33.,58.,68.,84.,114.
TABLE NTOTMT(1-6)= 0.24,8.30,22.33,37.41,51.03,58.84

* first and last values are dummy's
PARAM SLAC = 0.0013
FUNCTION SLAFAC=0.0,3.62,0.152,3.62,0.323,2.26,0.653,1.72,...
                 0.787,1.01,1.011,1.00,1.464,1.26,2.011,1.03,2.1,1.03

FUNCTION XWLVGT =( 0.,   6.4),...
                  (16.,   6.4),(34., 116.3),(58.,693.2),...
                  (68.,1203.5),(84.,1513.5),(97.,926.7),(114.,545.2)...
FUNCTION XWLVDT =( 0.,  0.0),...
                  (16.,  0.0),(34.,   0.0),( 58.,  59.6),(68.,277.6),...
                  (84.,663.9),(97.,1094.4),(114.,1608.2
FUNCTION XWSTTB =( 0.,   5.1),...
                  (16.,   5.1),(34.,  90.2),( 58., 844.0),...
                  (68.,2133.1),(84.,3632.2),(97.,2619.3),(114.,2202.7)
FUNCTION XWSOTB =( 0.,  0.0),...
                  (16.,  0.0),(34.,   0.0),( 58.,   0.0),(68.,0.0),...
                  (84.,646.7),(97.,4003.5),(114.,5608.3)
FUNCTION XWTDMT =(0.,   11.5),...
                  (16.,  11.5),(34., 206.5),( 58.,1596.8),...
                  (68.,3616.2),(84.,6456.3),(97.,8640.9),(114.,9964.4)
FUNCTION XWRTLT =(0.,    0.0),(114.,  0.0)

FUNCTION XLAITB =(  0.,0.03),...
                  ( 16.,0.03),(34.,0.34),(58.,1.54),...
                  ( 68.,1.57),(84.,1.96),(97.,1.51),...
                  (114.,0.73)
FUNCTION XNFLVT =( 0.,0.578),(...
                  (16.,0.578),(34.,1.707),( 58.,1.056),...
                  (84.,1.274),(97.,0.806),(114.,0.713)
FUNCTION SLATB  =(  0.,0.0047),...
                  ( 16.,0.0047),(34.,0.0029),(58.,0.0022),...
                  ( 68.,0.0013),(84.,0.0013),(97.,0.0016),...
                  (114.,0.0013)

FUNCTION XNLV   =( 0.,2.71),(17.,4.99),(42.,2.35),(52.,1.98),...
                  (68.,1.65),(82.,1.31),(98.,0.96)
FUNCTION XNST   =( 0.,1.26),(17.,2.77),(42.,0.72),(52.,0.64),...
                  (68.,0.53),(82.,0.35),(98.,0.35)
FUNCTION XNSO   =( 0.,0.00),(17.,0.00),(42.,0.00),(52.,0.00),...
                  (68.,1.04),(98.,0.82)
FUNCTION XNRT   =( 0.,0.00),(98.,0.00)

FUNCTION FLVT   =(0.000,0.550),(0.244,0.563),(0.495,0.434),...
                  (0.720,0.284),(0.899,0.126),(1.221,0.000),...
                  (1.720,0.000),(2.100,0.000)
FUNCTION FSTT   =(0.000,0.450),(0.244,0.437),(0.495,0.566),...
                  (0.720,0.716),(0.899,0.610),(1.221,0.000),...
                  (1.720,0.000),(2.100,0.000)
FUNCTION FSOT   =(0.000,0.000),(0.244,0.000),(0.495,0.000),...
                  (0.720,0.000),(0.899,0.264),(1.221,1.000),...
                  (1.720,1.000),(2.100,1.000)

END


************************************************************
* R. Torres et al., IRRI, The Philippines
* 1992 dry season
* variety:   IR72
* treatment: 180 KG/HA
************************************************************

TITLE R. TORRES ET AL.  1992 DS  IR72-180N


* PARAM RGRL     = 0.0090

PARAM NA = 3
TABLE DNAPT(1-3)  = 16.,34.,120.
PARAM NS = 6
TABLE DNOST(1-6)  = 16.,33.,58.,68.,84.,114.
TABLE NTOTMT(1-6) = 0.24,11.20,93.73,135.45,135.10,137.00

* first and last values are dummy's
PARAM SLAC = 0.0019
FUNCTION SLAFAC=0.000,2.56,0.152,2.46,0.323,1.63,0.653,1.15,...
                0.787,1.11,1.011,1.00,1.464,0.92,2.011,0.83,2.1,0.83

FUNCTION XWLVGT=( 0.,    6.4),...
                (16.,    6.4),(34., 148.1),(58.,2011.7),...
                (68.,3024.3),(84.,3118.4),(97.,2430.7),(114.,1325.7)

FUNCTION XWLVDT=( 0.,  0.0),...
                (16.,  0.0),(34.,  0.0),(58.,  43.2),...
                (68.,247.3),(84.,717.3),(97.,1889.4),(114.,3004.0)
FUNCTION XWSTTB=( 0.,   5.1),...
                (16.,   5.1),(34., 112.1),( 58.,1720.1),...
                (68.,3317.4),(84.,4813.5),(97.,4307.5),(114.,3918.4)
```

```
FUNCTION XWSOTB=( 0.,0.0),...
                (16.,0.0),(34.,    0.0),(58.,    0.0),...
                (68.,0.0),(84.,1195.7),(97.,6212.3),(114.,9944.8)
FUNCTION XWTDMT=( 0.,  11.5),...
                (16.,  11.5),(34., 260.2),(58., 3775.0),...
                (68.,6589.0),(84.,9844.9),(97.,14839.9),(114.,18192.9)
FUNCTION XWRTLT=( 0.,   0.0),(114.,  0.0)

FUNCTION XLAITB=( 0.,0.03),...
                (16.,0.03),(34.,0.46),( 58.,4.43),( 68.,6.40),...
                (84.,5.95),(97.,4.28),(114.,2.11)
FUNCTION XNFLVT=( 0.,0.578),...
                (16.,0.578),(34.,1.685),( 58.,1.592),(68.,1.507),...
                (84.,1.371),(97.,1.127),(114.,0.761)

FUNCTION SLATB =( 0.,0.0047),...
                (16.,0.0047),(34.,0.0031),( 58.,0.0022),...
                (68.,0.0021),(84.,0.0019),(97.,0.0018),(114.,0.0016)

FUNCTION XNLV  =( 0.00,2.71),(17.00,5.23),(42.00,3.51),(52.00,3.19),...
                (68.00,2.62),(82.00,1.99),(98.00,1.21)
FUNCTION XNST  =( 0.00,1.26),(17.00,3.08),(42.00,1.35),(52.00,1.18),...
                (68.00,0.86),(82.00,0.55),(98.00,0.50)
FUNCTION XNSO  =( 0.00,0.00),(17.00,0.00),(42.00,0.00),(52.00,0.00),...
                (68.00,1.04),(98.00,1.02)
FUNCTION XNRT  =( 0.00,0.00),(98.00,0.00)


FUNCTION FLVT  =(0.000,0.550),(0.244,0.570),(0.495,0.537),...
                (0.720,0.388),(0.899,0.034),(1.221,0.000),...
                (1.720,0.000),(2.100,0.000)
FUNCTION FSTT  =(0.000,0.450),(0.244,0.430),(0.495,0.463),...
                (0.720,0.612),(0.899,0.537),(1.221,0.000),...
                (1.720,0.000),(2.100,0.000)
FUNCTION FSOT  =(0.000,0.000),(0.183,0.000),(0.495,0.000),...
                (0.720,0.000),(0.899,0.429),(1.221,1.000),...
                (1.720,1.000),(2.100,1.000)

END

**************************************************************
* R. Torres et al., IRRI, The Philippines
* 1992 dry season
* variety:   IR72
* treatment: 225 KG/HA
**************************************************************

TITLE R. TORRES ET AL.  1992 DS  IR72-225N

PARAM NA = 5
TABLE DNAPT(1-5)  = 16.,34.,58.,84.,120.
PARAM NS = 6
TABLE DNOST(1-6)  = 16.,33.,58.,68.,84.,114.
TABLE NTOTMT(1-6) = 0.26,10.28,82.35,129.21,123.17,158.50

* first and last values are dummy's
PARAM SLAC = 0.0019
FUNCTION SLAFAC=0.000,2.42,0.152,2.42,0.323,1.72,0.653,1.44,...
                0.787,1.08,1.011,1.00,1.464,0.88,2.011,0.88,2.1,0.88

FUNCTION XWLVGT=( 0.,   0.0),( 16.,   6.4),(34., 138.1),...
                (58.,1873.8),( 68.,2840.1),(84.,3030.2),...
                (97.,2828.6),(114.,1431.8)
FUNCTION XWLVDT=( 0.,   0.0),( 16.,   0.0),(34.,  0.0),...
                (58.,  47.4),( 68., 233.6),(84.,658.8),...
                (97.,1448.1),(114.,2269.4
FUNCTION XWSTTB=( 0.,   0.0),( 16.,   5.1),(36., 109.0),...
                (58.,1577.2),( 68.,2902.4),(84.,4771.4),...
                (97.,4372.2),(114.,4243.4)
FUNCTION XWSOTB=( 0.,0.0),(16.,  0.0),(34.,   0.0),( 58.,   0.0),...
                (68.,0.0),(84.,816.4),(97.,5718.9),(114.,9558.3)
FUNCTION XWTDMT=( 0.,    0.0),( 16.,  11.5),(34., 247.1),...
                (58., 3498.4),( 68.,5976.1),(84.,9276.8),
                (97.,14363.8),(114.,17503.)
FUNCTION XWRTLT=( 0.,    0.0),(114.,   0.0)

FUNCTION XNFLVT=( 0.,0.578),(16.,0.578),(34.,1.531),( 58.,1.028),...
                (68.,1.557),(84.,1.286),(97.,1.373),(114.,0.834)
FUNCTION XLAITB=( 0.,0.03),(16.,0.03),(34.,0.46),( 58.,5.22),...
                (68.,5.97),(84.,5.88),(97.,4.82),(114.,2.45)
FUNCTION SLATB =( 0.,0.0047),(16.,0.0047),(34.,0.0033),( 58.,0.0028),...
                (68.,0.0021),(84.,0.0019),(97.,0.0017),(114.,0.0017)

FUNCTION XNLV  =( 0.00,2.71),(17.00,5.10),(42.00,2.86),(52.00,3.27),...
                (68.00,2.50),(82.00,2.34),(98.00,1.43)
FUNCTION XNST  =( 0.00,1.26),(17.00,2.98),(42.00,1.82),(52.00,1.25),...
                (68.00,0.81),(82.00,0.72),(98.00,0.58)
FUNCTION XNSO  =( 0.00,0.00),(17.00,0.00),(42.00,0.00),(52.00,0.00),...
                (68.00,1.11),(98.00,1.19)
FUNCTION XNRT  =( 0.00,0.00),(98.00,0.00)

FUNCTION FLVT  =(0.000,0.600),(0.244,0.559),(0.495,0.542),...
                (0.720,0.388),(0.899,0.034),(1.221,0.000),...
                (1.728,0.000),(2.100,0.000)
FUNCTION FSTT  =(0.000,0.400),(0.244,0.441),(0.495,0.458),...
                (0.720,0.612),(0.899,0.537),(1.221,0.000),...
                (1.720,0.000),(2.100,0.000)
FUNCTION FSOT  =(0.000,0.000),(0.217,0.000),(0.496,0.000),...
                (0.720,0.000),(0.899,0.429),(1.221,1.000),...
                (1.720,1.000),(2.100,1.000)

END

**************************************************************
* R. Torres et al., IRRI, The Philippines
* 1992 dry season
* variety:   LINE
* treatment: 0 KG/HA
**************************************************************

TITLE R. TORRES ET AL.  IRRI 1992 DS      LINE ON


PARAM DOYS   =  16.
PARAM IDOYTR =  16
PARAM FGHDAY = 128.0

INCON WLVGI  =  5.6
INCON WSTSI  =  5.1
INCON WRTLI  = 10.7

PARAM FNSTI  = 0.0134
PARAM FNLVI  = 0.0261
PARAM FNRTI  = 0.0134

PARAM DVSI   = 0.127
PARAM TSI    = 202.6

PARAM FSTR   = 0.40
* PARAM RGRL = 0.0060
PARAM DVRV   = 0.000625
PARAM DVRR   = 0.001629


PARAM NA = 2
TABLE DNOST(1-2)  = 16.,135.
```

```
PARAM NS = 6
TABLE DNOST(1-6)  = 16.,34.,70.,79.,98.,128.
TABLE NTOTMT(1-6) = 0.21,17.22,32.11,40.13,43.64,56.38

FUNCTION XWLVGT=( 0.,    5.6),...
                (16.,    5.6),(34., 103.3),( 70.,1055.3),...
                (79.,1322.5),(98.,1531.5),(114.,1124.2),(128., 614.6)
FUNCTION XWLVDT=( 0.,    0.0), ...
                (16.,    0.0),(34.,    0.0),( 70., 252.4),...
                (79., 349.3),(98.,1107.3),(114.,1682.7),(128.,2452.1)
FUNCTION XWSTTB=( 0.,    5.1),...
                (16.,    5.1),(34.,  74.1),( 70.,1817.8),  ...
                (79.,2492.7),(98.,4099.0),(114.,3659.7),(128.,2725.0)
FUNCTION XWSOTB=( 0.,    0.0),(16.,    0.0),...
                (79.,    0.0),(98., 458.9),(114.,3597.2),(128.,5781.3)
FUNCTION XWTOMT=( 0.,  10.7),...
                (16.,  10.7),(34., 177.4),( 70., 3125.5),...
                (79.,4164.5),(98.,7196.7),(114.,10063.8),(128.,11573.0)
FUNCTION XWRTLT=( 0.,    0.0),(128.,  0.0)

FUNCTION XLAITB=( 0.,0.03), ...
                (16.,0.03),( 34.,0.32),( 70.,1.78),(79.,2.28),...
                (98.,2.45),(114.,1.61),(128.,0.76)
FUNCTION XNFLVT=( 0.,0.487),...
                (16.,0.487),( 34.,1.627),( 70.,1.147),(79.,1.088),...
                (98.,0.918),(114.,0.742),(128.,0.645)
FUNCTION SLATB =( 0.,0.0054),...
                (16.,0.0054),( 34.,0.0031),( 70.,0.0017),...
                (79.,0.0017),(98.,0.0016),(114.,0.0014),(128.,0.0012)

FUNCTION XNLV  =( 0.00,2.61),(18.00,5.04),( 54.00,1.94),...
                (63.00,1.88),(82.00,1.47),( 98.00,1.06),(112.00,0.80)
FUNCTION XNST  =( 0.00,1.34),(18.00,2.71),( 54.00,0.64),...
                (63.00,0.62),(82.00,0.42),( 98.00,0.36),(112.00,0.33)
FUNCTION XNSO  =( 0.00,0.00),(18.00,0.00),( 54.00,0.00),...
                (63.00,0.00),(82.00,0.84),(112.00,0.74)
FUNCTION XNRT  =( 0.00,0.00),(112.00,0.00)

FUNCTION FLVT  =(0.000,0.550),(0.203,0.586),(0.478,0.353),...
                (0.730,0.388),(0.895,0.034),...
                (1.274,0.000),(1.774,0.000),(2.100,0.000)
FUNCTION FSTT  =(0.000,0.450),(0.203,0.414),(0.478,0.647),...
                (0.730,0.612),(0.895,0.537),...
                (1.274,0.000),(1.774,0.000),(2.100,0.000)
FUNCTION FSOT  =(0.000,0.000),(0.152,0.000),(0.478,0.000),...
                (0.723,0.000),(0.895,0.429),...
                (1.274,1.000),(1.774,1.000),(2.100,1.000)

END


*************************************************************
* R. Torres et al., IRRI, The Philippines
* 1992 dry season
* variety:   LINE
* treatment: 180 KG/HA
*************************************************************

TITLE R. TORRES ET AL.  IRRI 1992 DS  LINE 180N

* PARAM RGRL      = 0.0090

PARAM NA = 3
TABLE DNAPT(1-3)  = 16.,34.,135.
PARAM NS = 6
TABLE DNOST(1-6)  = 16.,34.,70.,79.,98.,128.
TABLE NTOTMT(1-6) = 0.21,9.74,90.55,120.95,151.72,151.72
```

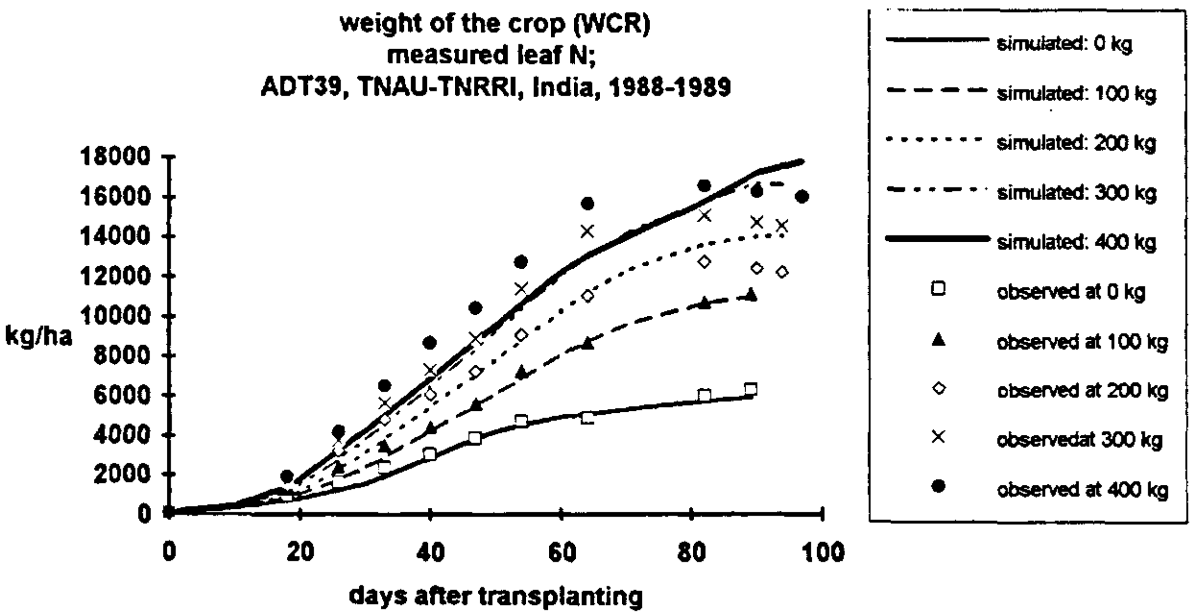
```
** OBSERVED VALUES FOR M10 LINE 180N
FUNCTION XWLVGT=( 0.,    5.6),...
                ( 16.,    5.6),( 34., 133.8),( 70.,2189.2),...
                ( 79.,3122.7),( 98.,4400.2),(114.,2765.9),(128.,1488.5)
FUNCTION XWLVDT=( 90.,    0.0), ...
                ( 16.,    0.0),( 34.,    0.0),( 70., 384.4),...
                ( 79., 426.9),( 98.,1809.1),(114.,2725.3),(128.,4508.3)
FUNCTION XWSTTB=(  0.,    5.1),...
                ( 16.,    5.1),( 34.,  98.8),( 70.,3107.5), ...
                ( 79.,4268.2),( 98.,7824.8),(114.,5906.4),(128.,4443.8)
FUNCTION XWSOTB=(  0.,    0.0),...
                ( 16.,    0.0),( 79.,    0.0),( 98., 748.6),
                (114.,6498.0),(128.,9304.2)
FUNCTION XWTOMT=( 90.,  10.7),( 16.,  10.7),...
                ( 34., 232.6),( 70., 5684.4),( 79., 7817.8),...
                (98.,14782.7),(114.,17895.6),(128.,19744.8)
FUNCTION XWRTLT=( 0.,    0.0),(128.,   0.0)

FUNCTION XLAITB=( 0.,0.03),...
                (16.,0.03),( 34.,0.39),( 70.,4.13),(79.,5.99),...
                (98.,8.02),(114.,4.31),(128.,2.52)
FUNCTION XNFLVT=( 0.,0.487),...
                (16.,0.487),( 34.,1.760),( 70.,1.451),(79.,1.339),...
                (98.,1.100),(114.,1.022),(128.,0.600)
FUNCTION SLATB =( 0.,0.0054),...
                (16.,0.0054),( 34.,0.0029),( 70.,0.0019),(79.,0.0019),...
                (98.,0.0018),(114.,0.0016),(128.,0.0017)

FUNCTION XNLV  =( 0.,2.61),( 18.,5.13),( 54.,2.74),(63.,2.57),...
                (82.,2.01),( 98.,1.59),(112.,1.02)
FUNCTION XNST  =( 0.,1.34),( 18.,2.92),( 54.,0.99),(63.,0.96),...
                (82.,0.72),( 98.,0.50),(112.,0.43)
FUNCTION XNSO  =( 0.,0.00),( 18.,0.00),( 54.,0.00),(63.,0.00),...
                (82.,1.01),(112.,0.94)
FUNCTION XNRT  =( 0.,0.00),(112.,0.00)

FUNCTION FLVT  =(0.000,0.550),(0.203,0.578),(0.478,0.406),...
                (0.730,0.388),(0.895,0.034),...
                (1.274,0.000),(1.774,0.000),(2.100,0.000)
FUNCTION FSTT  =(0.000,0.450),(0.203,0.422),(0.478,0.594),...
                (0.730,0.612),(0.895,0.537),...
                (1.274,0.000),(1.774,0.000),(2.100,0.000)
FUNCTION FSOT  =(0.000,0.000),(0.180,0.000),(0.478,0.000),...
                (0.730,0.000),(0.895,0.429),...
                (1.274,1.000),(1.774,1.000),(2.100,1.000)

END


*************************************************************
* R. Torres et al., IRRI, The Philippines
* 1992 dry season
* variety:   LINE
* treatment: 225 KG/HA
*************************************************************

TITLE R. TORRES ET AL.  IRRI 1992 DS  LINE 225N


FUNCTION XWLVGT=( 0.,    5.6),...
                (16.,    5.6),(34., 141.0),( 70.,2469.1),...
                (79.,3180.0),(98.,3755.6),(114.,3348.5),(128.,1507.3)
FUNCTION XWLVDT=( 0.,   0.0),...
                (16.,   0.0),(34.,    0.0),( 70., 362.8),...
                (79.,404.0),(98.,1665.8),(114.,2311.4),(128.,3995.8)
FUNCTION XWSTTB=( 0.,    5.1),...
                (16.,    5.1),( 34.,   99.5),( 70.,3487.7),...
                (79.,4082.4),(98.,6846.6),(114.,5859.4),(128.,4297.9)
FUNCTION XWSOTB=( 0.,0.0),(16.,  0.0),...
```

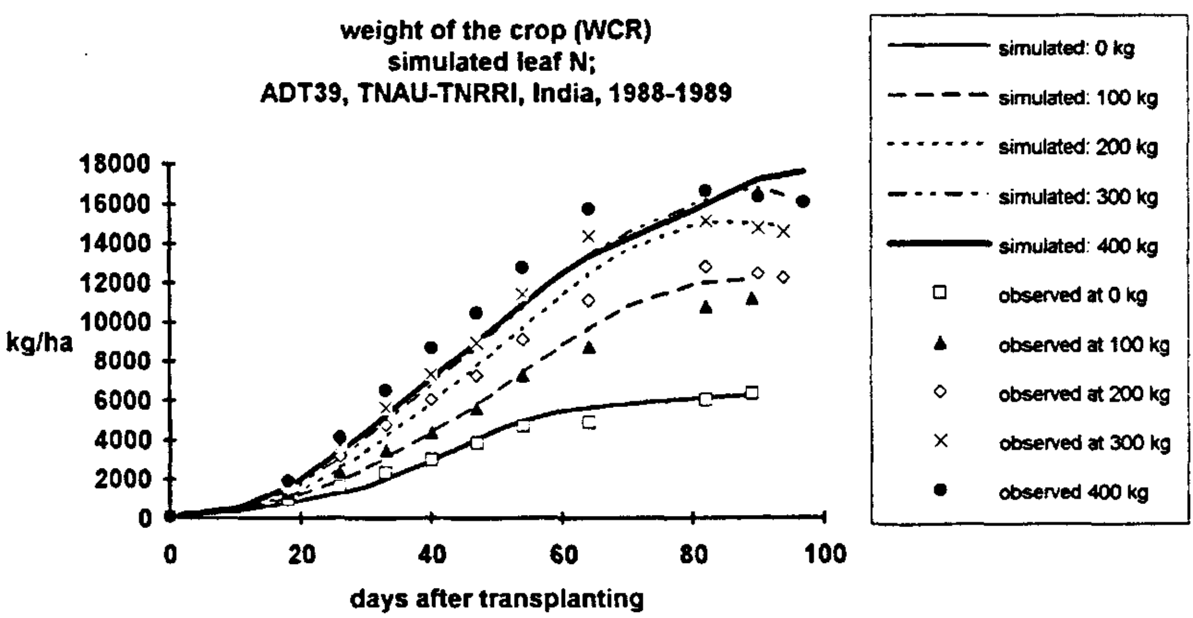
```
               (79.,0.0),(98.,991.6),(114.,7258.7),(128.,9709.4)
FUNCTION XWTOMT=( 0.,   10.7),( 16.,   10.7),...
               (34.,  240.5),( 70., 6319.6),( 79., 7666.4),...
               (98.,13259.6),(114.,18778.0),(128.,19510.4)
FUNCTION XWRTLT=(0.,     0.0),(128.,     0.0)

FUNCTION XLAITB=( 0.,0.030),...
               (16.,0.030),( 34.,0.42),( 70.,4.65),(79.,5.91)),...
               (98.,7.608),(114.,5.42),(128.,2.11)
FUNCTION XNPLVT=( 0.,0.487),...
               (16.,0.487),( 34.,1.740),( 70.,1.460),(79.,1.336),...
               (98.,1.076),(114.,1.192),(128.,0.773)
FUNCTION SLATB =( 0.,0.0054),...
               (16.,0.0054),(34.,0.0030),( 70.,0.0019),...
               (79.,0.0019),(98.,0.0020),(114.,0.0016),(128.,0.0014)

FUNCTION XNLV  =( 0.,2.61),( 18.,5.18),( 54.,2.75),(63.,2.48),...
               (82.,2.18),( 98.,1.93),(112.,1.08)
FUNCTION XNST  =( 0.,1.34),( 18.,3.07),( 54.,0.99),(63.,0.92),...
               (82.,0.72),( 98.,0.58),(112.,0.44)
FUNCTION XNSO  =( 0.,0.00),( 18.,0.00),( 54.,0.00),(63.,0.00),...
               (82.,1.18),(112.,1.24)
FUNCTION XNRT  =( 0.,0.00),(112.,0.00)

PARAM NA = 5
TABLE DNAPT(1-5)  = 16.,34.,70.,98.,135.
PARAM NS = 6
TABLE DNOST(1-6)  = 16.,34.,70.,79.,98.,128.
TABLE WTOTMT(1-6) = 0.21,10.36,102.53,116.52,142.48,155.13

FUNCTION FLVT  =(0.000,0.550),(0.203,0.589),(0.478,0.407),...
               (0.730,0.388),(0.895,0.034),...
               (1.274,0.000),(1.774,0.000),(2.100,0.000)
FUNCTION FSTT  =(0.000,0.450),(0.203,0.411),(0.478,0.593),...
               (0.730,0.612),(0.895,0.537),...
               (1.274,0.000),(1.774,0.000),(2.100,0.000)
FUNCTION FSOT  =(0.000,0.000),(0.203,0.000),(0.478,0.000),...
               (0.730,0.000),(0.895,0.429),...
               (1.274,1.000),(1.774,1.000),(2.100,1.000)

END
```

Appendix VI: Results of validation

TNAU-TNRRI, Tamil Nadu, India, 1988-1989

N-limited Production

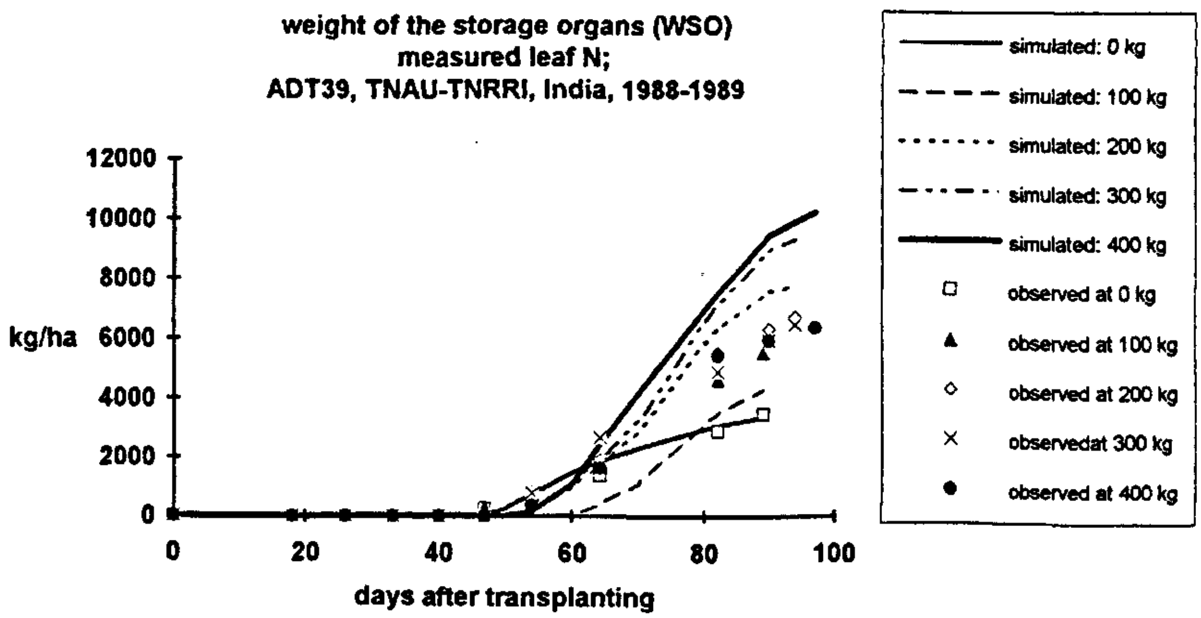


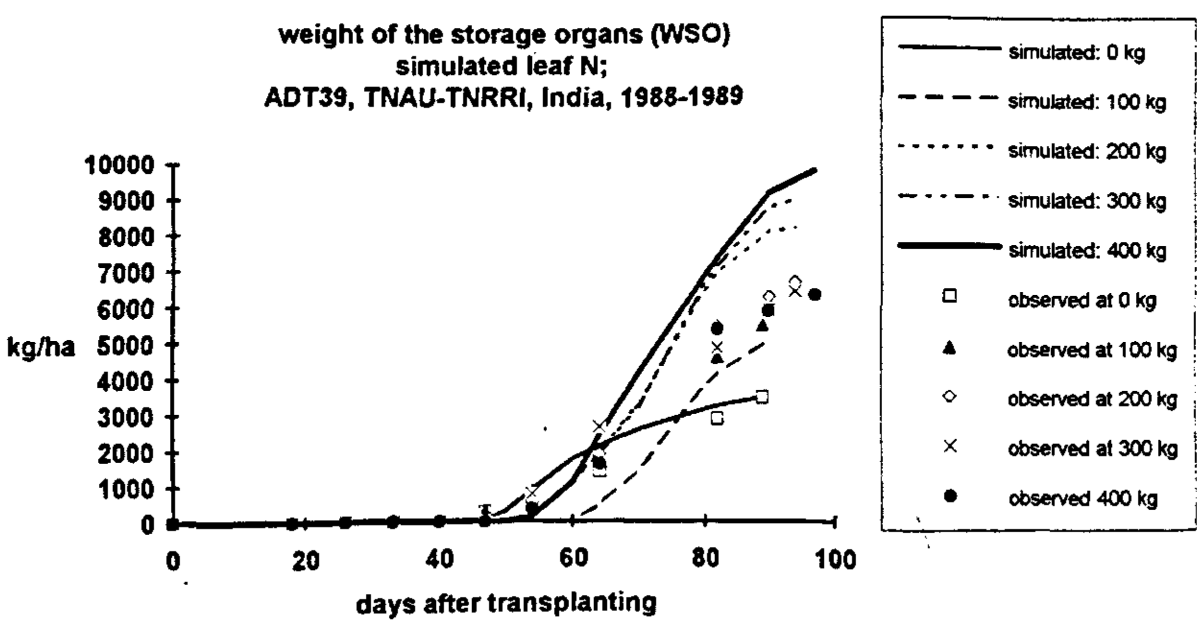


VI-2

TNAU-TNRRI, Tamil Nadu, India, 1988-1989

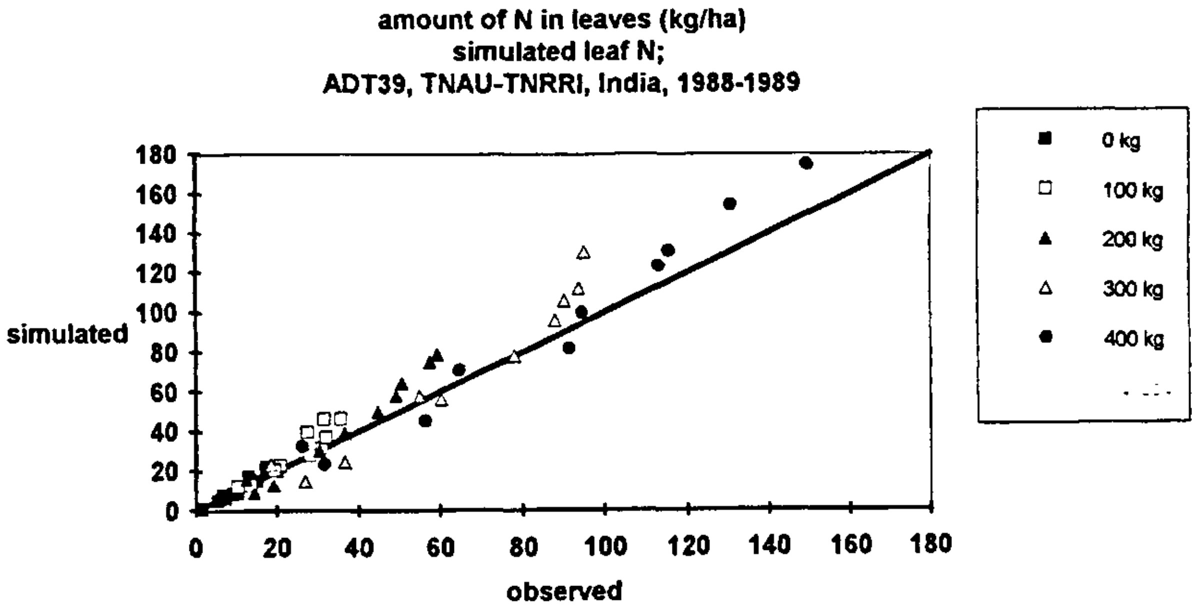
N-limited Production

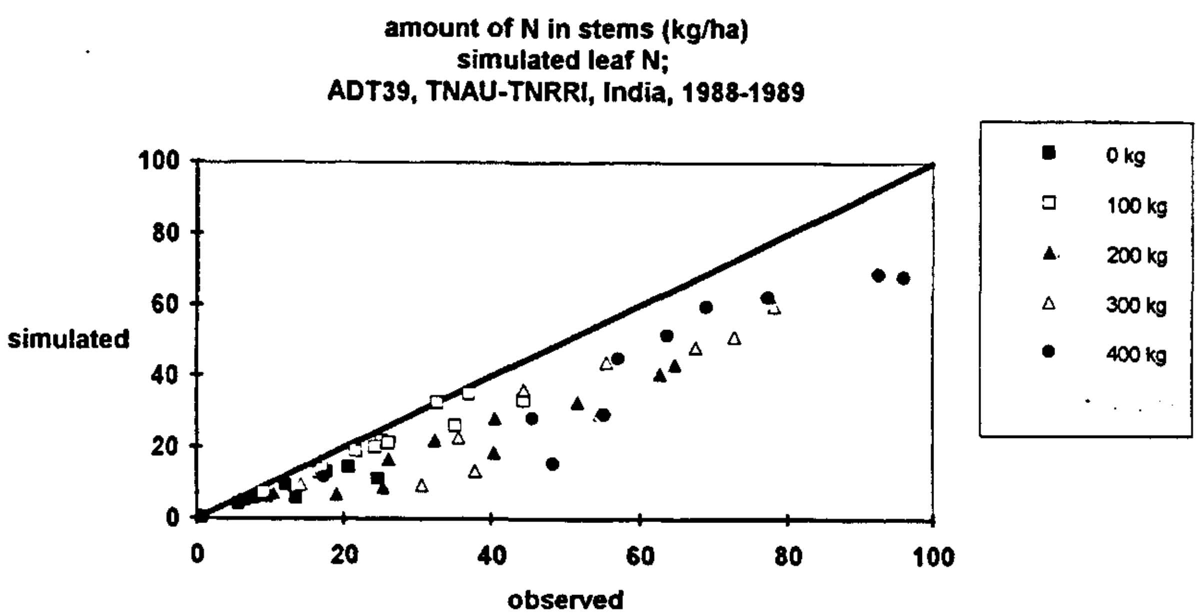




TNAU-TNRRI, Tamil Nadu, India, 1988-1989

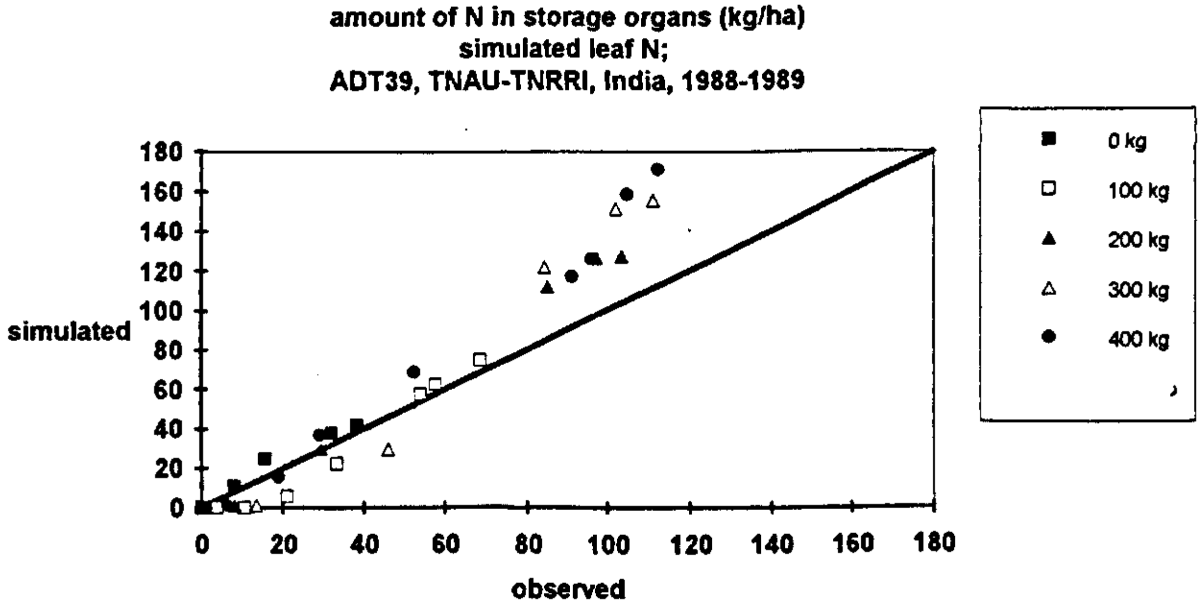
N-limited Production

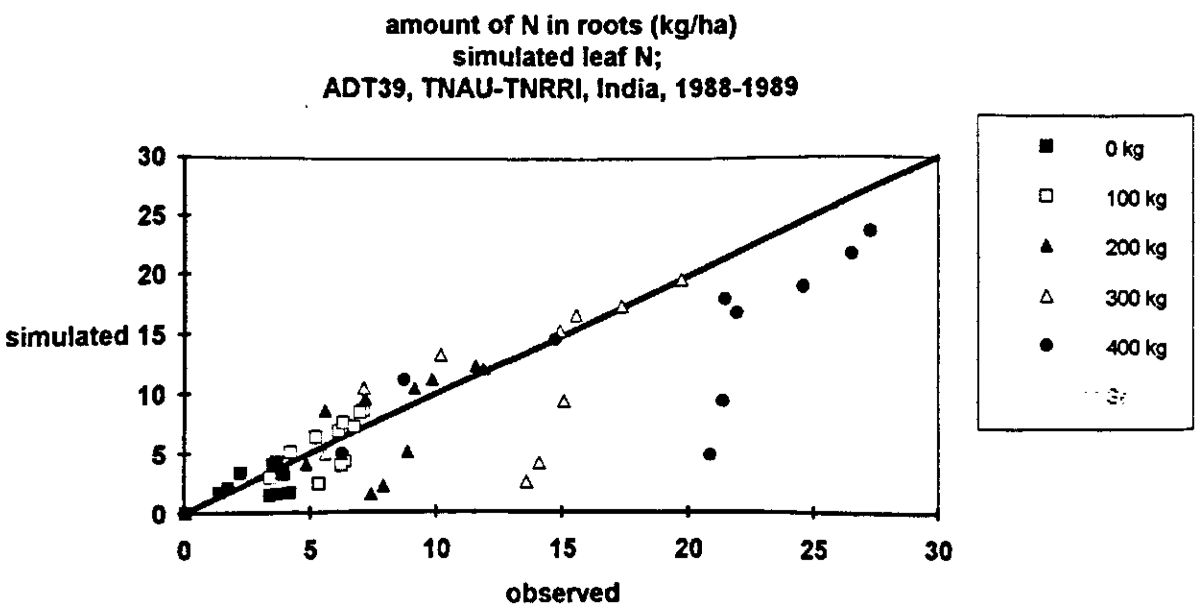




TNAU-TNRRI, Tamil Nadu, India, 1988-1989

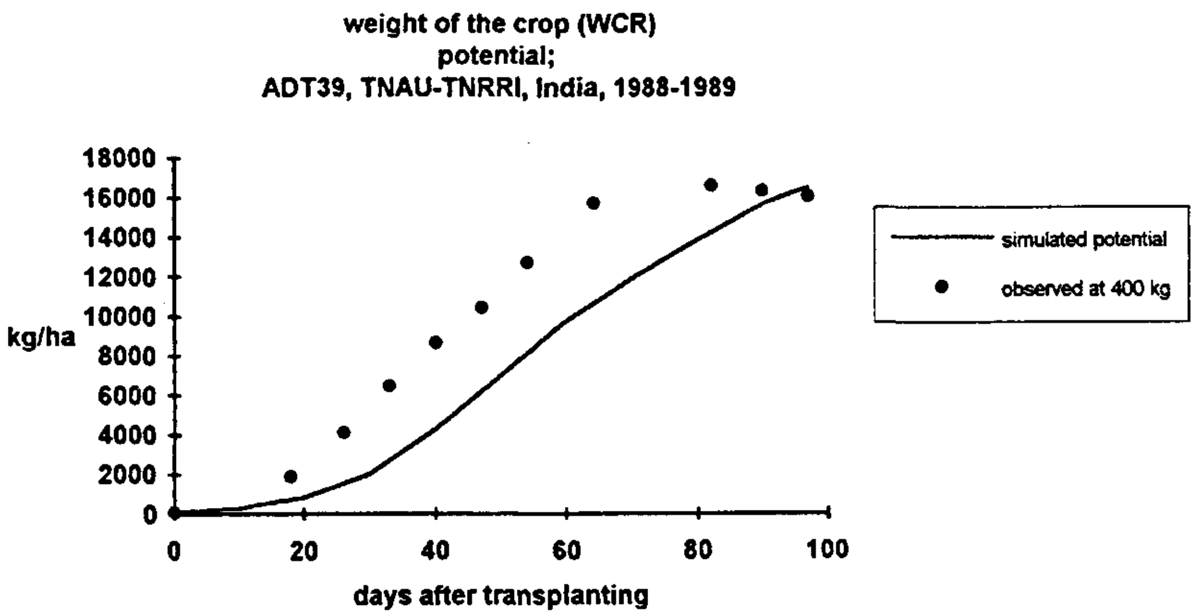
N-limited Production

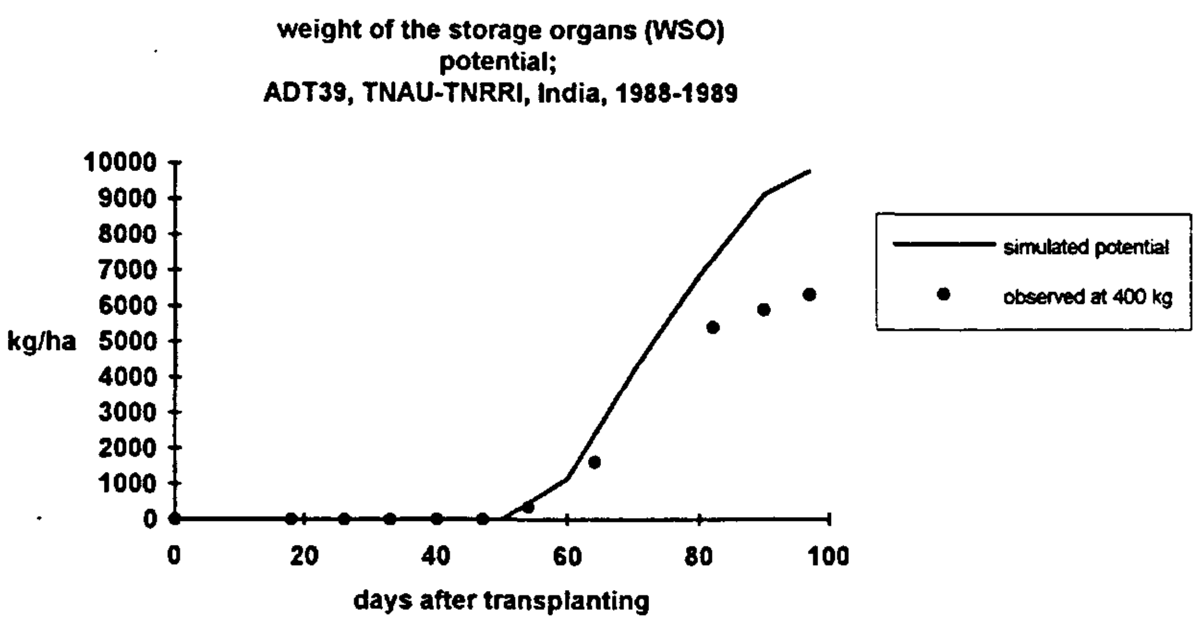




TNAU-TNRRI, Tamil Nadu, India, 1988-1989

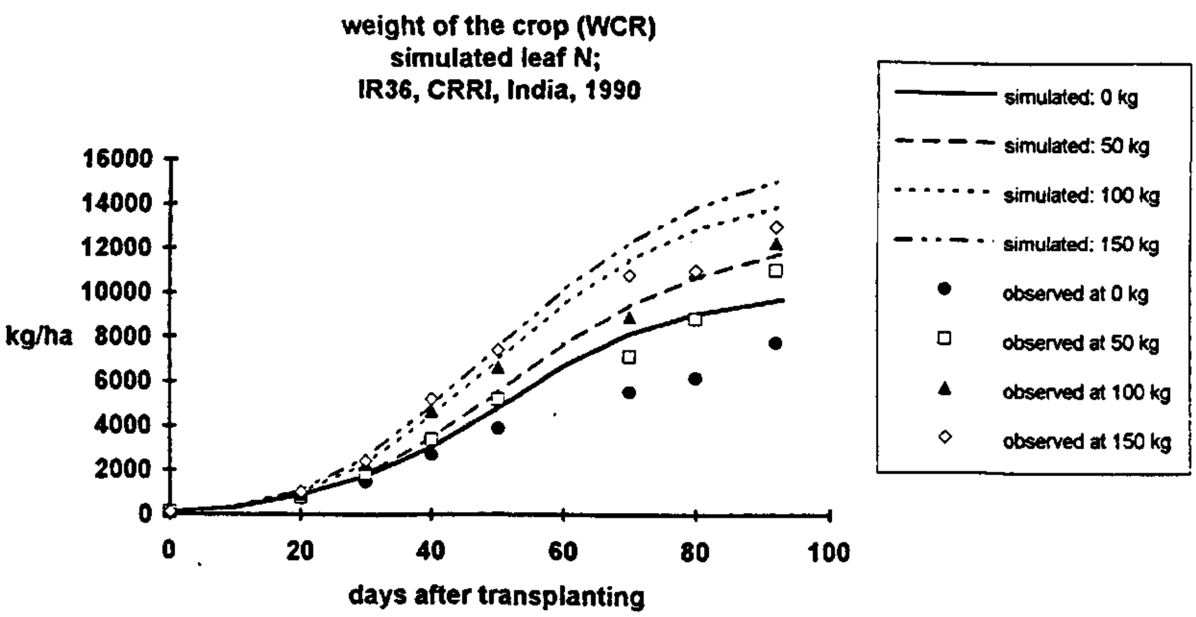
Potential Production

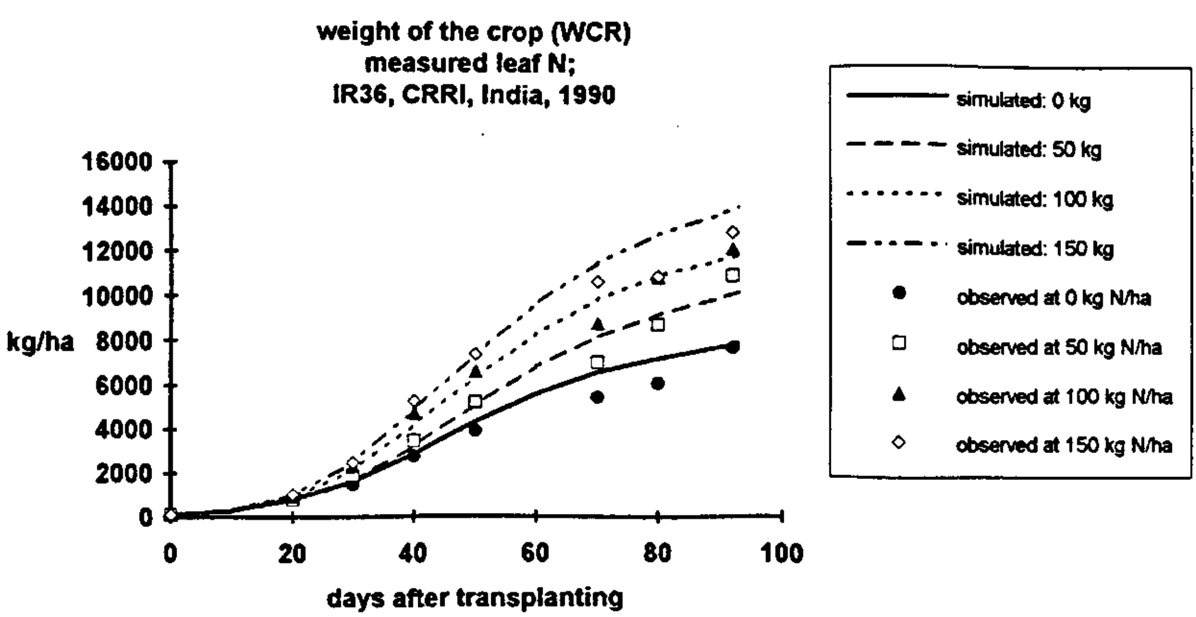




CRRI, Cuttack, India, 1990

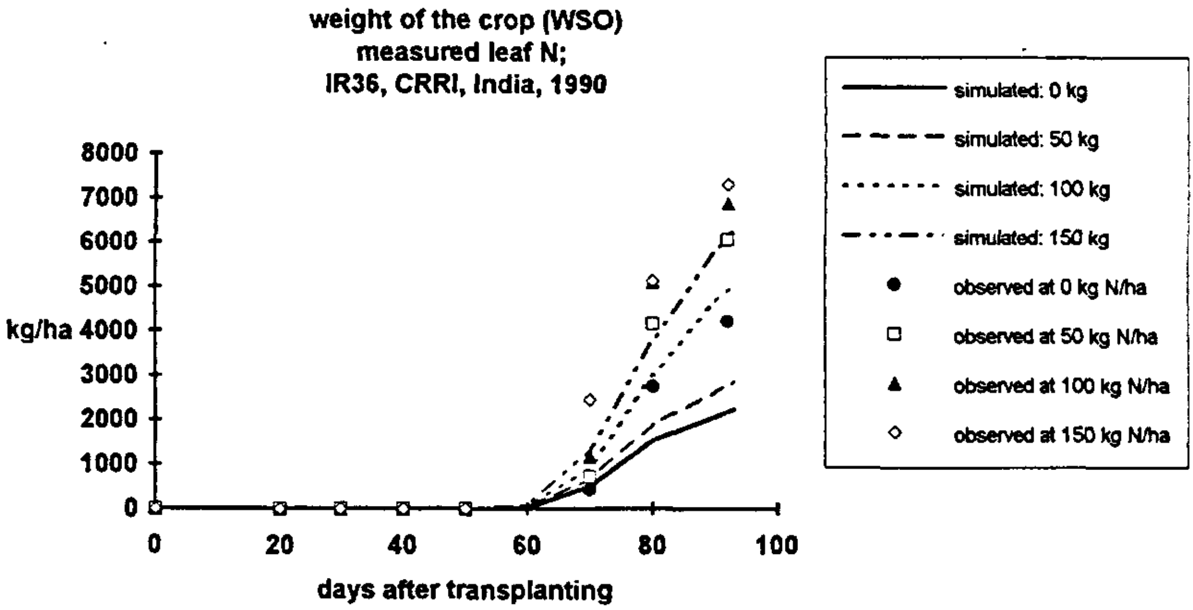
N-limited Production

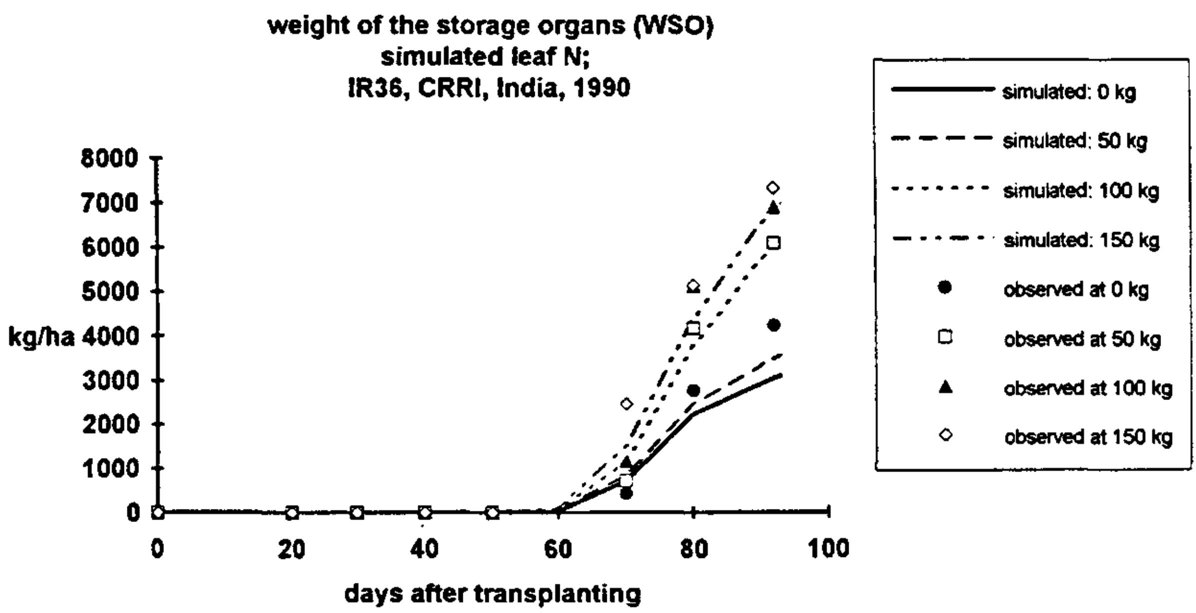




CRRI, Cuttack, India, 1990

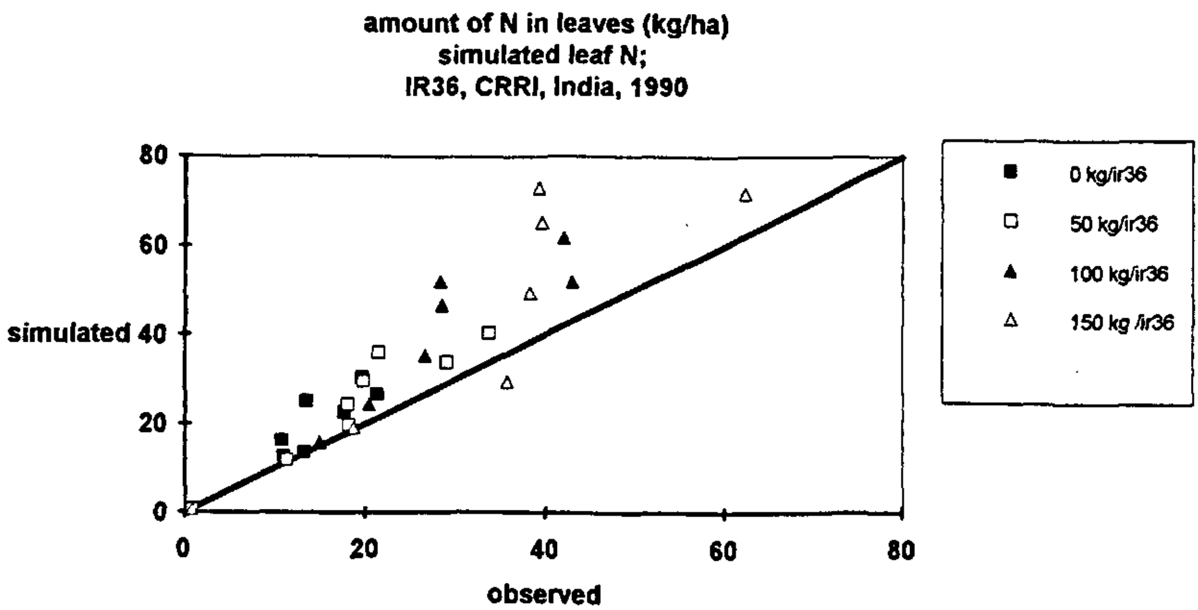
N-limited Production

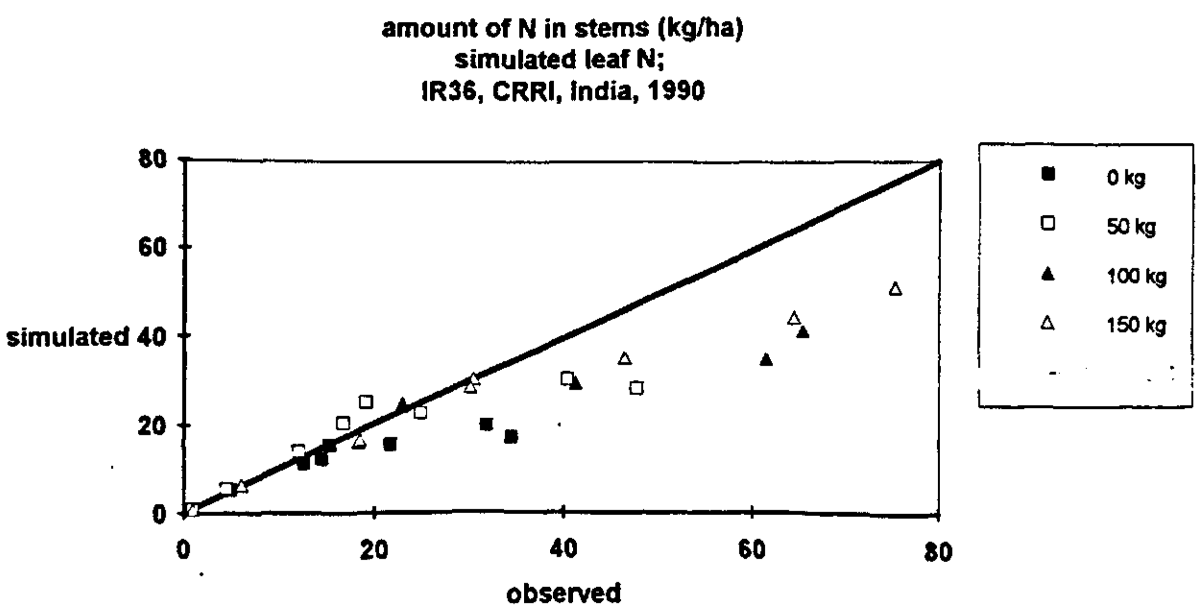




VI-8
CRRI, Cuttack, India, 1990

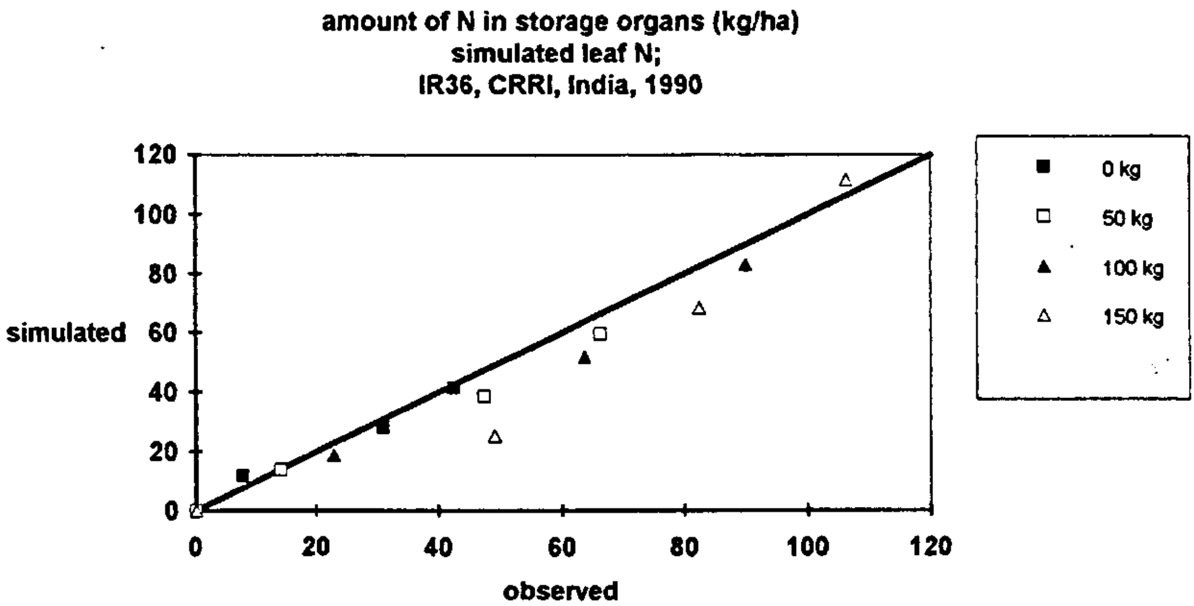
N-limited Production

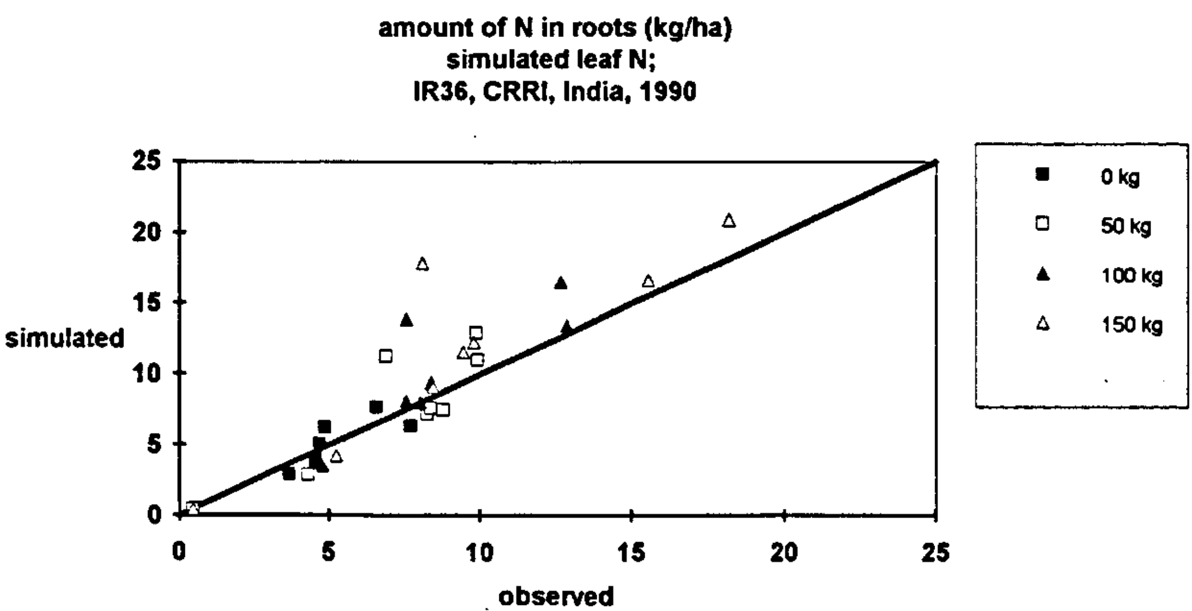




CRRI, Cuttack, India, 1990

N-limited Production

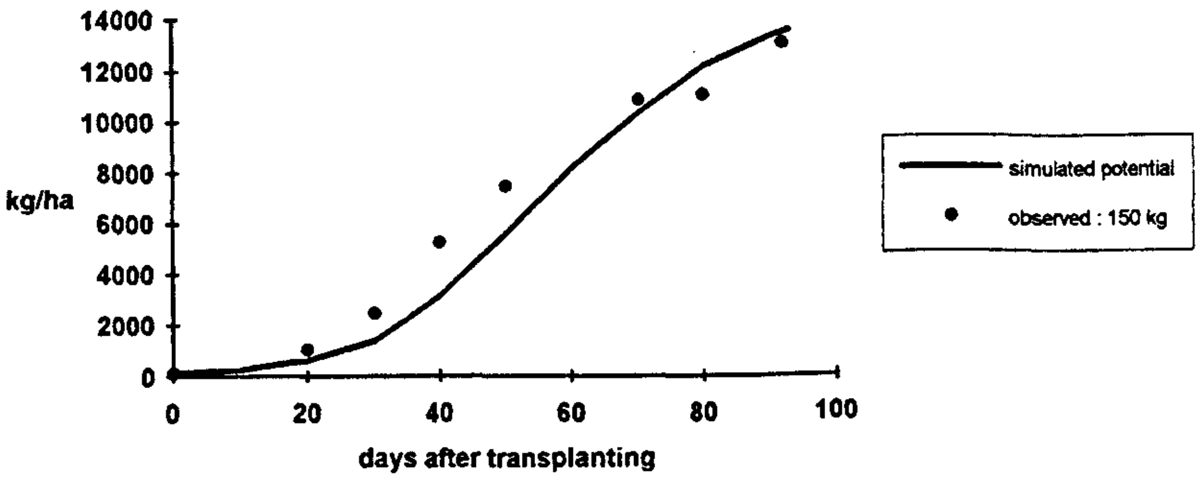




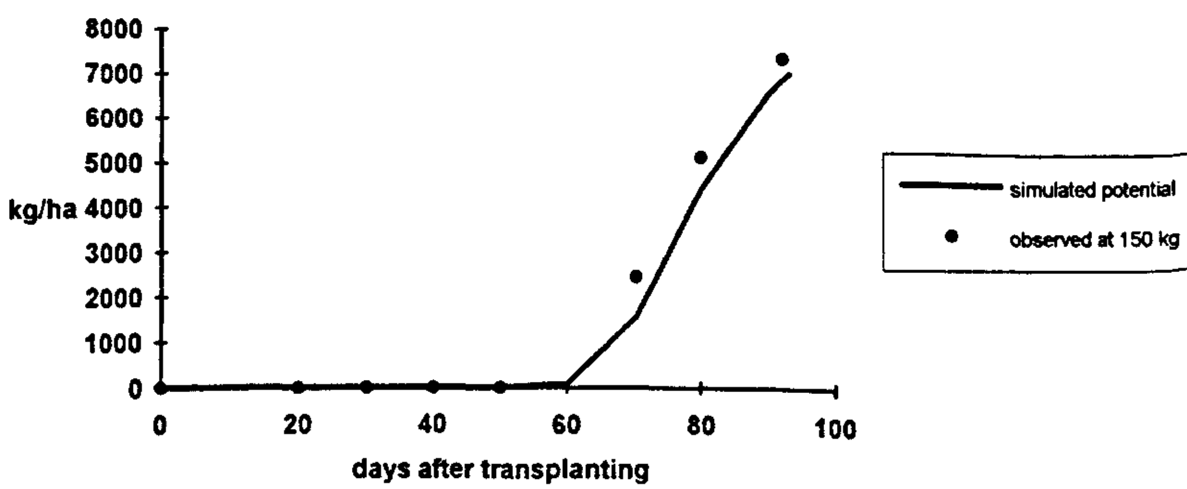
VI-10
CRRI, Cuttack, India, 1990

Potential Production

weight of the crop (WCR)
potential;
IR36, CRRI, India, 1990

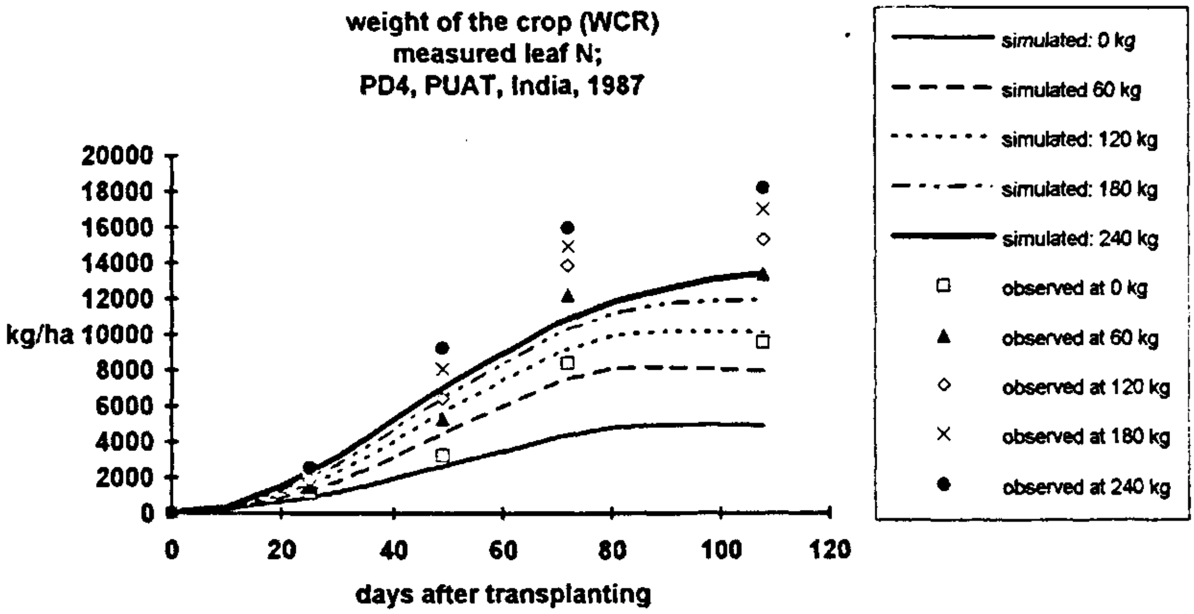


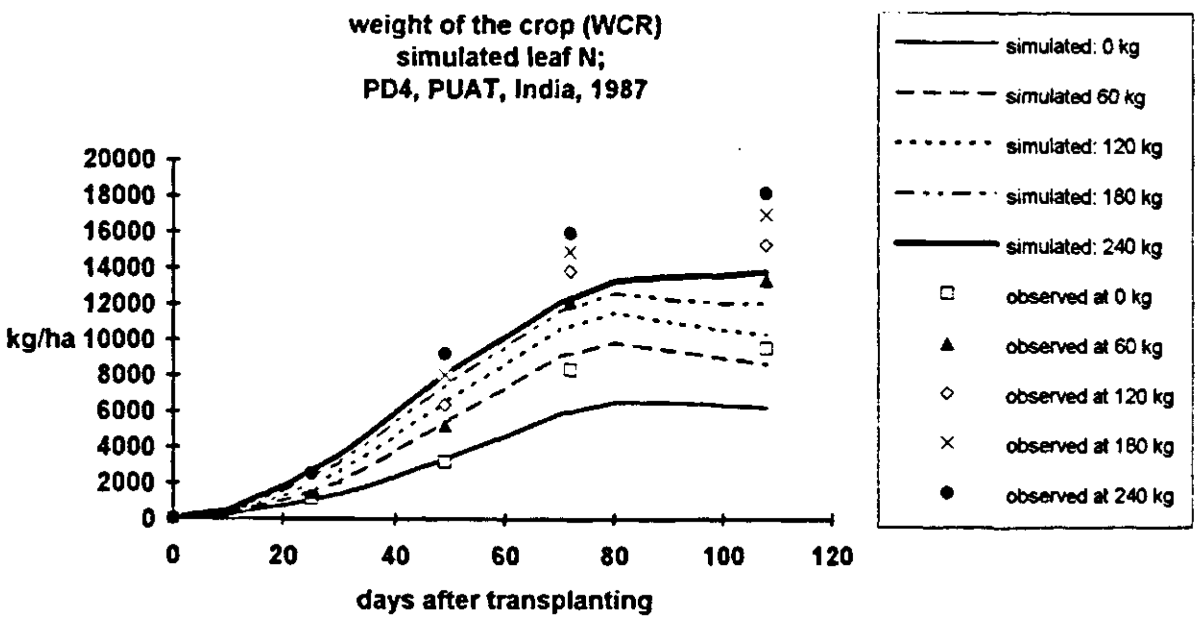
weight of the storage organs (WSO)
potential;
IR36, CRRI, India, 1990



PUAT, Pantnagar, India, 1987

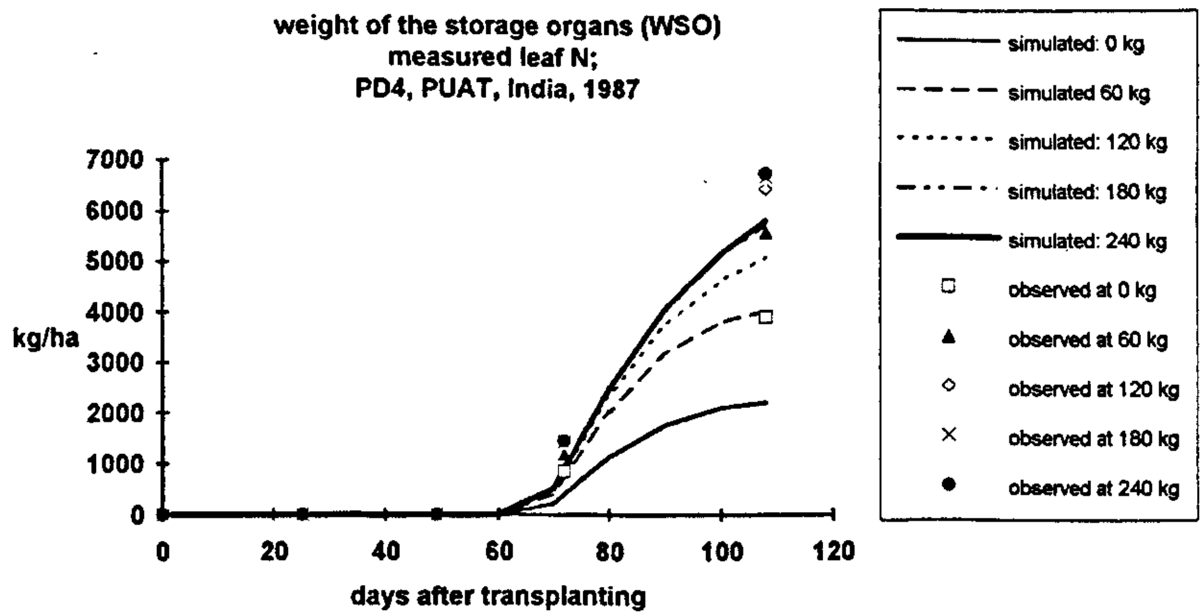
N-limited Production

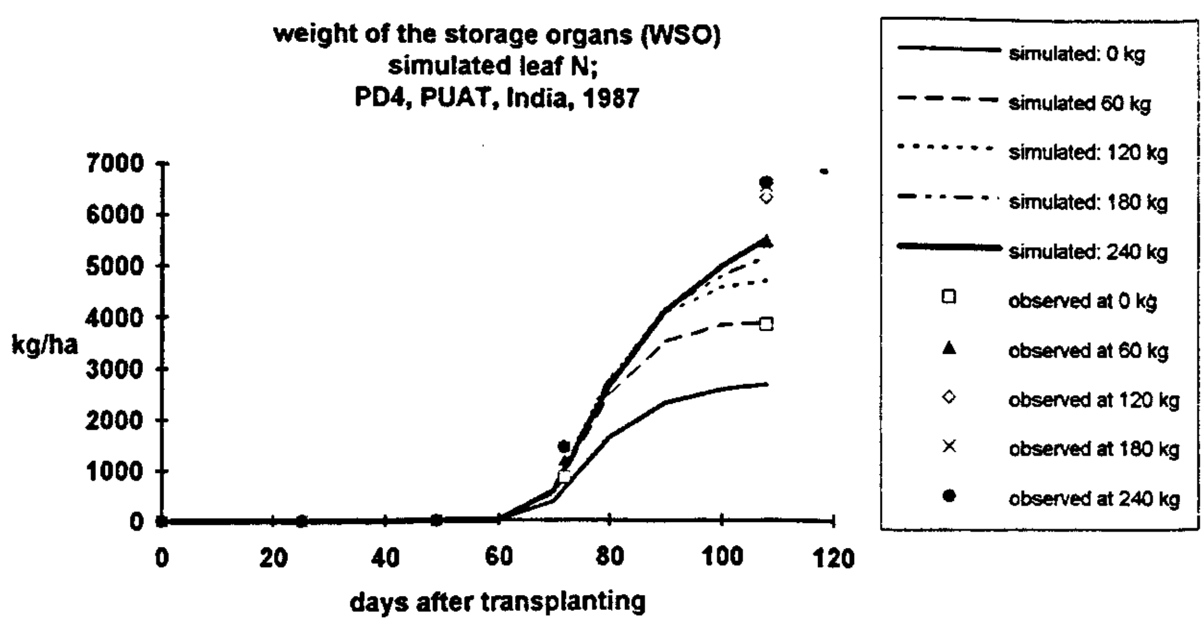




VI-12
PUAT, Pantnagar, India, 1987

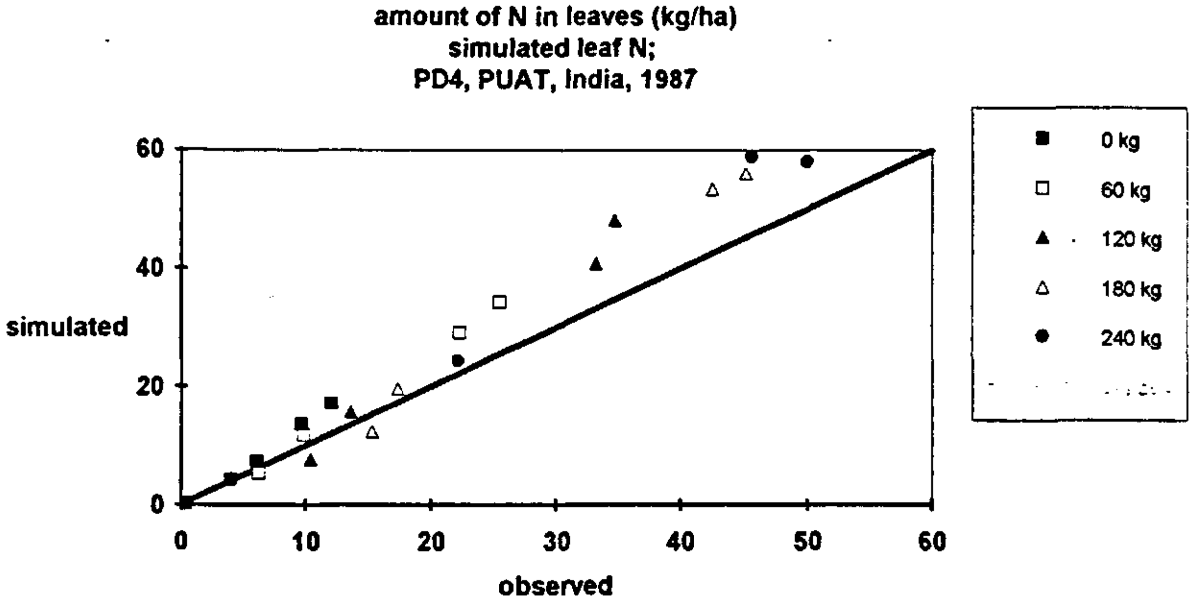
N-limited Production

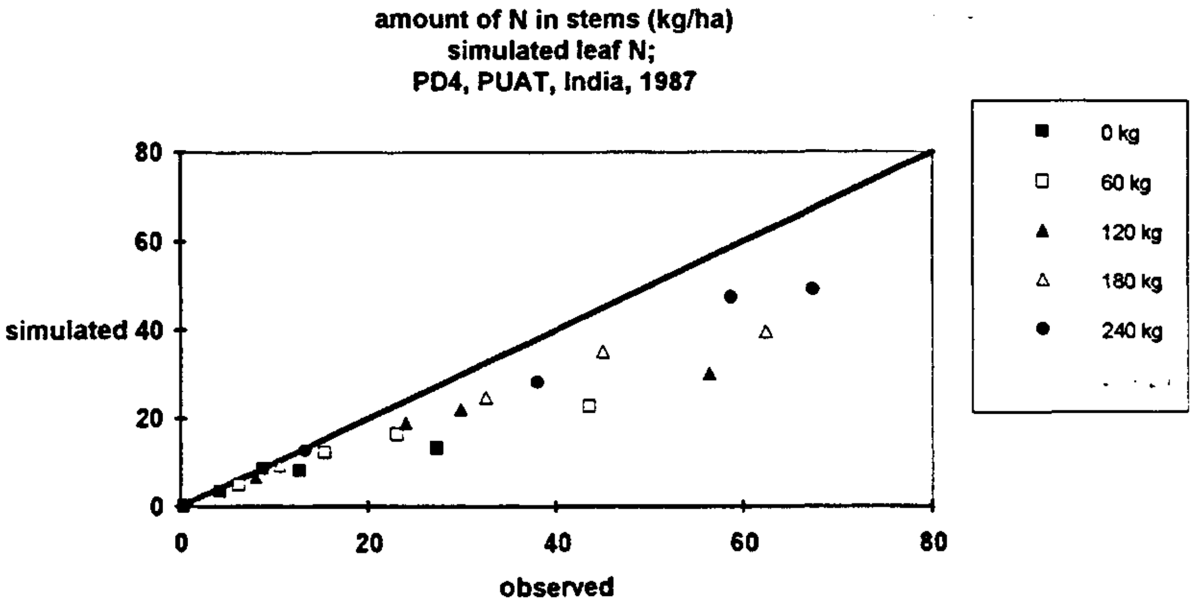




PUAT, Pantnagar, India, 1987

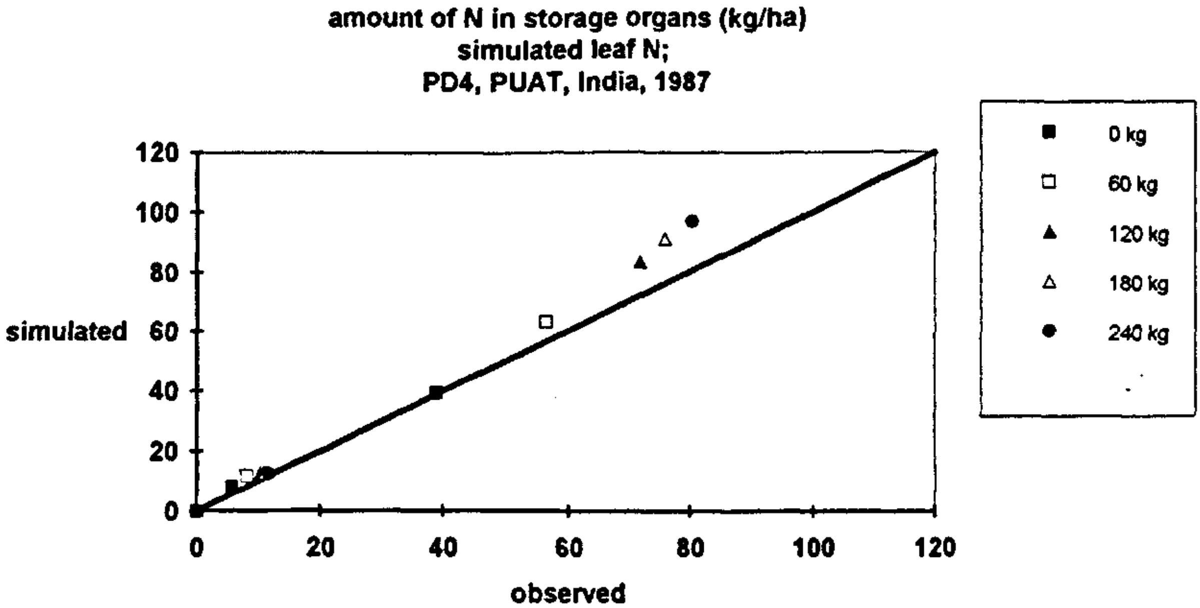
N-limited Production

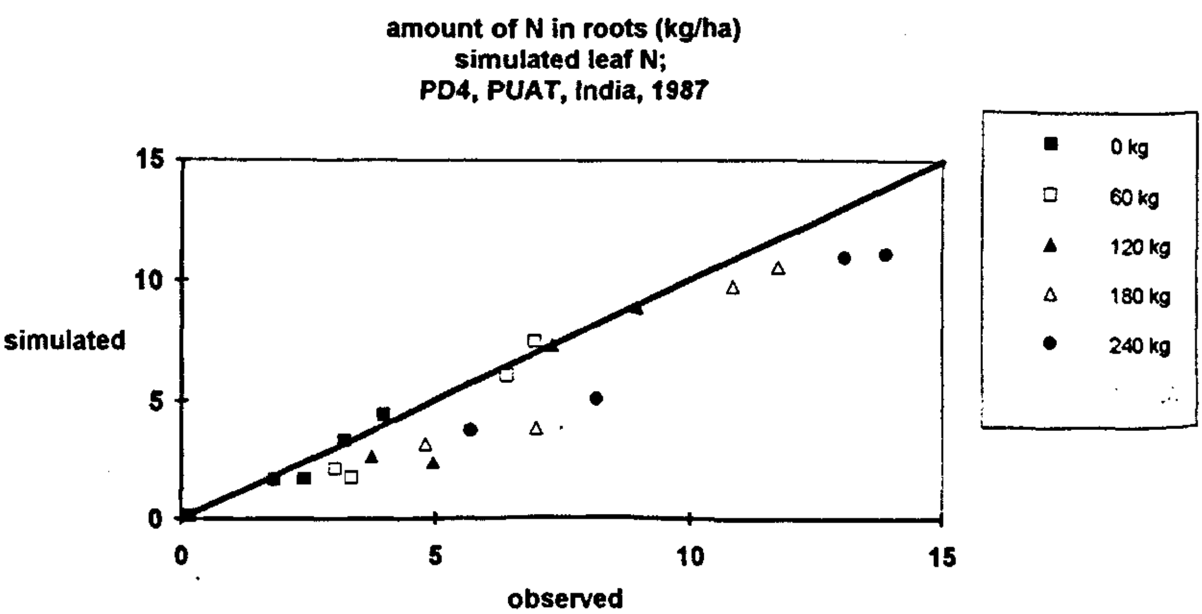




PUAT, Pantnagar, India, 1987

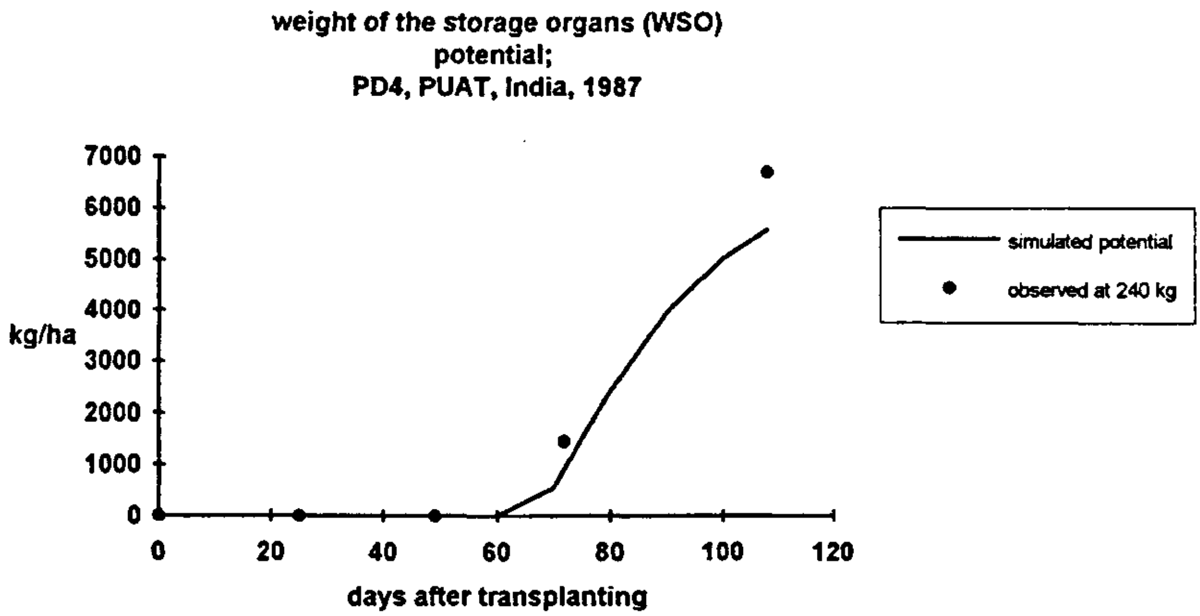
N-limited Production

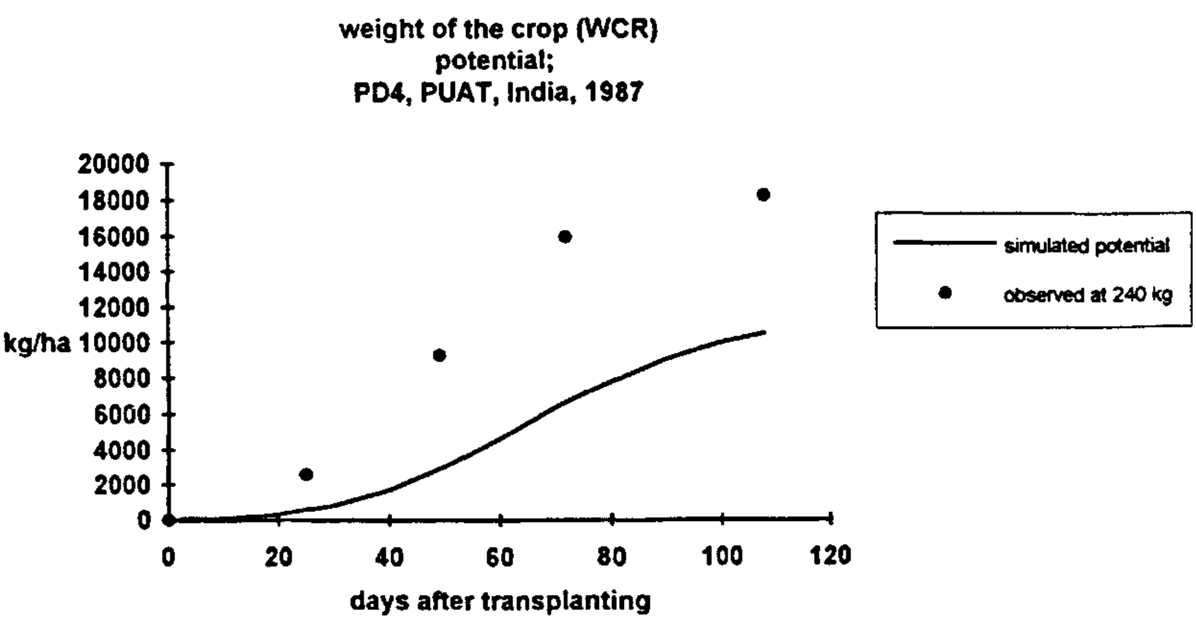




PUAT, Pantnagar, India, 1987

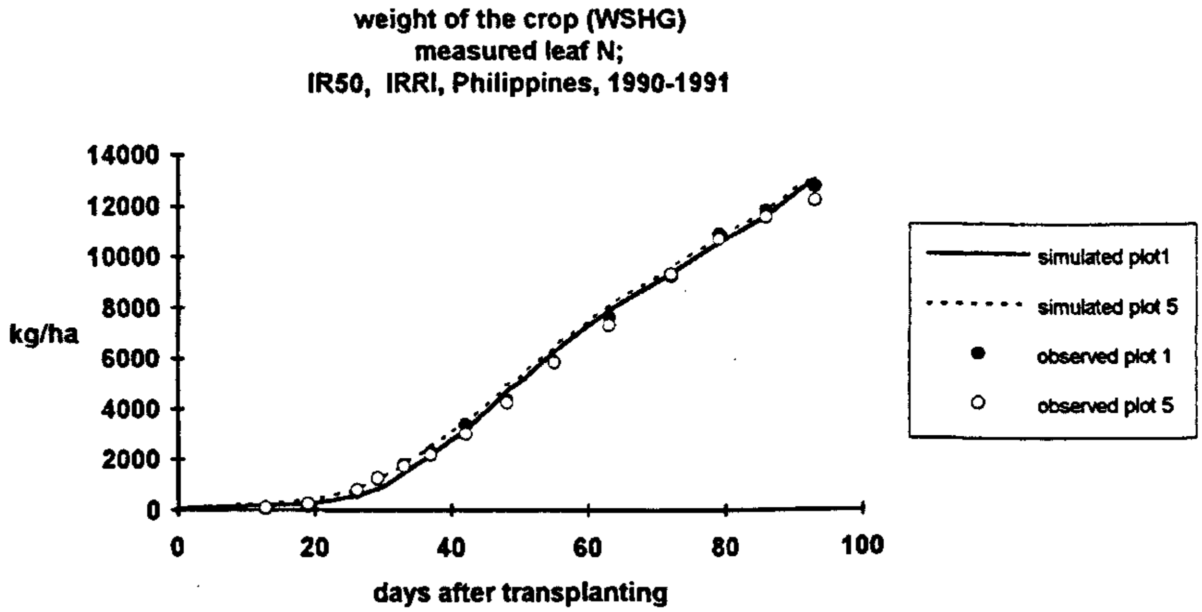
Potential Production

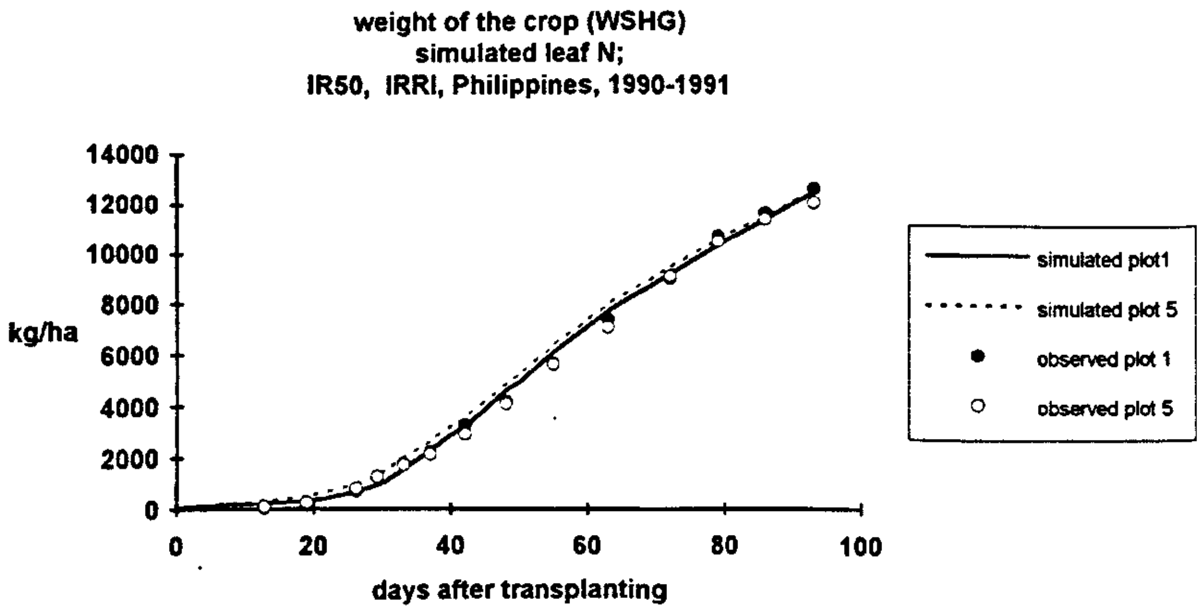




IRRI, Los Baños, Philippines, 1990-1991

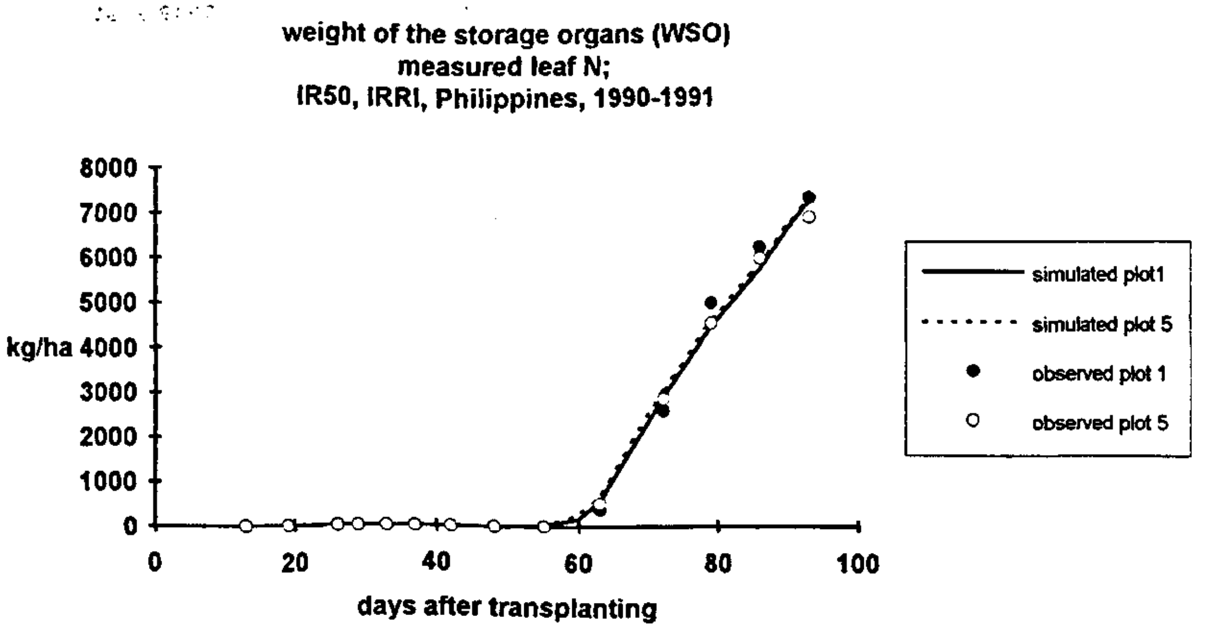
N-limited Production

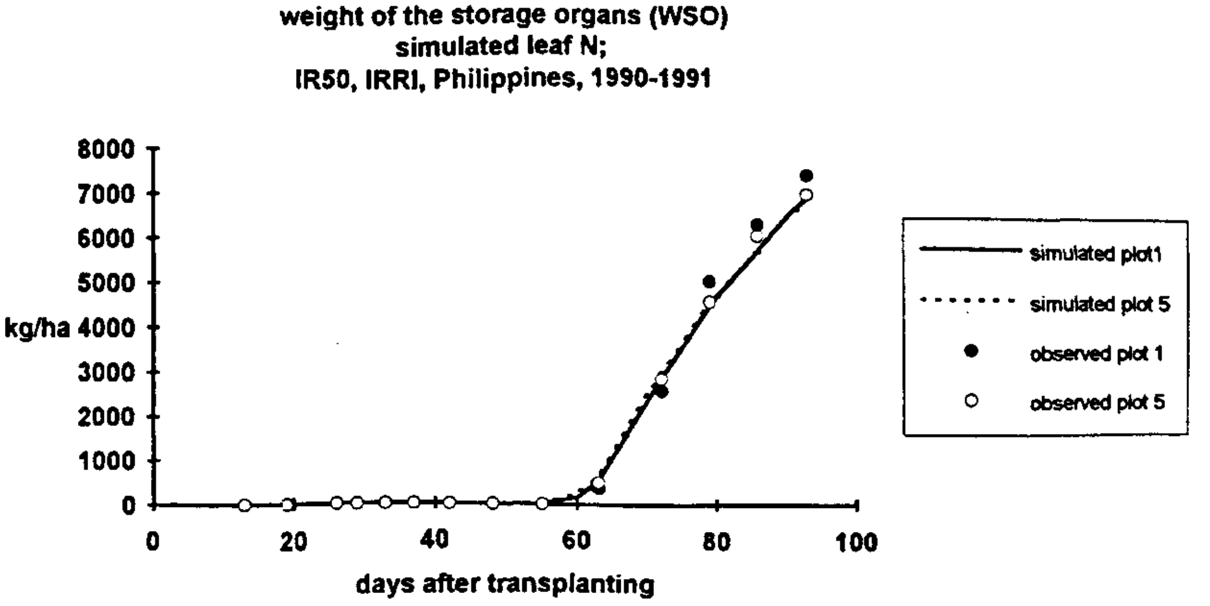




IRRI, Los Baños, Philippines, 1990-1991

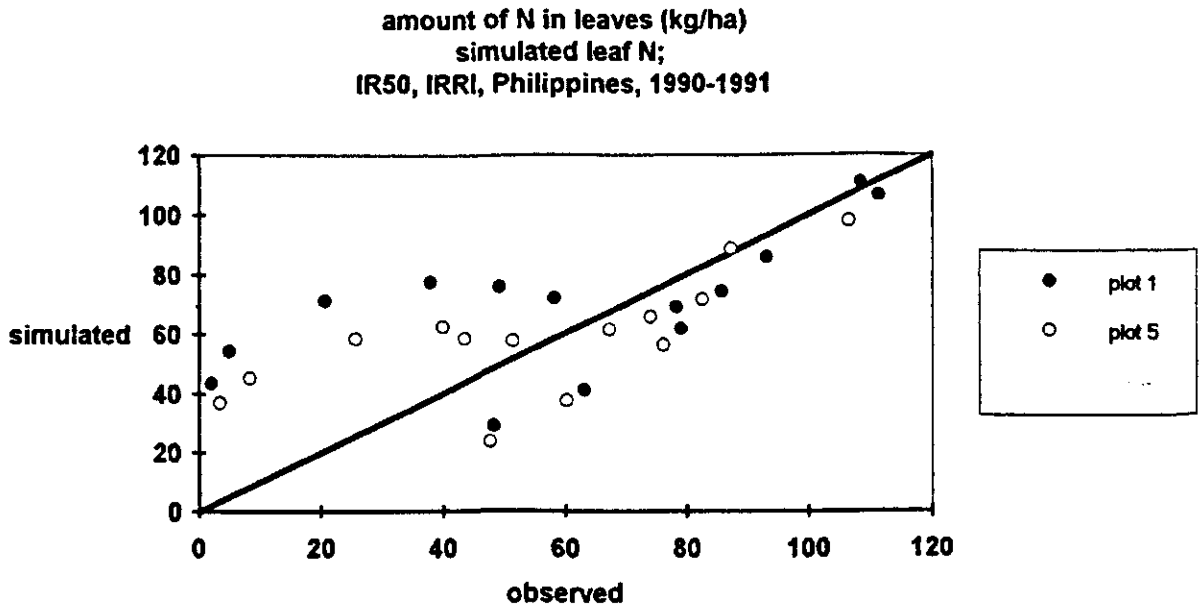
N-limited Production

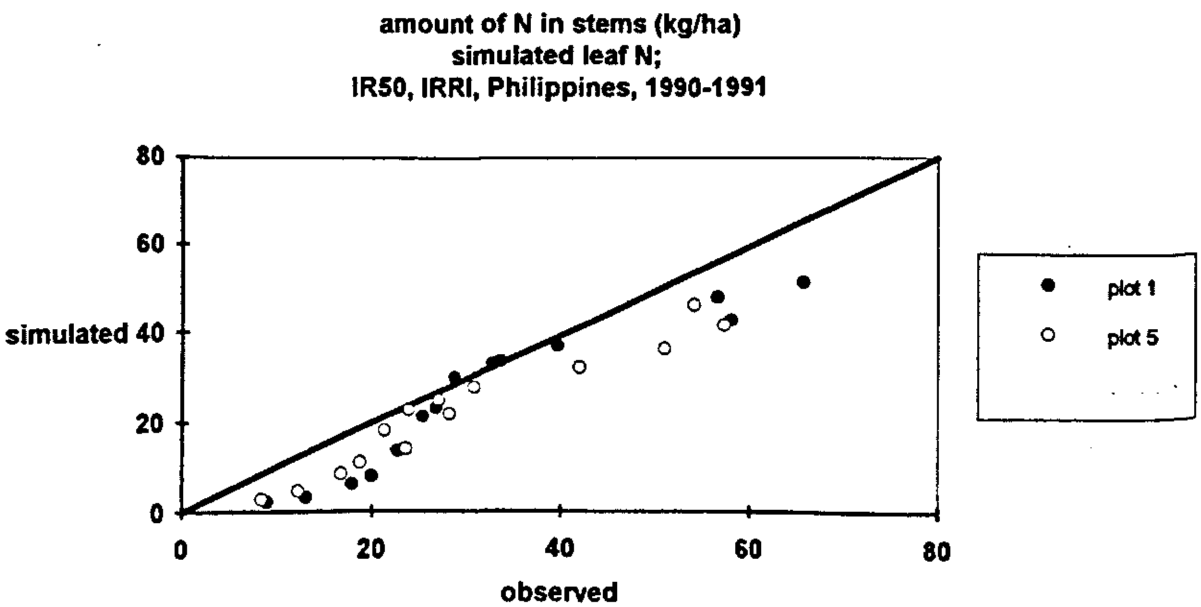




IRRI, Los Baños, Philippines, 1990-1991

N-limited Production

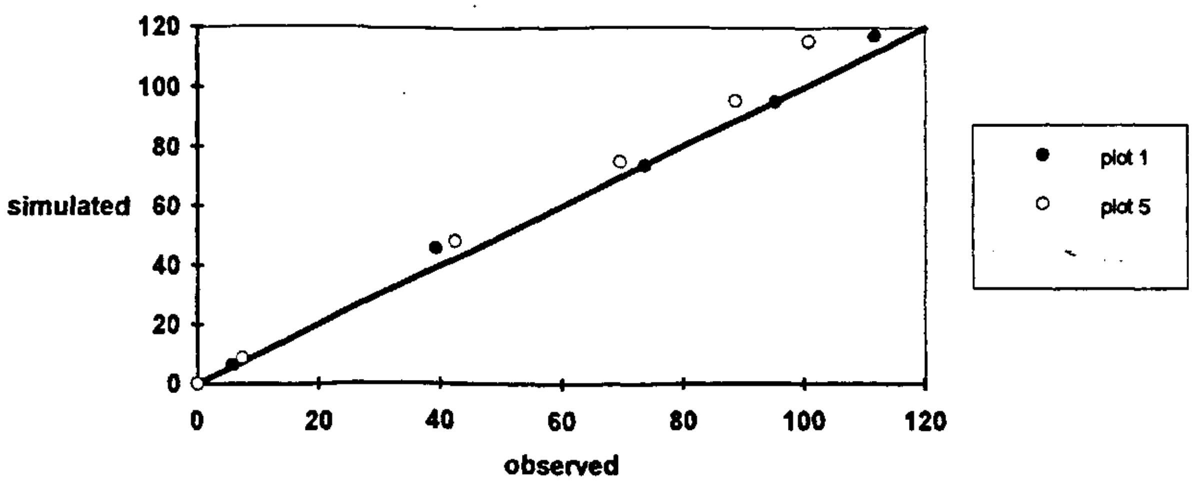




IRRI, Los Baños, Philippines, 1990-1991

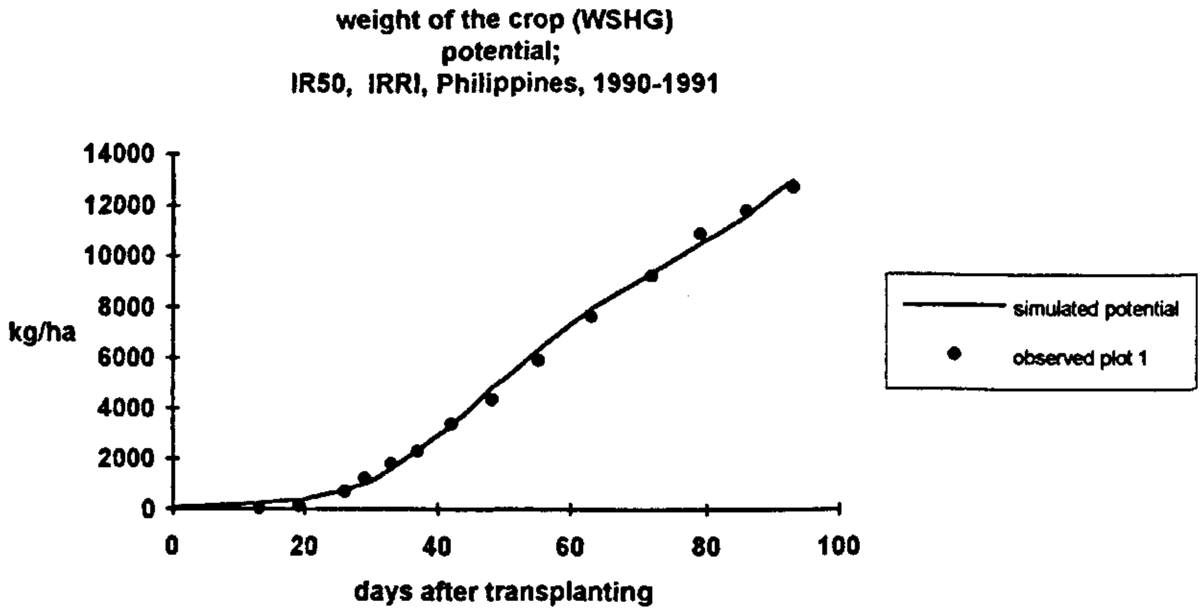
N-limited Production

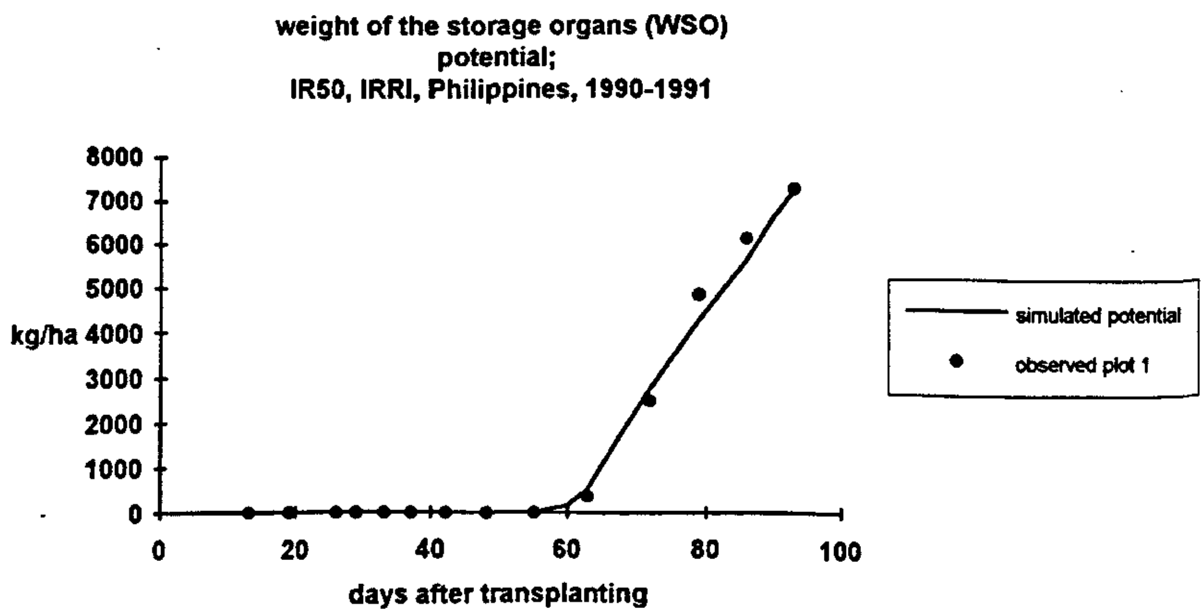
amount of N in storage organs (kg/ha)
simulated leaf N;
IR50, IRRI, Philippines, 1990-1991



IRRI, Los Baños, Philippines, 1990-1991

Potential Production

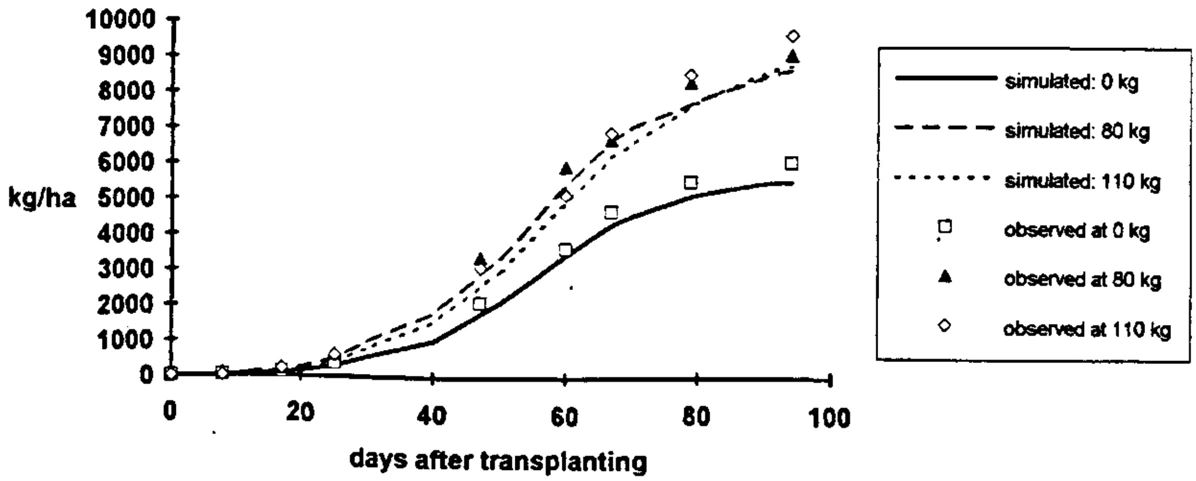




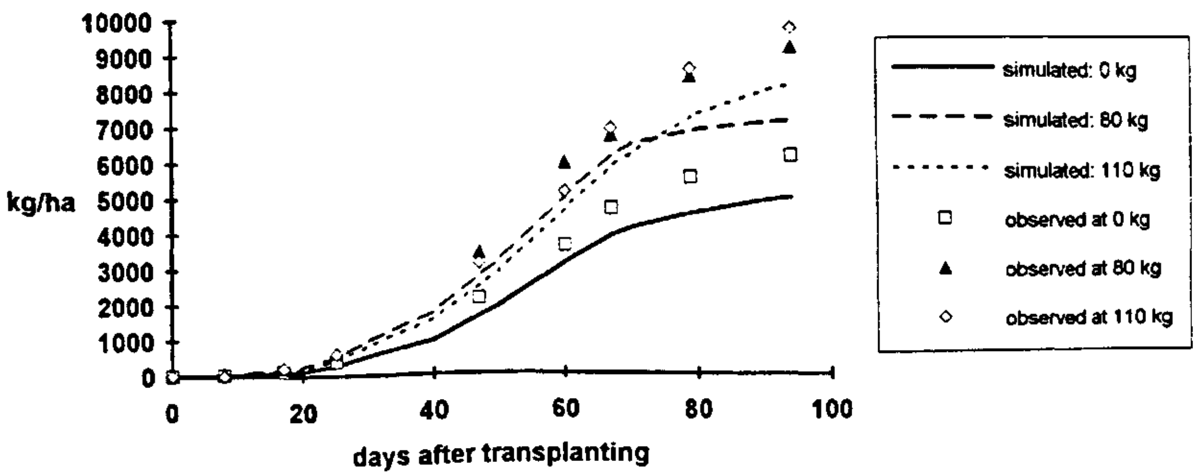
IRRI, Los Baños, Philippines, 1991

N-limited Production

weight of the crop (WSHG)
measured leaf N;
IR72, IRRI, Philippines, 1991



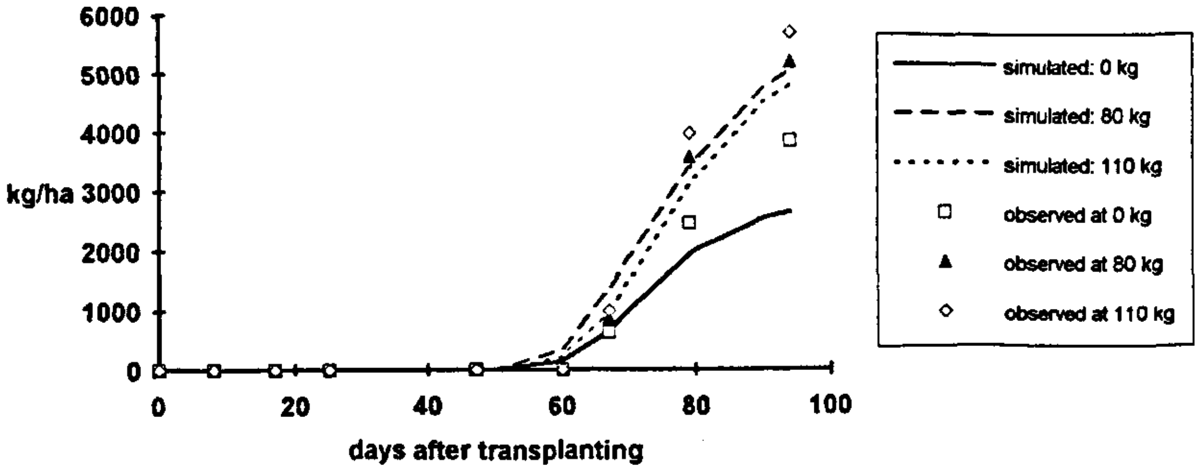
weight of the crop (WSHG)
simulated leaf N;
IR72, IRRI, Philippines, 1991



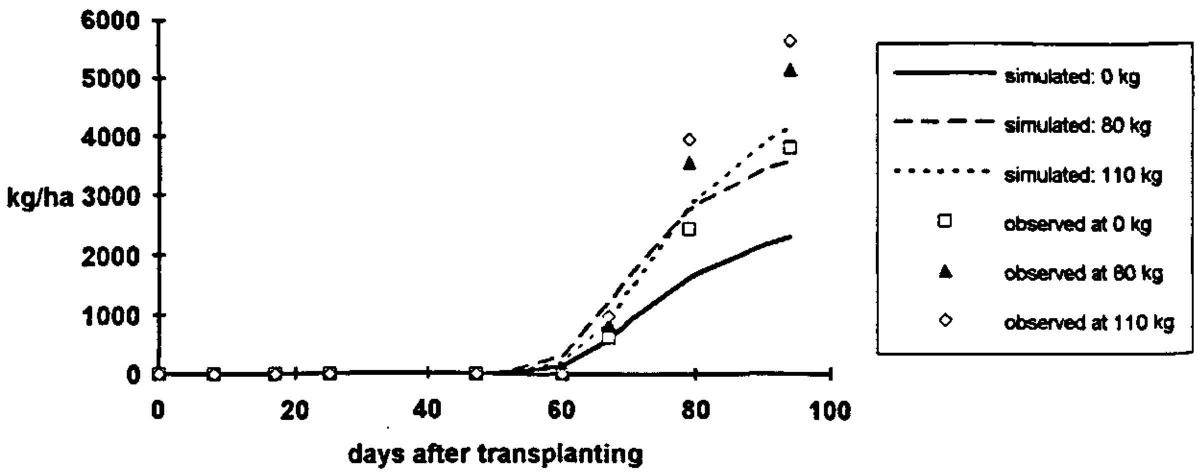
IRRI, Los Baños, Philippines, 1991

N-limited Production

weight of the storage organs (WSO)
measured leaf N;
IR72, IRRI, Philippines, 1991



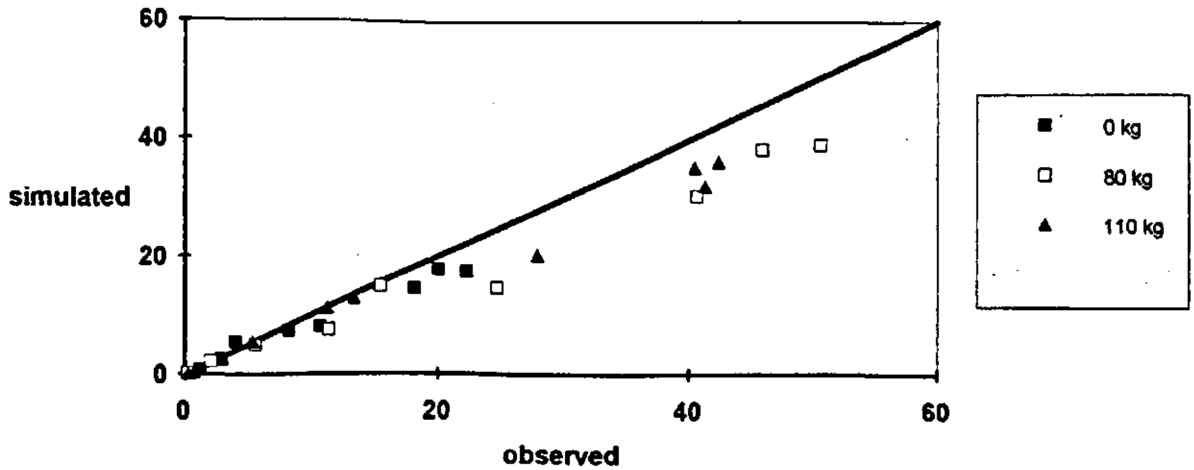
weight of the storage organs (WSO)
simulated leaf N;
IR72, IRRI, Philippines, 1991



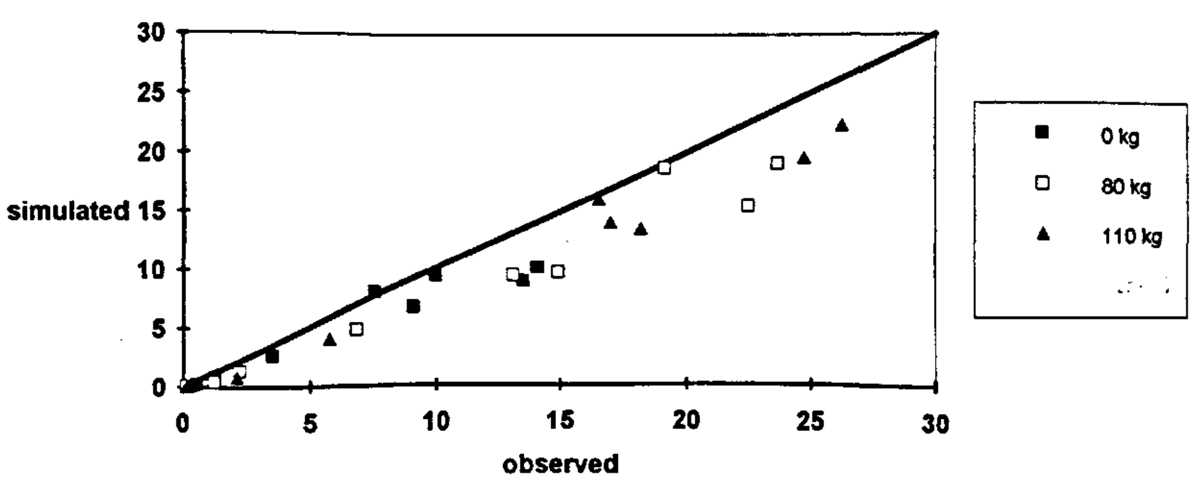
IRRI, Los Baños, Philippines, 1991

N-limited Production

amount of N in leaves (kg/ha)
simulated leaf N;
IR72, IRRI, Philippines, 1991



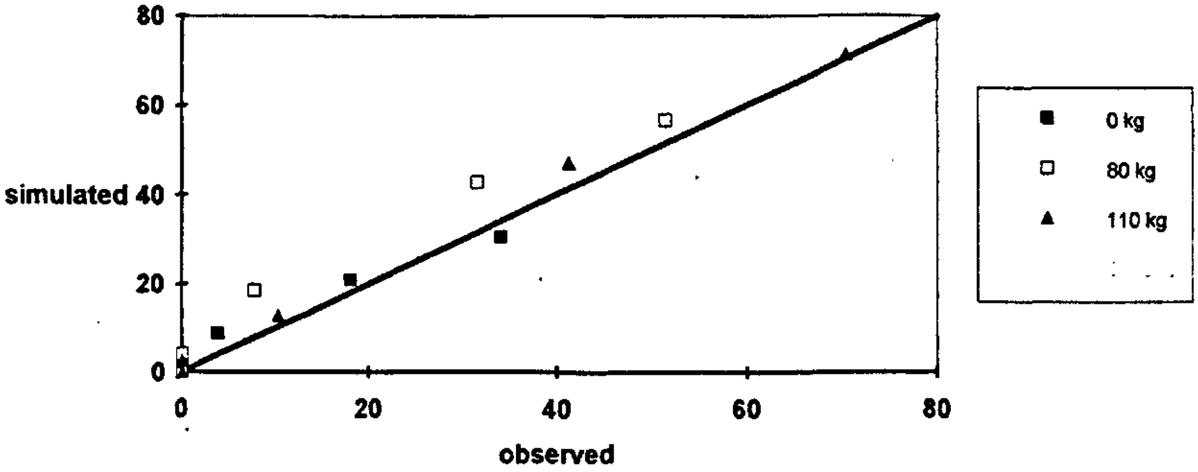
amount of N in stems (kg/ha)
simulated leaf N;
IR72, IRRI, Philippines, 1991



IRRI, Los Baños, Philippines, 1991

N-limited Production

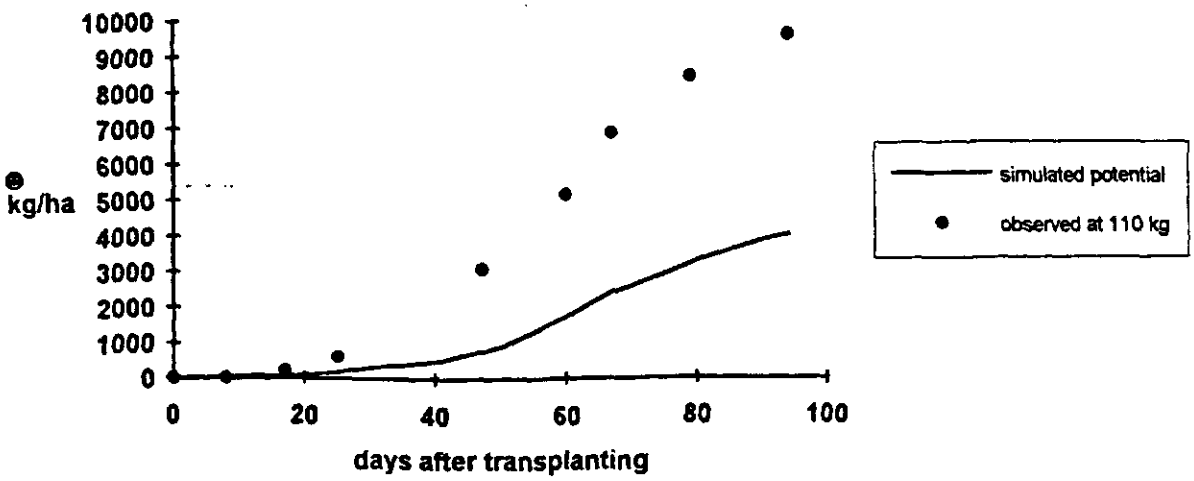
amount of N in storage organs (kg/ha)
simulated leaf N;
IR72, IRRI, Philippines, 1991



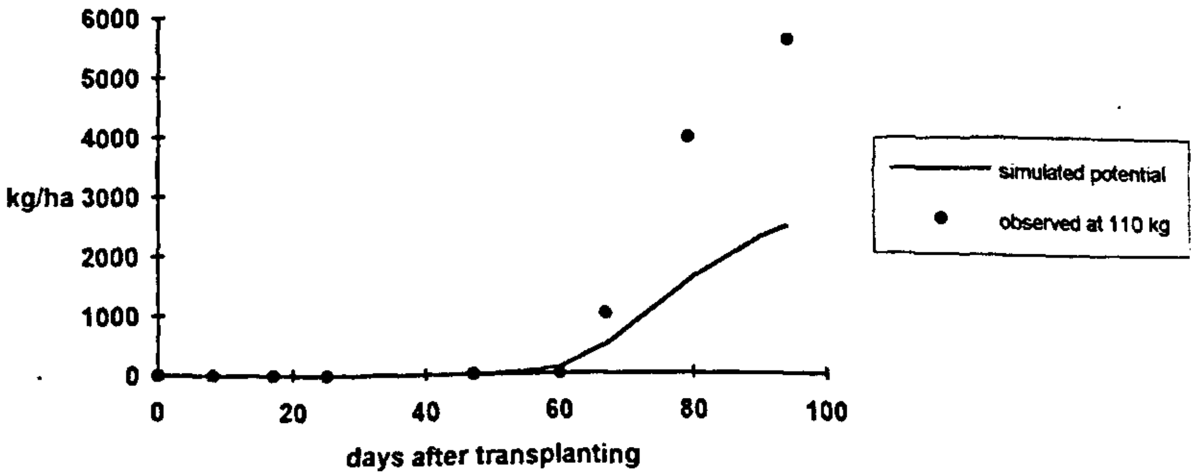
IRRI, Los Baños, Philippines, 1991

Potential Production

weight of the crop (WSHG)
potential;
IR72, IRRI, Philippines, 1991

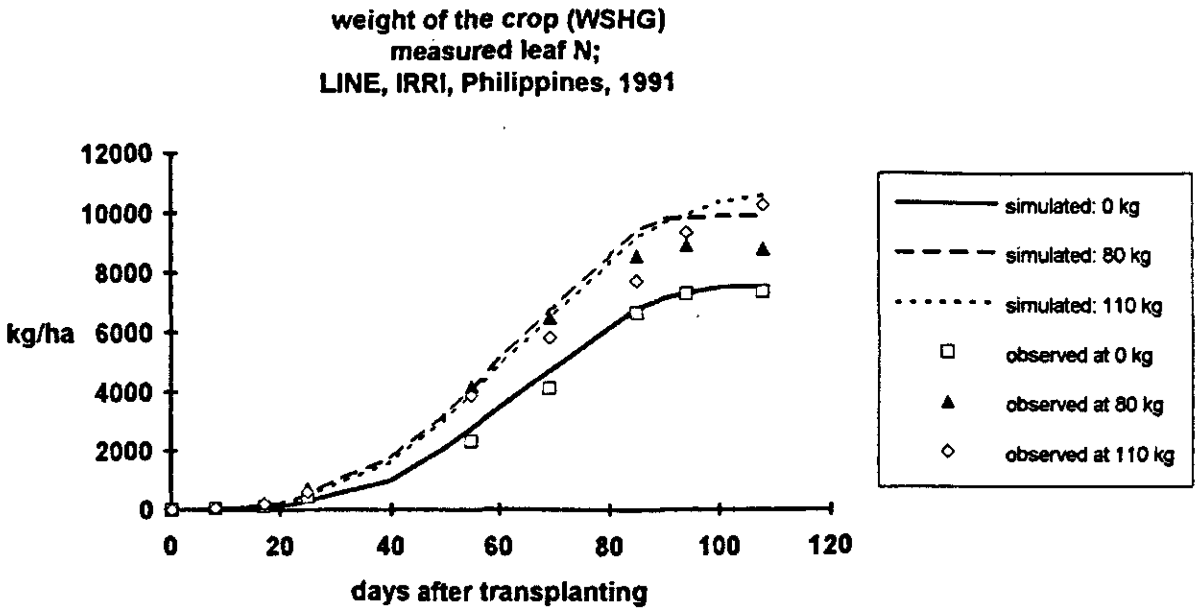


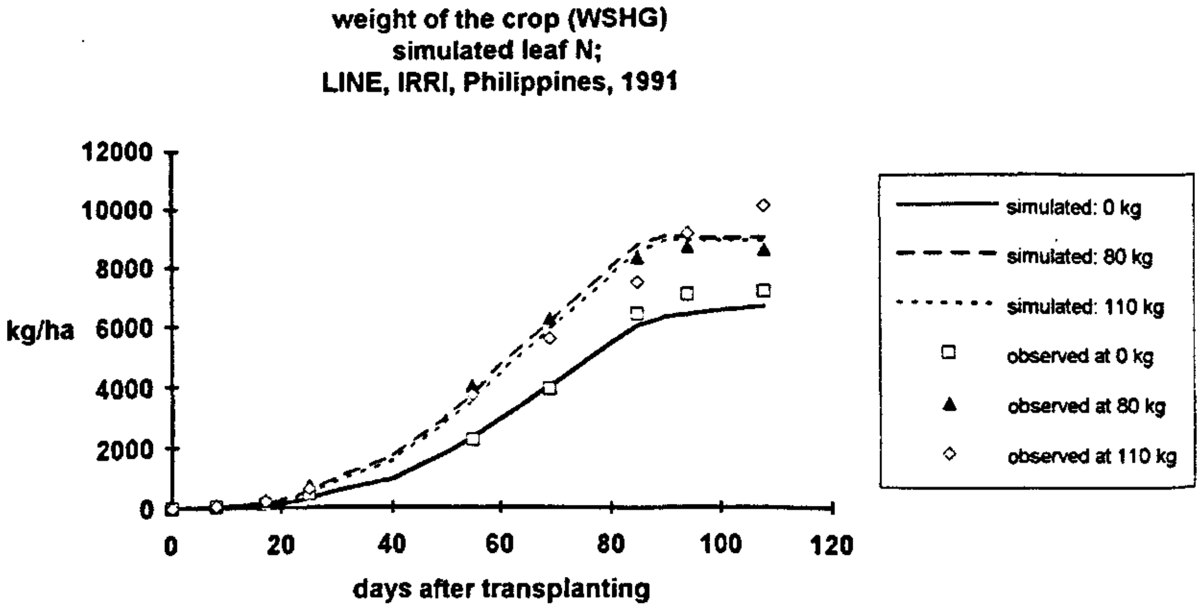
weight of the storage organs (WSO)
potential;
IR72, IRRI, Philippines, 1991



IRRI, Los Baños, Philippines, 1991

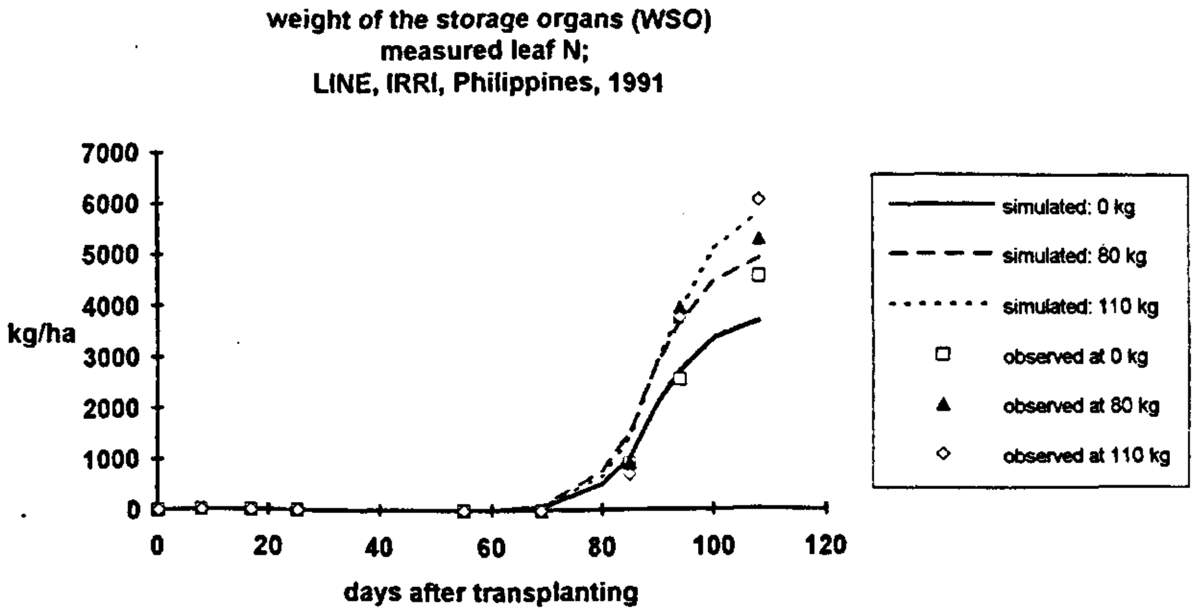
N-limited Production

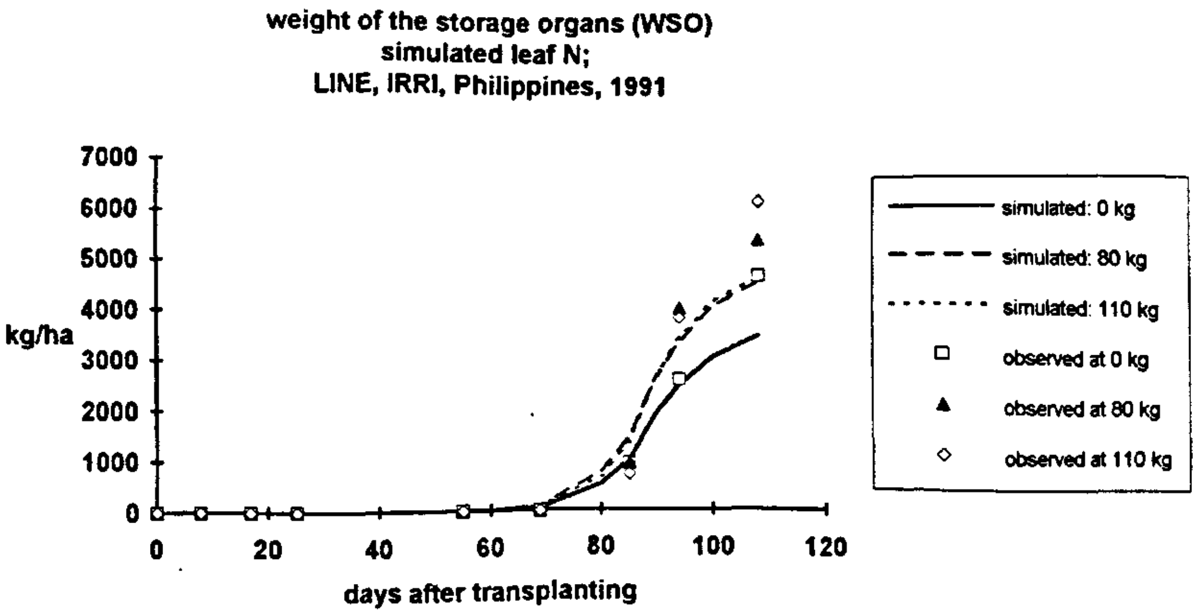




IRRI, Los Baños, Philippines, 1991

N-limited Production

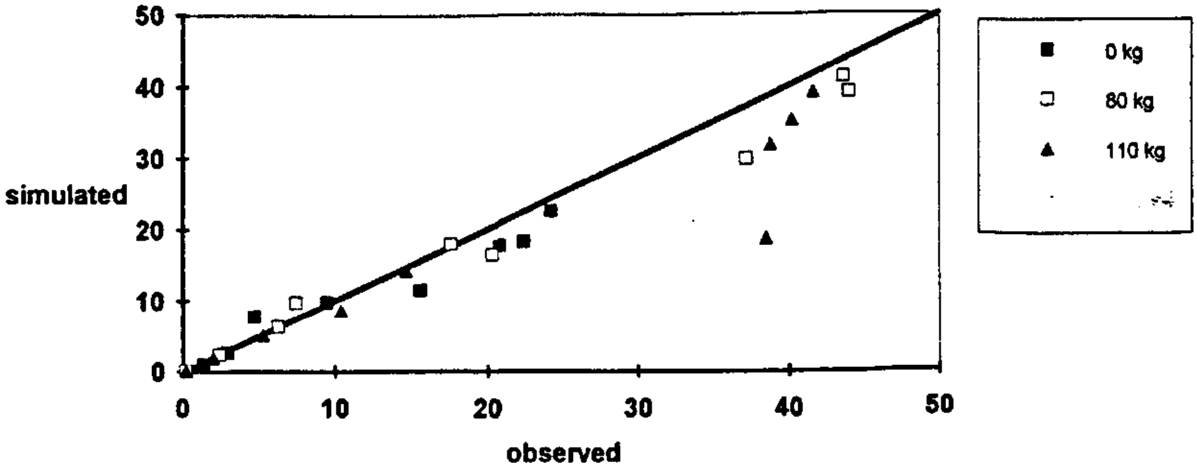




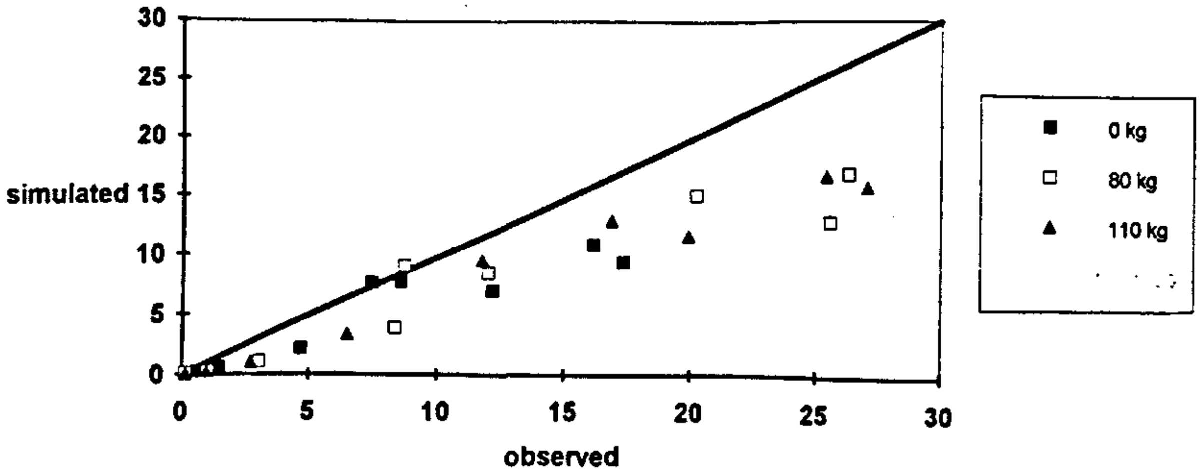
IRRI, Los Baños, Philippines, 1991

N-limited Production

amount of N in leaves (kg/ha)
simulated leaf N;
LINE, IRRI, Philippines, 1991



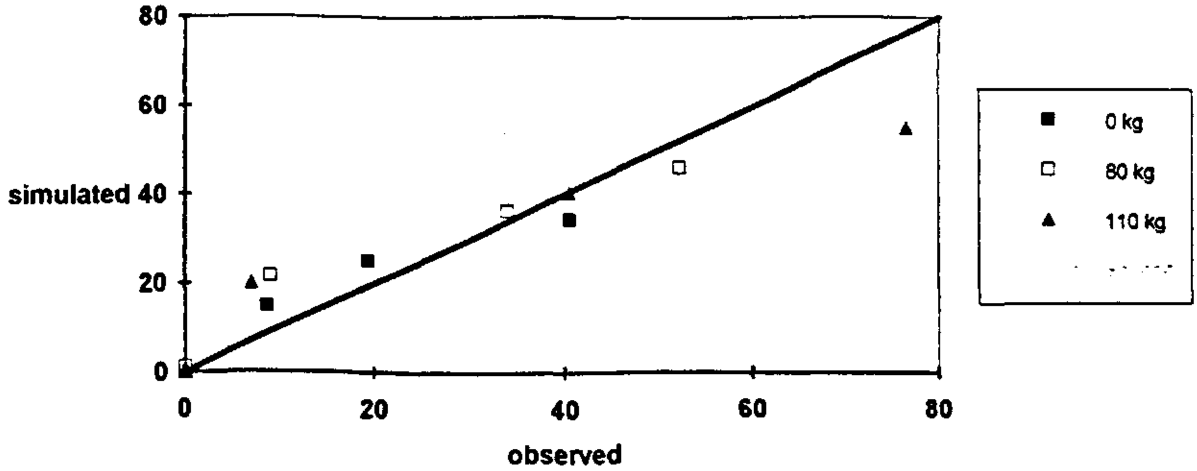
amount of N in stems (kg/ha)
simulated leaf N;
LINE, IRRI, Philippines, 1991



IRRI, Los Baños, Philippines, 1991

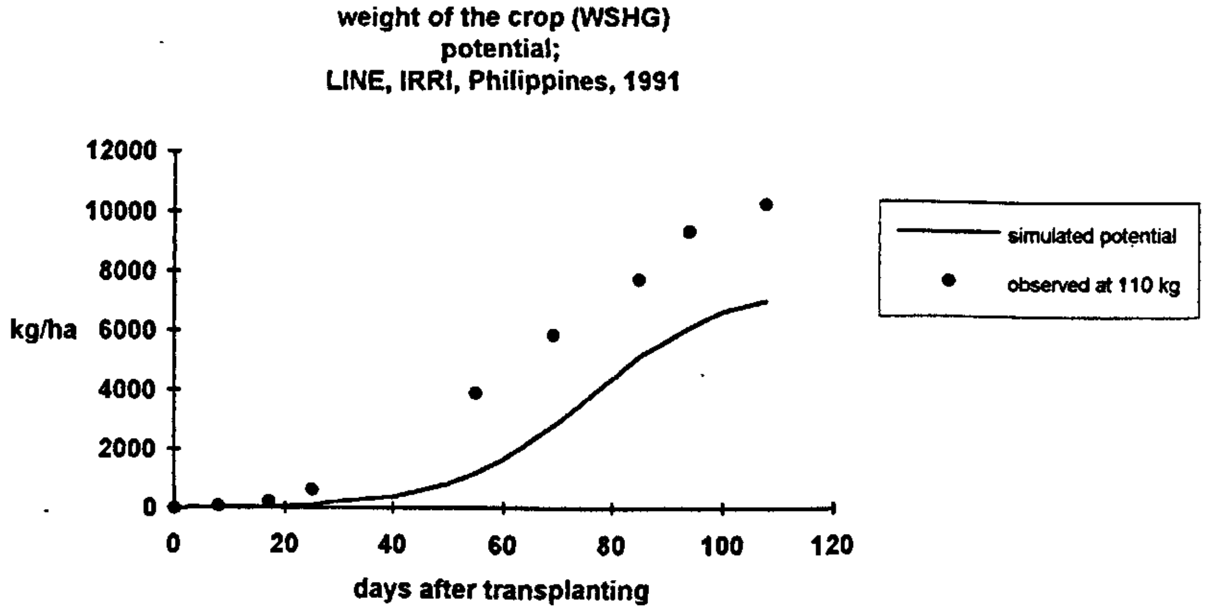
N-limited Production

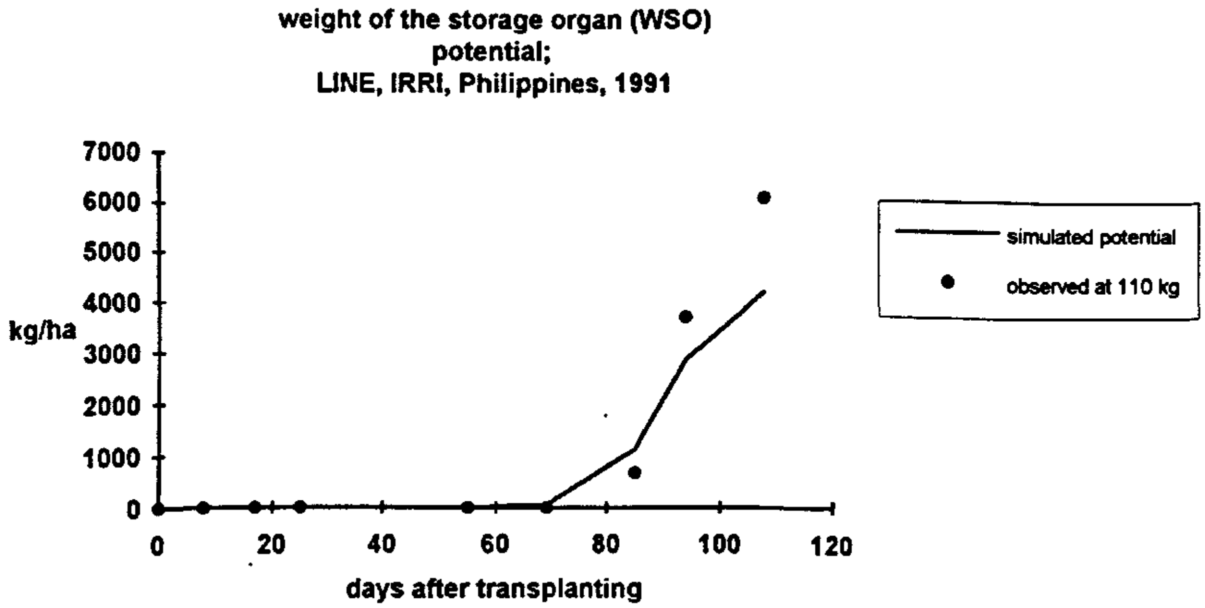
amount of N in storage organs (kg/ha)
simulated leaf N;
LINE, IRRI, Philippines, 1991



IRRI, Los Baños, Philippines, 1991

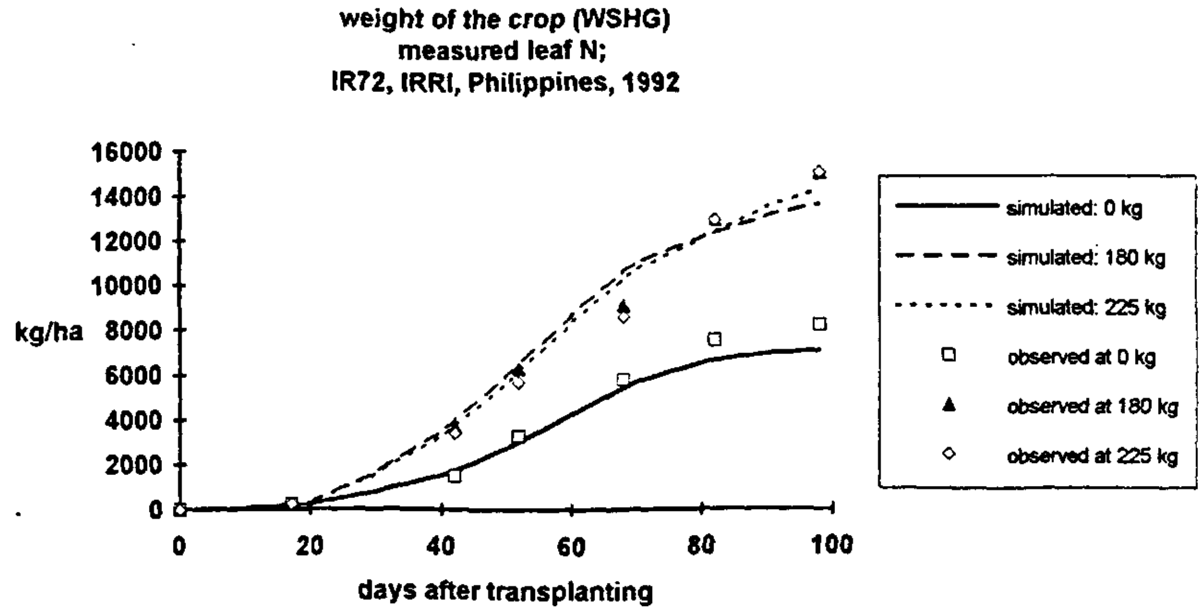
Potential Production

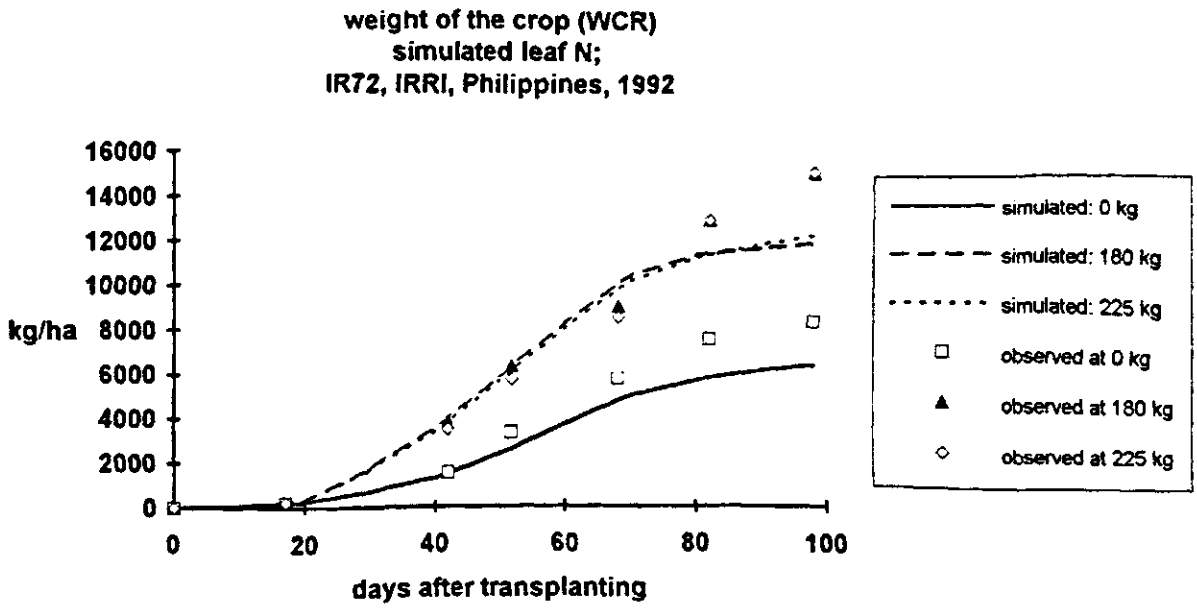




IRRI, Los Baños, Philippines, 1992

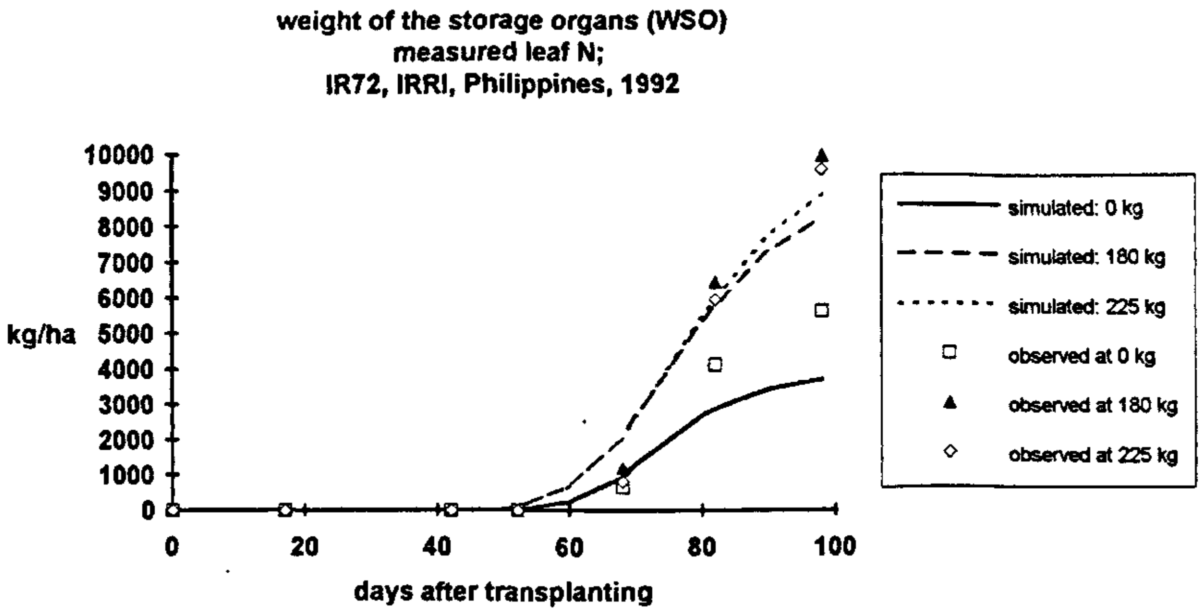
N-limited Production

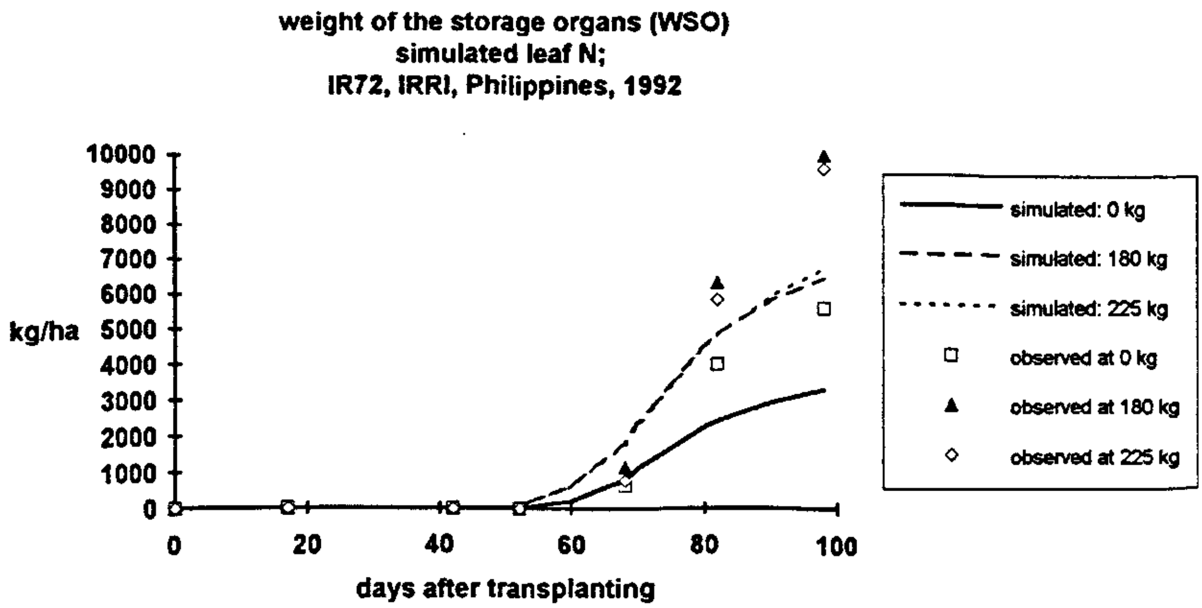




IRRI, Los Baños, Philippines, 1992

N-limited Production

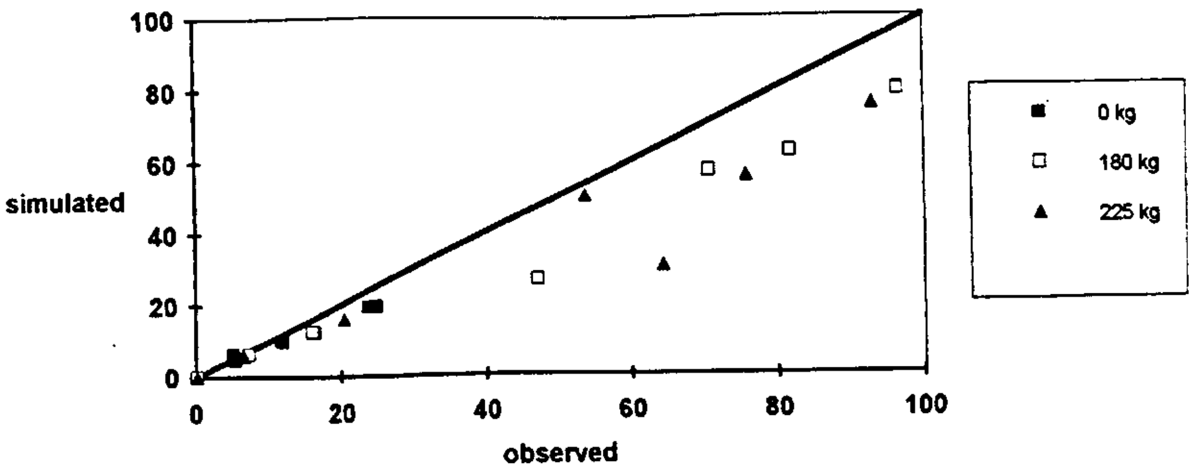




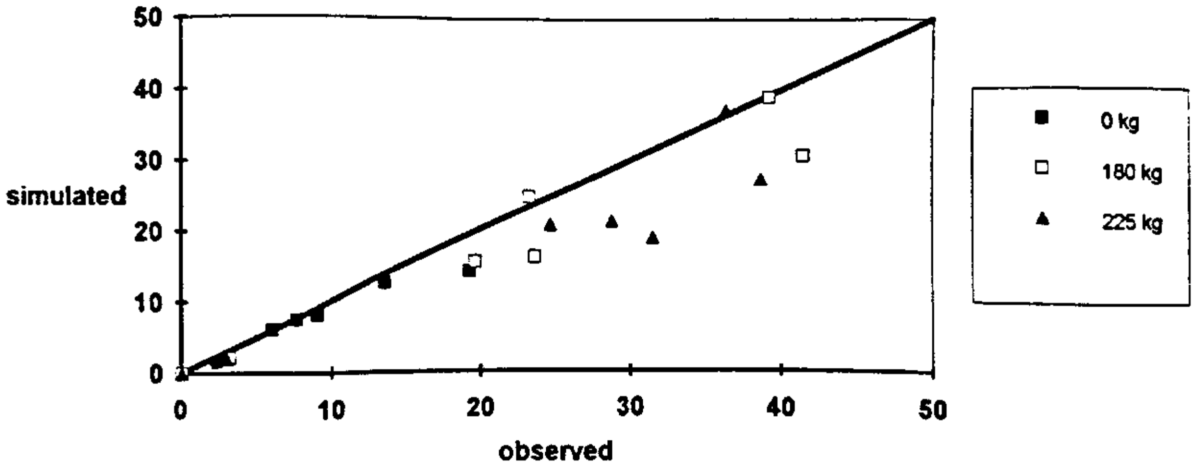
IRRI, Los Baños, Philippines, 1992

N-limited Production

amount of N in leaves (kg/ha)
simulated leaf N;
IR72, IRRI, Philippines, 1992



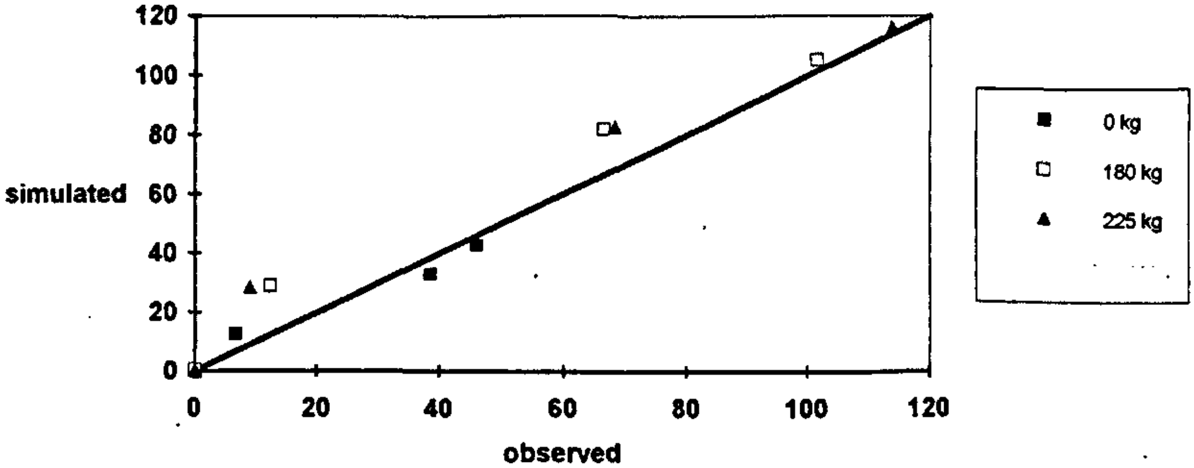
amount of N in stems (kg/ha)
simulated leaf N;
IR72, IRRI, Philippines, 1992



IRRI, Los Baños, Philippines, 1992

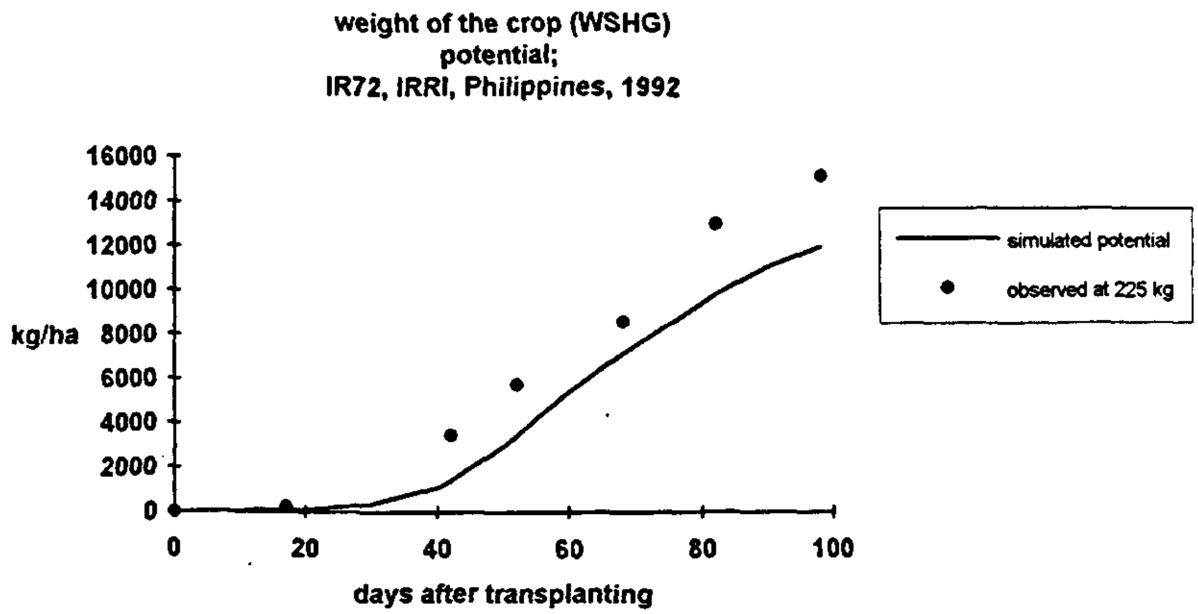
N-limited Production

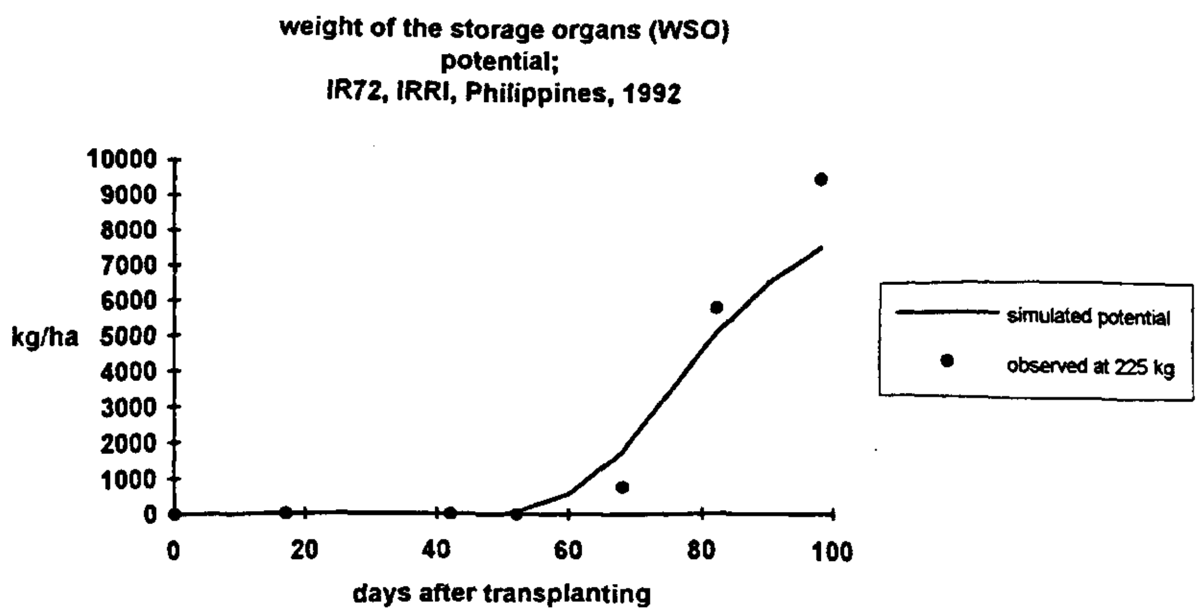
amount of N in storage organs (kg/ha)
simulated leaf N;
IR72, IRRI, Philippines, 1992



IRRI, Los Baños, Philippines, 1992

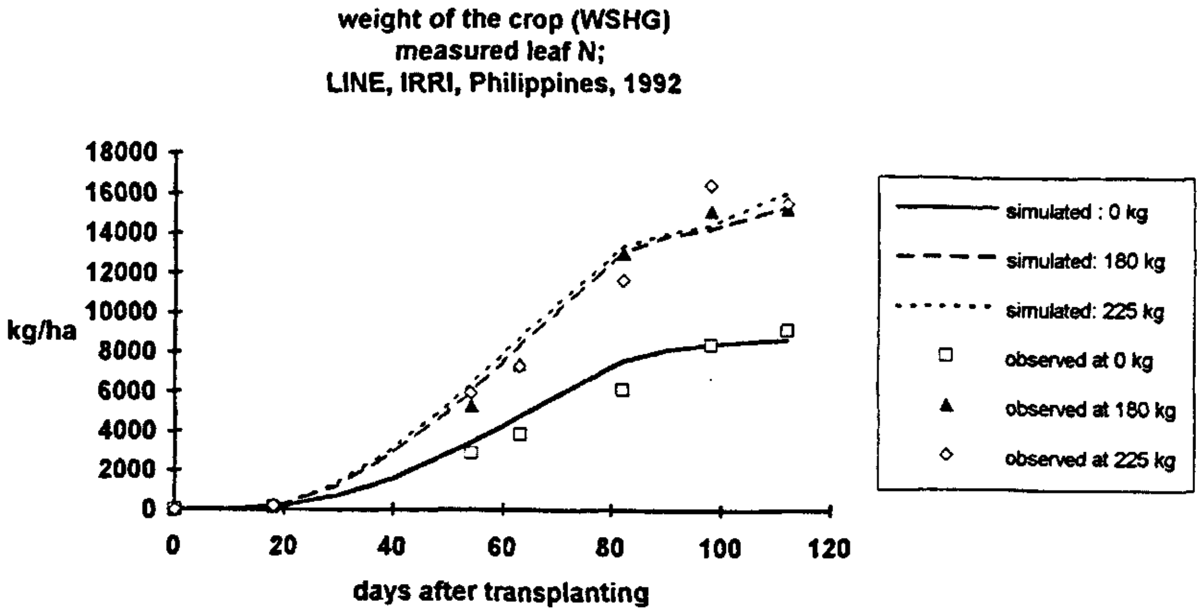
Potential Production

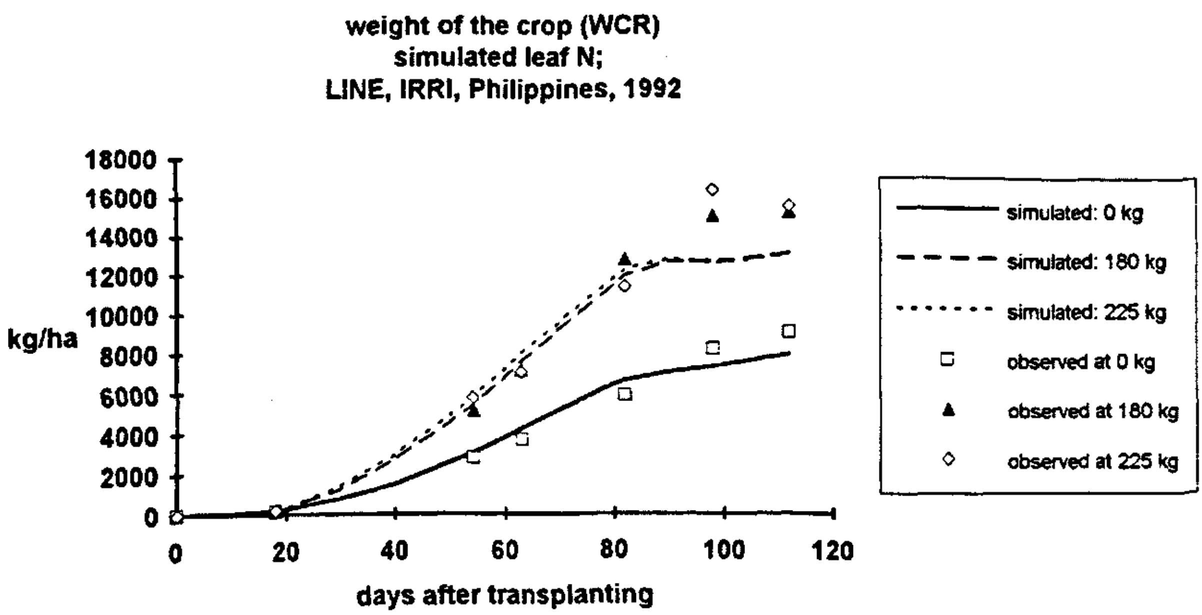




IRRI, Los Baños, Philippines, 1992

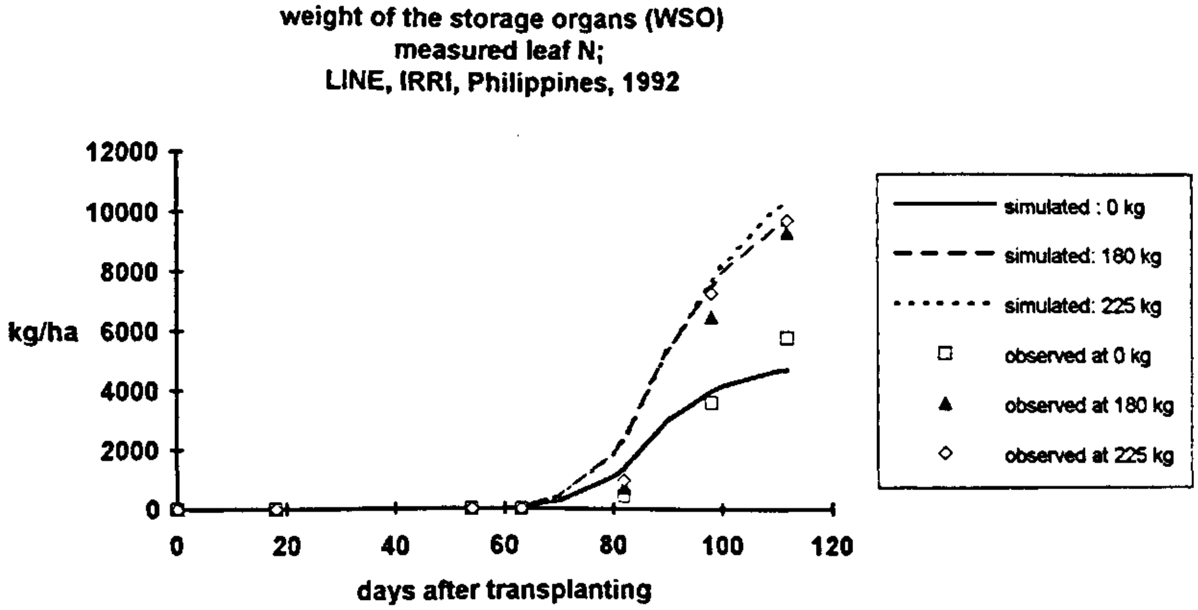
N-limited Production

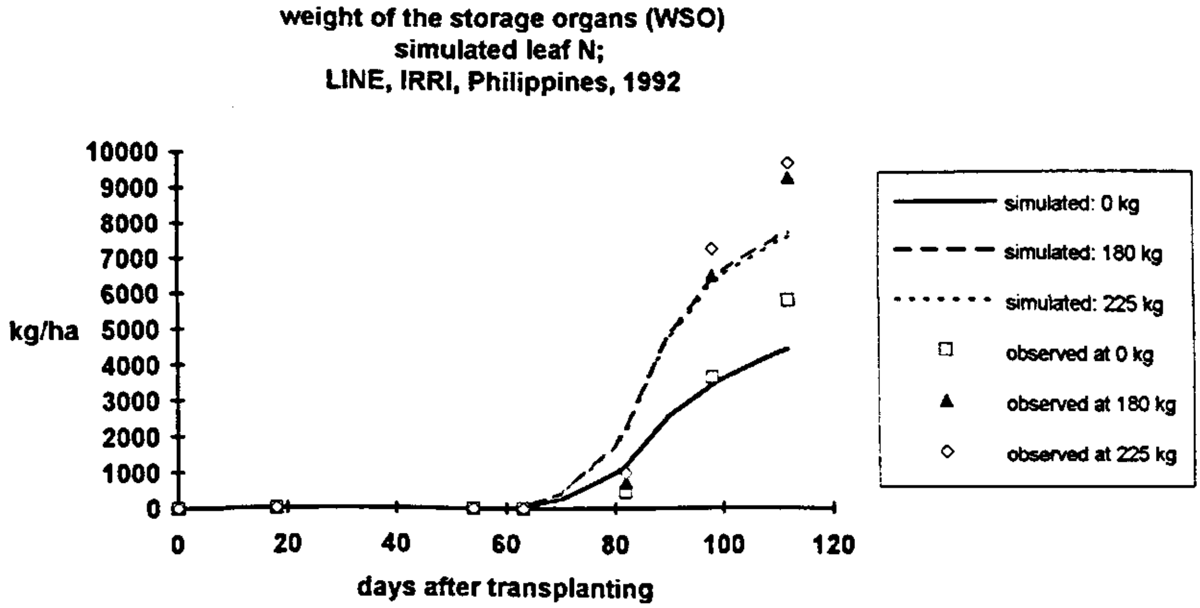




IRRI, Los Baños, Philippines, 1992

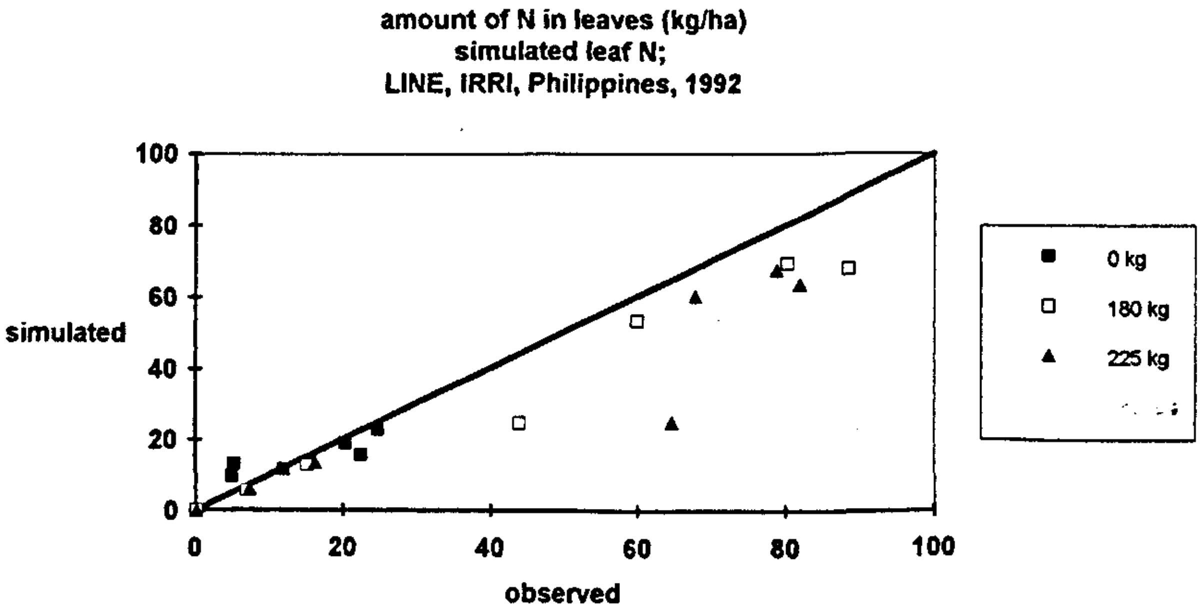
N-limited Production

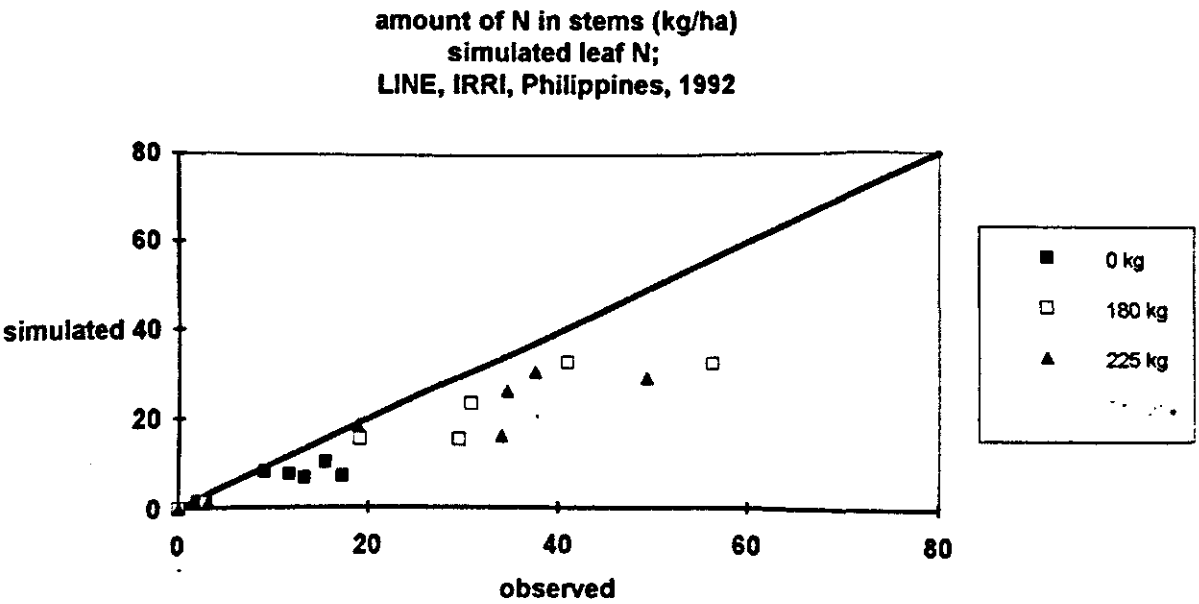




IRRI, Los Baños, Philippines, 1992

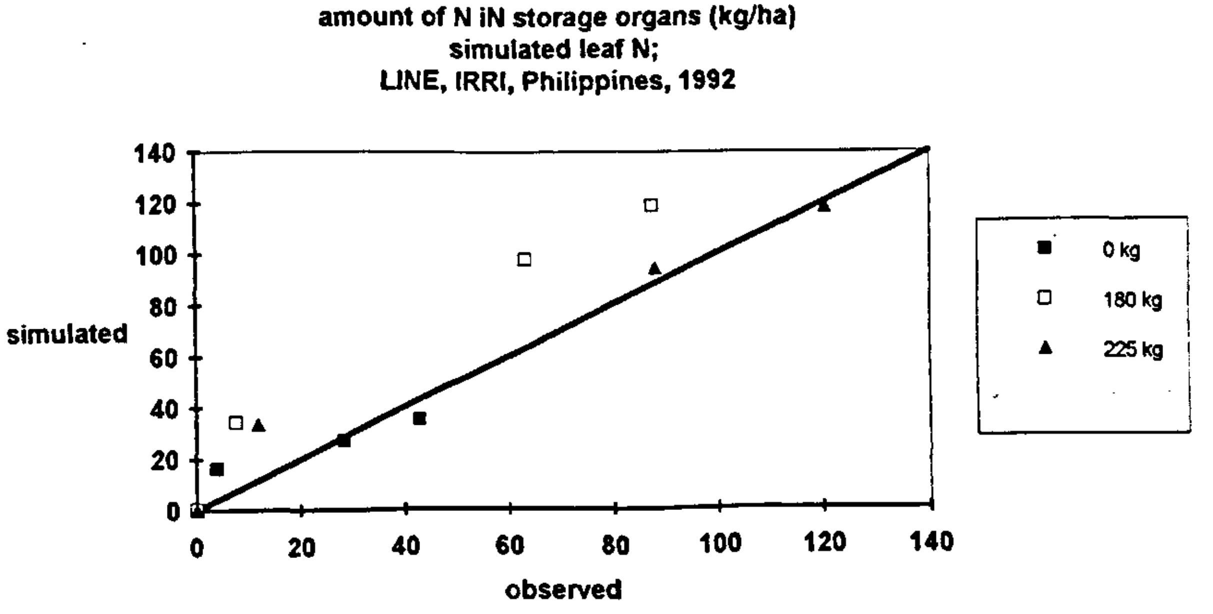
N-limited Production





IRRI, Los Baños, Philippines, 1992

N-limited Production



IRRI, Los Baños, Philippines, 1992

Potential Production