TECHNICAL REPORT 1

Experimental Design and Data Collection Procedures for IBSNAT

The minimum data set for systems analysis and crop simulation

Third Edition
Revised 1988

International Benchmark Sites Network for Agrotechnology Transfer

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IBSNAT Technical Report 1
Third Edition, Revised 1988

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FOREWORD TO THE THIRD EDITION

The first two editions (1984, 1986) of IBSNAT Technical Report 1 have been in use now for three years. As a result of comments and remarks received from IBSNAT researchers, scientists, and collaborators using both the 1984 and 1986 editions, we have prepared this third edition. Our objective is to give Technical Report 1 users a document that contains a more detailed and precise explanation of each of the minimum data set (MDS) Forms A-S.

Information necessary for the user to complete each of the Forms A-S will be found on the facing page of every form. This page has been divided into two sections, "Importance" and "Notes." The "Importance" section explains why the data on that form is important to the IBSNAT Project. The "Notes" section contains specific information about or explanations for a particular data item or set of items on the form. All but one of the appendices contained in the earlier editions have been eliminated and the information contained in them presented on the facing pages for easier reference.

Many of the MDS forms have been changed in order to make data recording easier. In particular, Form R-2 has been significantly altered. The generic Form R-2 has been replaced with a set of R-2 forms, each one of which is specific for a crop or group of crops, thus minimizing the difficulties users encountered when associating phenological stages with biomass harvests.

Users of the previous editions of Technical Report 1 most often submitted photocopied MDS forms. Therefore, this edition does not contain a supplemental booklet of tear-out blank forms as was the case in the first two editions. Instead, a packet containing Forms A-S, identical to the forms found in TR1 itself, has been placed in the inside back cover pocket of this report. The forms in this packet should be photocopied and the data from experiments recorded on the copies. The page numbering on these forms remains the same as the page numbers found on the forms within the report. This is so a user can easily reference the instruction page for a particular form.

The loose-leaf format of this third edition is for economical reasons. Any future changes in a form can now be incorporated on a replacement page rather than within an entirely new publication. With this in mind, the version number and date of this edition is printed at the top outside margin of every page. When updated material is sent to users, the version number and date of its pages will change sequentially to reflect their hierarchial order. It is strongly suggested that the registration form on page 73 be completed and sent to IBSNAT to ensure the receipt of all future versions.

IBSNAT is indebted to the members of the IBSNAT Technical Advisory Committee and to IBSNAT collaborators, model developers, and systems developers working at various universities and research institutes around the world for making contributions to or reviewing drafts of this publication. IBSNAT especially wishes to thank the participants in the IBSNAT short course held in Honolulu, Hawaii in January 1987 and in the workshops held in Venezuela, Jordan, Taiwan, Malaysia, and India whose comments and suggestions were largely responsible for the decision to produce this third edition.

Sharon L. Balas
Staff Editor
March 1988

INTRODUCTION

Need for Minimum Data Sets

The IBSNAT minimum data set (MDS) of weather, soil, management, and crop response data are essential components of the IBSNAT Decision Support System for Agrotechnology Transfer (DSSAT). These data sets must be complete and accurate so they can be used to run the models and validate outputs.

In order to adequately validate each crop simulation model developed by IBSNAT, a number of minimum data sets for each crop need to be collected. These MDS are used to compare observed with simulated crop growth. From these comparisons, IBSNAT will be able to identify the limitations of the simulation models and areas for additional research.

The IBSNAT MDS Forms A-S in this report serve a dual purpose. First, they provide a convenient log of initial conditions, management activities, weather data, and crop and soil responses for the data generator or user. From the data submitted on Forms A-S, IBSNAT will send each collaborator data summaries in convenient tabular and graphic forms. Second, the MDS are stored in DSSAT for sharing among other data generators and model developers. All IBSNAT collaborators will then have a common framework for building a useful system to evaluate the potentials and limitations of growing crops on specific soils, in specific climates, and under specific management conditions.

The data items on Forms A-S that are asterisked (*) and printed in bold type are essential data required to run the crop models. Collaborators should make every effort to provide data for these items. This is not to imply that the remaining items are not essential. To the contrary, all of the items in the minimum data set provide important accessory information for model validation. If human error, instrument failure, or time constraints preclude obtaining the entire minimum data set, the partial set should be sent to IBSNAT. The packet of Forms, A-S, which will be found in the pocket of the inside back cover of this report, are to be photocopied and the collected data entered on the copies.

The minimum data sets need not be collected for each plot or each treatment of an experiment. For example, a full factorial of a two-factor fertility experiment could have 25 treatments. The collaborator should not collect the minimum data set from all 25 treatments. Instead, the optimum treatment or a combination of representative treatments should be selected for MDS collection.

Please note that the instructions contained in this report for entering data on the forms and the instructions for inputting the same data into the DSSAT data base may vary slightly. Users should consult Technical Report 3, *DSSAT Level 1: User's Guide for Experiment Data Entry*, if discrepancies occur when inputting data into DSSAT.

Send the completed MDS forms to IBSNAT Project, Krauss 22, 2500 Dole Street, University of Hawaii, Honolulu 96822, USA.

FORM A

Institutional Information

Importance: The "Institute ID" code forms part of the Decision Support system for Agrotechnology Transfer's (DSSAT) unique identification (ID) code assigned to every MDS. This unique MDS ID code allows both collaborators and modelers to retrieve a specific MDS from the data base of the IBSNAT DSSAT. The other components of an MDS ID code are the "Site ID" code, the "Experiment Number ID" code, the year of experiment, and the "Crop ID" code. In the following example, the DSSAT ID code assigned to an MDS collected by a collaborator working for the Thailand Land Development Department, at the Lampang Farm site, in the year 1986, on experiment number "5," with the crop Maize is:

```
THLP8605MZ
│ │ │ │ │
│ │ │ │ └──> Crop ID for Maize
│ │ │ │
│ │ │ └──> Experiment number ID
│ │ │
│ │ └──> Year of experiment
│ │
│ └──> Site ID for Lampang Farm
│
└──> Institute ID for Thailand Land Development Department
```

Note 1: A list of institute ID codes will be found in the Appendix of this report. If your institute is not listed in the appendix, write "99" in the space provided for the institute ID code on Form A. Upon receipt of your MDS, IBSNAT will assign your institute a unique ID code and inform you of this code when it acknowledges receipt of your MDS. It is important that only IBSNAT assign an **institute** ID code to ensure that there are no duplicate institute codes, and therefore no duplicate MDS ID codes in the DSSAT data base. Once your institute is assigned an institute ID code by IBSNAT, you must use this code on all future MDS submitted.

Note 2: "Site ID" and "Experiment Number ID" codes are assigned by the collaborator. The site ID can be any two-character or two-digit (or a combination of both; i.e , A2) code; this ID code should also be recorded on Form D. The experiment number ID must be a two-digit code.

Note 3: "Year of Experiment" is the numeric year date of planting. For example, if the crop were planted in December of 1986, then "86" would be recorded for "Year of Experiment."

Note 4: The "Crop ID" code must be one selected from the following codes.

Crop	Code	Crop	Code
Maize	MZ	Dry Bean	BN
Grain Sorghum	SG	Peanut	PN
Wheat	WH	Aroid	AR
Rice	RI	Cassava	CS
Millet	ML	Potato	PT
Soybean	SB	Barley	BA

FORM A

Institutional Information

***Institute ID: __** ***Site ID: __** ***Experiment number ID: __**

***Year of experiment: __** ***Crop ID: __**

Institute name: ____________________________________
____

Mailing address: ____________________________
____
____
____

Country: _________________________

Telex: _________________________

Cable: _________________________

Telephone: _________________________

Electronic
mail network: _________________________

Electronic
mail address: _________________________

FORM B

Nearby Long-term Climatic Stations

Importance: Generally, long-term climatic data imply records of 30 years or more. Availability of these data from a region will allow modelers to use the regional weather data in the models and will enable modelers and model users to run crop simulations over time. They may also be useful for developing weather generator models for the area.

Note 1: Send in all available weather records from this station (if these data are available in computer format, instructions for submitting the data are given in Note 1 of Form C). Even if the climatic station is also the on-site weather station (designated in Form C), this Form should still be completed.

Note 2: Under the column heading "Years of Record" write the number of years for which the climatic station has recorded data for each of the variables listed. For example, if the climatic station has recorded Tmin and Tmax temperatures for 20 years, then "20" should be entered in the designated spaces next to Tmin and Tmax. If the yearly records are complete, enter "C" in the "Complete/incomplete" column; if however, there are periods of missing data in the yearly records, enter "I" in this column.

Note 3: "Windrun" is the measurement of wind movement during a 24-hour period. It is usually recorded with an anemometer. "Rainfall intensity" means the amount of rainfall per unit time. If the experimental site is located in an area highly susceptible to erosion, then rainfall measurements during times of heavy rainfall should be made on a more frequent basis than the usual 24-hour period.

Note 4: If a variable listed under "Annual Records" has not been measured at the climatic station, then write "NA" for the variable under the subheading "Years of Record" to indicate the missing data.

FORM B
Nearby Long-Term Climatic Stations

Climatic station name: ____________________________

Address of responsible organization: ____

Latitude: deg.: ___ min.: __ direction (N, S): _

Longitude: deg.: ___ min.: __ direction (E, W): _

Elevation (m): ____

<u>ANNUAL RECORDS</u>

	Years of Record	Complete/Incomplete (C/I)
Tmin:	___	_
Tmax:	___	_
Precipitation:	___	_
Solar radiation:	___	_
Hours of sunshine:	___	_
Percent cloud cover:	___	_
Humidity:	___	_
Soil temperature:	___	_
Windrun:	___	_
Rainfall intensity:	___	_

FORM C-1 and C-2

Daily Weather (Required and Additional)

Importance: The required daily weather data are the "driving force" for the crop models since weather inputs enable the models to assess the effects of weather on the growth and development of a crop. The additional weather data enhance the models' ability to assess the effects of weather.

Note 1: If weather data for the experiment are already available to the collaborator in computer form, i.e., on floppy disk(s), then these data can be sent to IBSNAT on floppy disk(s) rather than re-encoding the data onto Forms C-1 and C-2. This is adequate even if the ordering of weather data is different from that in Forms C-1 and C-2. However, to ensure correct input into the IBSNAT data base, the procedures listed below **must** be followed.

1) The data must be in ASCII format.
2) The data files must contain, at the least, the four weather variables found in Form C-1 (i.e., Tmax, Tmin, Precip., Sol.Rad.) with dates.
3) An instruction sheet which includes the following must be submitted with the floppy disk(s).
   a) The variable names must be specified.
   b) The column format for each variable must be specified (i.e., "Tmax, column 1-5" would indicate that the Tmax value is formatted in column 1-5).
   b) The measurement unit used for each variable must be specified (i.e., "Tmax, °C").
   c) The number of decimal places used in each field must be specified (i.e., "Tmax, 2 decimal places" would indicate that the 5-digit number for this field contains 3 integers and 2 decimal places).

Note 2: If a weather station is not already in place at an experimental site, it should be installed at the site before planting. Detailed information on installing a weather station, the type of instrumentation required and available, and the methodology for data collection will be found in Technical Report 2, *Field and Laboratory Methods for IBSNAT Experiments.*

Note 3: "Weather station ID" is assigned by the collaborator and can be any two-character code. This ID code must also be recorded on Forms C-2, D, and E.

Note 4: Daily weather data collection is essential for simulating the experiment. Therefore, monitor weather station instrumentation regularly to ensure that it is functioning properly, and make weather observations at the *same* time every day. It is preferable that this time be either early in the morning or late in the evening. In "Time of normal weather observations" write the hour of daily weather observation. For example, 6:30 a.m. should be recorded if the observation is made at 6:30 a.m. and 6:30 p.m. should be written if the observation is made at 6:30 p.m.

Note 5: Begin the collection of weather data for a particular experiment, at a minimum, on or before the date of the initial soil sampling and continue until the date of the final harvest.

If gaps in the record occur due to equipment failure, human error, or other reasons, then write "NA" in the space for that date to indicate missing data, and include a note in the "Comments" section, specifying the reason for the missing value(s).

Note 6: On form C-1, indicate the unit of measurement for each variable by circling the appropriate unit used (for example, circle °F if Tmax and Tmin temperatures are measured in the English system). **Only** one of the two units of measurements listed for each varaible on Form C-1 may be selected.

Note 7: The additional weather data collected for Form C-2 permit estimations of potential evapotranspiration in the crop models with the Penman method. These estimations may be especially useful in arid regions where advection can occur.

(Notes continue...)

FORM C-1

Daily Weather (Required)

*Institute ID: _ _

*Weather station ID: _ _

*Time of normal weather observations: _ _ _ _ _ _ _ _ _ _

*Station name: _

*Year: _ _ *Month: _ _

*Date	*TMin (°F) (°C)	*TMax (°F) (°C)	*Precip. (in.) (mm)	*Sol. Rad. (MJ/m^2) (Cal/cm^2)	*Date	*TMin (°F) (°C)	*TMax (°F) (°C)	*Precip. (in.) (mm)	*Sol. Rad. (MJ/m^2) (Cal/cm^2)
1	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	16	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
2	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	17	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
3	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	18	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
4	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	19	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
5	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	20	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
6	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	21	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
7	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	22	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
8	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	23	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
9	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	24	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
10	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	25	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
11	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	26	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
12	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	27	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
13	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	28	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
14	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	29	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
15	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _	30	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _
					31	_ _ _._	_ _ _._	_ _ _ _	_ _ _._ _

COMMENTS:

_ _

_ _

_ _

Note 8: The fourth variable column in Form C-2 has been left blank so data for a weather variable not included in this form can be added. Insert the name of the variable in the column head and write the units in the parenthesis; for example, if PAR were measured, then "PAR" would be the column head and "E/m^2" the units.

Note 9: The "Dry bulb" temperature is the temperature of the air taken from a dry temperature-sensing element, such as the dry-bulb thermometer of a psychrometer. The "Wet bulb" temperature is the lowest temperature to be measured by evaporating water from a wick-covered temperature-sensing element, such as the wet-bulb thermometer of a psychrometer. "Windrun" is the measurement of wind movement during a 24-hour period. It is usually measured with an anemometer. Record readings daily (see Note 4).

Note 10: Submit all weather data collected, whether or not these data are listed in Forms C-1 and C-2. Moreover, if weather data from a nearby climatic station identified in Form B are available, then submit these data sets in addition to Forms C-1 and C-2.

Note 11: Regardless of whether or not an experiment is being conducted at a site, if weather data at the site are collected on a daily basis, then IBSNAT will accept these data independently of the other MDS forms, either on Forms C-1 and C-2 or in computer form (see Note 1 above). These data can be submitted to IBSNAT monthly, and IBSNAT will maintain a weather record for that site and provide the collaborator with an annual weather summary.

FORM C-2
Daily Weather (Additional)

Institute ID: __ Weather station ID: __

Time of normal weather observations: __________

Station name: ____

Year: __ Month: __

Date	Dry Bulb (°C)	Wet Bulb (°C)	Windrun (km/hour)	( )	Date	Dry Bulb (°C)	Wet Bulb (°C)	Windrun (km/hour)	( )
1	___._	___._	___.__	___._	16	___._	___._	___.__	___._
2	___._	___._	___.__	___._	17	___._	___._	___.__	___._
3	___._	___._	___.__	___._	18	___._	___._	___.__	___._
4	___._	___._	___.__	___._	19	___._	___._	___.__	___._
5	___._	___._	___.__	___._	20	___._	___._	___.__	___._
6	___._	___._	___.__	___._	21	___._	___._	___.__	___._
7	___._	___._	___.__	___._	22	___._	___._	___.__	___._
8	___._	___._	___.__	___._	23	___._	___._	___.__	___._
9	___._	___._	___.__	___._	24	___._	___._	___.__	___._
10	___._	___._	___.__	___._	25	___._	___._	___.__	___._
11	___._	___._	___.__	___._	26	___._	___._	___.__	___._
12	___._	___._	___.__	___._	27	___._	___._	___.__	___._
13	___._	___._	___.__	___._	28	___._	___._	___.__	___._
14	___._	___._	___.__	___._	29	___._	___._	___.__	___._
15	___._	___._	___.__	___._	30	___._	___._	___.__	___._
					31	___._	___._	___.__	___._

COMMENTS:

____

____

____

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FORM D
Experimental Site

Importance: Each IBSNAT site must be characterized as fully as possible because the site's soil classification data are needed to run the simulation models. Thus, the IBSNAT minimum data set (MDS) must include a complete characterization of the soil at each experiment site.

Note 1: If the Soil Conservation Service (SCS) of the United States Department of Agriculture (USDA) has sampled and described the soil at the experimental site, then the soil will have been classified according to *Soil Taxonomy* and been assigned a pedon number by the SCS. The pedon number is the identification number of the site's soil data file which is stored in the data base of the National Soil Survey Laboratory (NSSL) in Lincoln, Nebraska. When the pedon number for a site is available and entered in Form D, IBSNAT can retrieve from the NSSL soil data not included in the MDS forms but which are required to run the crop model.

Note 2: If an SCS pedon number or the classification of the soil at the site is unknown, then the collaborator should consult with his/her national soil survey organization. If the soil has been described, analyzed, and classified by a collaborator's national soil survey organization, then this soil profile and classification data must be submitted with the MDS.

Note 3: If no soil classification is available from any source, then the collaborator needs to either enlist the services of a competent pedologist to describe the soil profile and collect soil samples from each horizon or request assistance from Soil Management Support Services (SMSS) through the local U.S. AID Mission for soil analysis and classification. This must be done before the experiment is begun. These data must be submitted with the MDS.

FORM D
Experimental Site

***Site ID:** __

Site name: ________________________
____

***Pedon no.:** ______________

Soil series name: ____________________________________

***Soil classification (Family level of *Soil Taxonomy*):**
____
____

Description of site (Geomorphology or position in landscape):
____
____

Natural vegetation:
____
____

Years in cultivation and past management practice:
____
____

***Latitude: deg.: ___ min.: __ direction (N, S): _**

***Longitude: deg.: ___ min.: __ direction (E, W): _**

Elevation (m): ____

***Weather station ID: __**

FORM E

Experiment

Importance: Beginning and ending experiment dates are needed so IBSNAT can extract the relevant weather data from Forms C-1 and C-2 for the period of the experiment. Moreover, modelers can determine from these dates, used in conjunction with the data in Forms C-1 and C-2, whether or not the weather records are complete for the period of an experiment.

Note 1: If the "Experiment name" is longer than the spaces in the form allow, then add an additional line.

Note 2: The beginning date of the experiment is the planting date. If soil fertility or water are limiting factors in the experiment, the preplant soil sampling date is the beginning date. The ending date of the experiment is the harvest date. Where soil fertility or water are factors, the post harvest soil sampling date is the ending date.

Note 3: "Distance from weather station" is the distance from the experiment to the weather station designated in Form C. If the climatic station (identified in Form B) is the on-site weather station, then "Distance from weather station" is the distance from this station to the experiment.

Note 4: When experiments are conducted in valleys or near forests where the sun's direct rays are obstructed in the morning or evening, estimate and record the "Vertical angle" from the horizontal to the top of hills or other obstructions to the sun's rays.

FORM E
Experiment

Experiment name: ________________________________
____

Weather station ID: __

***Beginning date (dd/mm/yy):** __/__/__

Ending date (dd/mm/yy): __/__/__

Experiment description:
____
____
____
____

Responsible researcher(s):
____
____

Distance from weather station (m): _____

Experimental design:
____
____
____
____

Vertical angle from horizontal to the top of hills or other obstructions to sun's rays (deg): ___

FORMS F-1, F-2, F-3, F-4

Experimental Factors and Levels

Importance: Data from these forms enable DSSAT to provide crop modelers with standardized outputs for analysis of crop response data measured in each plot. The plot number and the treatment number in Form F-4 are combined to become the key used to retrieve from the DSSAT data base the factor and treatment levels described in Forms F-1, F-2, and F-3. The crop information by plot contained in Form R-2 in conjunction with the field assignment (Form F-4) and treatment design (Form F-3) enable complete statistical analyses of the data. Various outputs, including treatment summary tables and graphics, can be prepared from these data. Forms F-3 and F-4 are also utilized by the crop models to compare simulated with measured crop responses.

Note 1: In general, IBSNAT assumes that collaborators will use a randomized complete block design – that is, each treatment occurs once in each block of experimental plots. Assuming this to be true, when the term "replication" or "replicate" occurs in the text, it means one of the blocks of the design (see the example for Form G on page 20); and the term "plots" means the subdivided areas within each replication (see page 20). The term "treatment" means one of the experimental factor levels or a combination of levels of two or more factors. The number of treatments must correspond to the number of plots within each replication (or block), and all treatments must appear once in each replication (see page 20). For example, if a collaborator uses applied nitrogen as an experimental factor with three different nitrogen levels as treatments, and there are three replications (or blocks), then each replication must have a minimum of three plots, and the total number of plots will be nine (9). Furthermore, the three nitrogen treatment levels must be randomly assigned to each of the three plots in each replication (or block).

Note 2: Descriptive information and names for treatment factors and levels of each factor should be given in Forms F-1 and F-2. The number of possible experimental treatments is the product of the number of levels and each factor. For example, if there are two experimental factors (applied nitrogen and cultivars) with three levels of applied nitrogen (0 kg N/ha, 50 kg N/ha, and 200 kg N/ha) and two levels of cultivar (two different cultivars), then the number of treatments would be six (6). Each treatment should be given in terms of level names in Form F-3, while the plot assignments of each treatment in every replicate of the experiment should be recorded on Form F-4.

Note 3: On Form F-1, "Experimental Factors" are labeled by letter (starting with A), and a short description is needed for each factor. Using the example factors and levels described in Note 2 above, Factor A would be described as "applied nitrogen" on Form F-1, and Factor B would be described as "cultivar." For an experiment with more than five experimental factors, combine two or more into one factor for the purpose of this form.

Note 4: On Form F-2, each "Level" of each experimental factor should be described briefly as the amount applied when the factor is quantitative (continuous), e.g., rates of applied nitrogen; or described by a name when the factor is qualitative (categorical), e.g., cultivars. Using the example factors and levels described in Note 2 above, five (5) levels with accompanying descriptions would be recorded on Form F-2 as follows.

Form F-2 Example:

Level	Description
0	no applied nitrogen
50	50 Kg N/ha
200	200 Kg N/ha
H610	cultivar H610
X304C	cultivar X304C

(Notes continue...

FORM F-1
Experimental Factors and Levels

DESCRIPTION OF EACH FACTOR IN THE EXPERIMENT:

Factor Name	Description
FACTOR_A	------------------------------------
FACTOR_B	------------------------------------
FACTOR_C	------------------------------------
FACTOR_D	------------------------------------
FACTOR_E	------------------------------------

Note 5: On Form F-3, the "Level" of each experimental factor for each treatment should be recorded. The amount or name of the level will be the same as the information recorded on Form F-2. Each row will then show one level if there is only one experimental factor, or a combination of levels if there are two or more experimental factors for each treatment in the experiment. Using the example factors and levels described in Note 2 above, the following information would be recorded on Form F-3.

Form F-3 Example:

Trt. No.	Factor A	Factor B
01	0	X304C
02	50	X304C
03	100	X304C
04	0	H610
05	50	H610
06	100	H610

Note 6: On Form F-4, the information for each plot is entered in one row. The data requested include the "Plot Number" which should be two digits, the numbering beginning with "01" and no number repeated; the "Treatment Number" which should be two digits, the numbering beginning with "01" and repeated from replicate to replicate (or block to block); and the "Replication Number" which should be two digits, the numbering beginning with "01" and no number repeated. Using the example factors and levels described in Note 2 above and the examples on p. 20, the following information would be recorded on Form F-4.

Form F-4 Example:

Plot No.	Trt No.	Rep No.
02	01	01
03	02	01
04	03	01
05	04	01
01	05	01
06	06	01
10	01	02
....		
18	06	03 (for a total of 18 plots)

Note 7: It is not necessary to collect the MDS for each plot listed in Form F-4. The choice of treatment combination, and thus the plot or plots, selected for sampling of vegetative and reproductive stages of growth (i.e., biomass, harvest, etc. as stated in Forms R-1 and R-2) is a matter of individual preference.

FORM F-2
Experimental Factors and Levels

DESCRIPTION OF EACH LEVEL FOR EACH FACTOR:

Level (Amount or Name)	Description
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------
------	------------------------------------

FORM F-3
EXPERIMENTAL FACTORS AND LEVELS

<u>FACTOR AND LEVEL TREATMENT COMBINATIONS:</u>

Trt. No.	LEVELS (AMOUNTS OR NAMES) FOR EACH FACTOR: FACTOR_A	FACTOR_B	FACTOR_C	FACTOR_D	FACTOR_E
--	------	------	------	------	------
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FORM F-4
EXPERIMENTAL FACTORS AND LEVELS

TREATMENT AND REP NUMBER FOR EACH PLOT:

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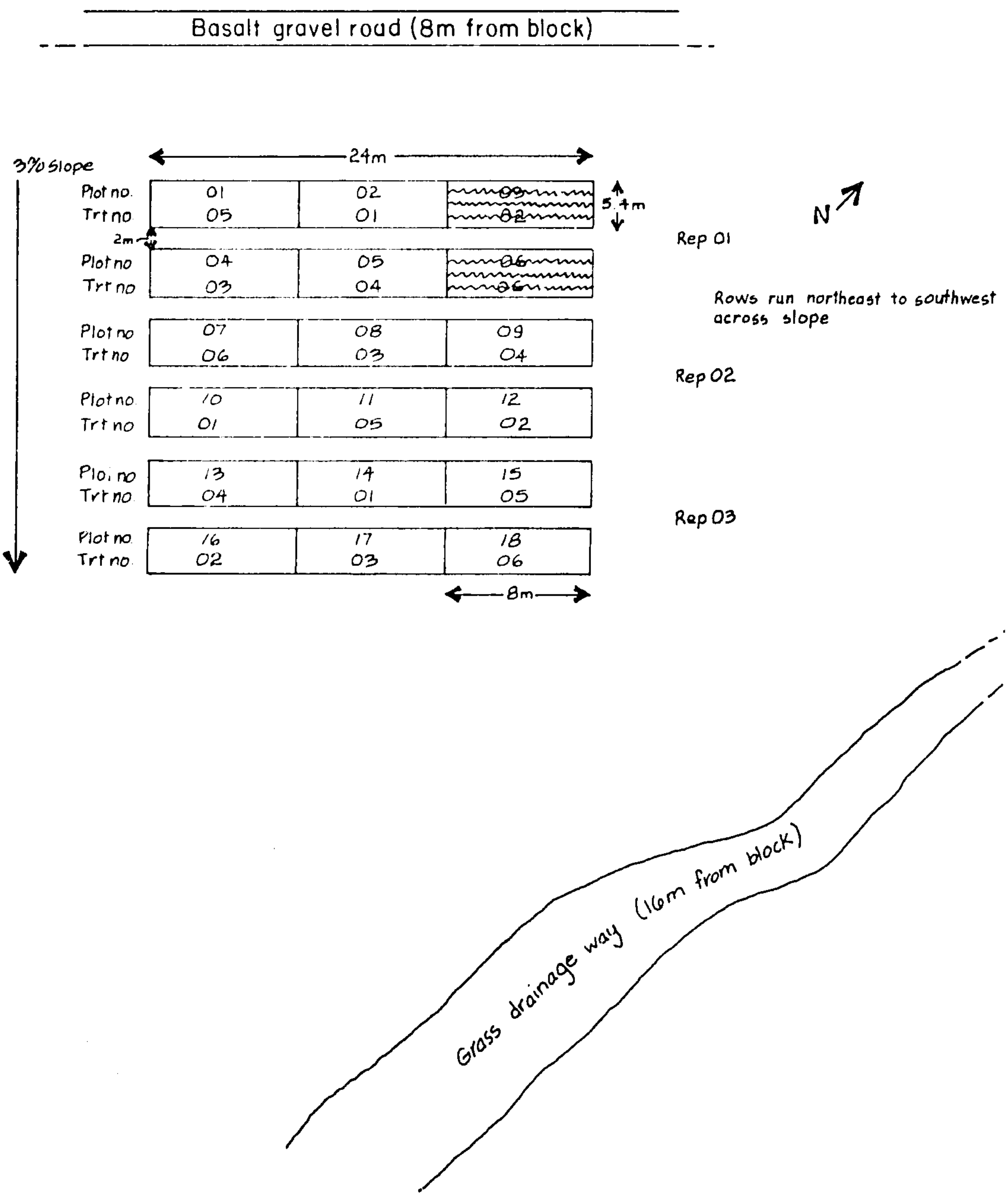
FORM G

Experimental Layout

Importance: The relative position in the landscape of the experiment layout can provide information on the physical or environmental gradients as they may affect crop growth across the experimental plots.

Note: Draw the experiment's layout and its relative position in the landscape on this form. The drawings should be labeled with two-digit plot numbers, treatment numbers, and replicate numbers, each number corresponding with those listed in Form F-4. Indicate the direction of North and row direction and slope, if any. The example diagram below illustrates the information which should be included on this form for an experimental layout.



FORM G

Draw and Label Experiment Layout

FORM H

Experimental Plots

<u>Importance</u>: These data are necessary for the nitrogen and water balance components of the crop models. The residue data also have an impact on the run-off curve number, the soil water content, soil evaporation, and bare soil albedo.

<u>Note 1</u>: In "Amt. of weed/crop residue incorporated during land preparation," report weed/crop residues cut close to the ground and taken away from the experimental plot as 0 (zero).

<u>Note 2</u>: If weed/crop residue is a treatment factor in the experiment, then residue for each treatment should be identified in Forms F-1 and F-2 and reported in Form N.

<u>Note 3</u>: Whether or not weed/crop residue is a treatment factor in the experiment, if it is incorporated, report the amount of weed/crop residue on this form and report it on a dry-weight basis. The recommended procedure for estimating the dry-weight amount of weed/crop residue can be found in Technical Report 2.

<u>Note 4</u>: If residue is burned and incorporated, then determine the amount of the residue before burning (see Note 5 below).

<u>Note 5</u>: Identify the type of residue incorporated, visually estimate, and report the percentage(s) of each type on this form under the section "Type of Residue."

<u>Note 6</u>: In general, information on "Slope and Slope length" are required to alert modelers to the site's susceptibility to soil erosion. If the topography of the site is level and no erosion is expected, then the value entered for "Slope" would be 0 (zero), and the value for "Slope length" would be the width of the experiment.

If large unprotected blocks or plots are used, however, the "Slope" can be determined by an Abney level or clinometer.

"Slope length" is the distance from the nearest break in slope above the experiment to the nearest break in slope, or concentration of runoff into an outlet or channel, below the experiment.

<u>Note 7</u>: "Aspect" is the orientation of the slope in respect to magnetic North. Use the designations N, NE, E, SE, S, SW, W, NW. For example, if the site is on an East-facing slope, then aspect is West relative to magnetic North, and a "W" should be recorded for "Aspect." However, if the slope is 0 (zero), then the aspect is 0 (zero).

<u>Note 8</u>: "Depth of soil drain" is the vertical distance from the soil surface to either a buried tile (pipe) drainage system or the water table.

<u>Note 9</u>: If a particular plot(s) differs in respect to any of the data listed in this form, then that information should be noted in "Specific comments." Other factors which may limit crop performance in the plots should also be noted in this space. These might include the presence of plow pans, gravel layers, poor drainage, crusting problems, or any number of other problems which may be important in interpreting experimental results.

FORM H
Experimental Plots

Plot area (m^2): ___

Slope (%): __

Slope length (m): ____

Aspect (deg. from north): __

Depth of soil drain (cm): ____

Distance between drains (m): ___

***Amt. of weed/crop residue incorporated during land preparation(kg/ha): ____**

***Depth of residual incorporated during land preparation (cm): __**

Was residue burned and incorporated? (Y/N)?: _

Specific comments:

____

____

____

____

TYPE OF RESIDUE:

Crop	Percent (%)	Crop	Percent (%)
Other	___	Aroids	___
Cassava	___	Dry broad leaf weeds	___
Dry grass weeds	___	Dry beans	___
Green broad leaf weeds	___	Green grass weeds	___
Grain sorghum	___	Maize	___
Peanuts	___	Potato	___
Rice	___	Soybean	___
Shrubs/trees	___	Wheat	___

FORMS I-1 & I-2

Soil Fertility Measurements

Importance: Accurate measurement of pH and nitrogen components of the soil at the time of planting is necessary to run the nitrogen subroutine of the crop models. Root distribution by soil layer is also affected by chemical constraints.

Note 1: Conduct preplant soil sampling for fertility measurements within the month prior to planting date and record them on Form I-1. Samples from all soils EXCEPT Andepts should be dried immediately at 50-60 °C to prevent mineralization and degradation of soil proteins. Store andepts in air-tight containers and analyze as soon as possible (see Technical Report 2).

Note 2: Sample the soil by individual plot, by grouping plots receiving the same treatment, or, if the experimental area is homogeneous, by the entire experimental area using a single composite sample which represents the entire area.

Note 3: When composite samples representing the entire experimental area are used, then write "99" under "Plot(s)."

Note 4: For measurement purposes, each soil layer should not exceed 15 cm in depth, and if possible, the first layer designated should not exceed 10 cm. Below the surface 30 cm, if a soil layer exceeds 30 cm, then it should be divided into two parts, each at least 15 cm. These layers must match those designated in Form J-1 for ease in matching nutrient analysis with water content. In fact, the same soil samples collected for fertility measurements can be used to determine the initial water content necessary for Form J-1.

Note 5: If soil fertility measurements are taken at times other than at preplant, then use Form I-2. Sampling should be done in the way described in Notes 2, 3, and 4 above.

Note 6: See Technical Report 2 for recommended procedures and methodologies for obtaining soil fertility measurements.

FORM I-1

Preplant Soil Fertility Measurements

Method of P-extraction: ----------------------------

*Date dd/mm/yy	*Plot(s)	*Upper (----cm----)	*Lower	-----pH----- *H_2O	*KCl	*NO_3-N (----------------g/Mg	*NH_4-N	P	K ----------------)	Al %
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COMMENTS:

FORM I-2

Other Soil Fertility Measurements

*Date dd/mm/yy	*Plot(s)	*Upper (----cm----)	*Lower	-----pH----- *H_2O	*KCl	*NO_3-N (---------------g/Mg---------------)	*NH_4-N	P	K	Al %
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COMMENTS:

FORMS J-1 & J-2
Soil Water Contents

Importance: Data values from Form J-1 give the preplant soil water contents by layer which are used directly to run the water balance submodules of the models. Values from Form J-2 are used for model validation.

Note 1: Forms J-1 and J-2 must be completed for rainfed experiments or for experiments where irrigation is a treatment factor.

Note 2: Forms J-1 and J-2 do **not** need to be completed if the crops will never experience a water deficit. A no-water-deficit condition means that either 1) the crops are irrigated, but not as a treatment factor, or 2) the crops are grown under lowland conditions. In these two cases, write either "Irrigated" or "Lowland" in the "Comments" section.

Note 3: In Form J 1 up to 10 soil layers may be identified, although 6 to 8 are usually sufficient. These layers must match those designated in Form I-1, and the following three rules should be observed.

1) The total measured depth of the soil layers should be at least 1 m unless bedrock or other impermeable layers occur at a more shallow depth. For deep soils, the total measured depth should not exceed 2.2 m. Since soil roots can sometimes grow to a depth of 2 m, the soil layer information is important in order to determine if the plants will experience nutrient or water stress.

2) For measurement purposes, each soil layer should not exceed 15 cm in depth, and if possible, the first layer designated should not exceed 10 cm.

3) Below the surface 30 cm, if a soil layer exceeds 30 cm, then it should be divided into two parts, each at least 15 cm, for soil water determination.

Note 4: See Technical Report 2 for the recommended procedure to determine the volumetric water content of the soil.

FORM J-1

Preplant Soil Water Contents

Layers	1	2	3	4	5	6	7	8	9	10
*Upper (cm)	___	___	___	___	___	___	___	___	___	___
*Lower (cm)	___	___	___	___	___	___	___	___	___	___

*Date dd/mm/yy	*Plot(s)	*Volumetric Water Content in % for Layer: 1	2	3	4	5	6	7	8	9	10
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COMMENTS:

FORM J-2

Other Soil Water Contents

*Date dd/mm/yy	*Plot(s)	*Volumetric Water Content in % for Layer: 1	2	3	4	5	6	7	8	9	10
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COMMENTS:

FORM K

Tillage

Importance: Data collected for Form K are used to determine the depth of incorporation of any surface residues (described in Form H) and fertilizers (described in Form N).

Note 1: If no till is done, then this should be indicated on the first line of Form K by writing "No till" in the "Comments" section.

Note 2: When *all* plots have the same requested information, then write "99" under "Plot(s)."

Note 3: Field implements and their codes are listed below. However, many field implements listed by one name here may have a different name in other countries. If your implement is not listed or named below, if you use code "21" (animal drawn), or if you are uncertain as to which field implement to select, then write "99" in the "Imp. Code" column and sketch and/or describe the implement in the "Comments" section.

Field Implement Codes:

Implement	Code	Implement	Code
Combine	01	Harrow-spike	13
Tandem Disk	02	Rotary hoe	14
Offset Disk	03	Roto-tiller	15
Oneway Disk	04	Row crop planter	16
Moldboard plow	05	Drill	17
Chisel plow	06	Shredder	18
Disk plow	07	Hoe	19
Subsoiler	08	Planting stick	20
Bedder/Lister	09	Animal-drawn implement	21
Field cultivator	10	Hand	22
Row crop cultivator	11	Manual hoeing	23
Harrow-springtooth	12	Other	99

FORM K
Tillage

Date dd/mm/yy	Plot(s)	Imp. Code	Depth (cm)	Other Information
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COMMENTS:

FORM L
Cultivar

Importance: The data supplied on Form L will assist in assigning cultivar-specific coefficients used in most crop growth models and in interpreting a cultivar's response to various stresses.

Note 1: A cultivar name is defined as the cultivated variety name. If a cultivar has other or equivalent names, then these should be given under "Other Name." For example, if a collaborator is using the maize cultivar variety named "H610," then "H610" should be entered under "Cultivar Name." If this variety is also known by another name in the collaborator's country, then write this name under "Other Name."

Note 2: If a cultivar name or other name is longer than 10 characters, then give the full name in the "Comments" section. When further explanation about the cultivar is necessary for identification, this information should be noted in the "Comments" section.

Note 3: If cultivars are a treatment factor, then all cultivars used must be named under "Cultivar Name."

Note 4: Under "Type" indicate cultivar characteristics such as, open-pollinated, hybrid, inbred, maturity group, photoperiod sensitivity, short-season, long-season, determinate, indeterminate, spring wheat, winter wheat, dwarf, semidwarf, tall, bush, climbing, etc. When the "Type" description exceeds 10 characters, use the "Comments" section to note background and special characteristics of the cultivar(s).

Note 5: "Seed Weight" is dried seed weight. Oven dry seed at 70 °C until constant weight.

1) For cereals and legumes, seed weight is the dry weight of 100 seeds (selected at random).
2) For root crops, seed weight is the average dry weight of at least 10 seed pieces or tubers (selected at random).

Note 6: "Seed Age" refers to the time from harvest to planting and gives an indication of the viability of the seed. For potato, this is the interval that elapses from harvest until planting of seed tubers and includes the dormancy period plus any other period in storage.

Note 7: "Sprout Length" is MDS-required data for potato **only**, and need not be recorded for any other crop. To measure, take a random sample of seed tubers at planting time and measure the length of at least four sprouts per tuber. Calculate mean sprout length. Record 0.0 if no sprouts are visible.

FORM L
Cultivar

*Cultivar Name	Other Names	Type	Seed Weight/ # seeds (g)	Seed Age (days)	Sprout Length (mm)
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COMMENTS:

FORM M
Planting

__Importance__: Row spacing and plant count data enable the models to determine the plant population in the experimental plot. Seed depth data can be used to relate date of germination to date of emergence.

__Note 1__: Unless row spacing, plant count, and seed depth are defined as treatment factors in the experiment, the crop models assume **uniform** row spacing, plant count, and seed depth. If uniformity is not maintained, then simulation results may not compare well with actual experimental results.

__Note 2__: For "Method of Planting," record a "1" for broadcast, a "2" for sowing by rows, or a "3" for transplanting (or sowing by hill).

__Note 3__: "Row Spacing" is the distance between rows. "Plant Count" is the standing plant count typically taken after emergence, and defined as the number of plants per meter row that will stand for the entire season. "Plant Pop." is the plant count per square meter.

__Note 4__: When the seed is sown in **rows**, then "Row Spacing" and "Plant Count" need to be recorded in Form M. "Plant Pop." will **not** need to be measured.

__Note 5__: When the seed is **broadcast**, then "Plant Pop." will need to be measured. "Row Spacing" and "Plant Count" will **not** need to be measured. To determine "Plant Pop.," select a grid size, say 1 x 1 meter, randomly select several grid-sized areas within the experiment, count the number of plants within each grid area selected, and determine the average "Plant Pop." value.

__Note 6__: When the seed is **transplanted**, then "Hills/m^2" and "Plants/hill" will need to be measured. "Row Spacing" will **not** need to be measured.

To determine "Hills/m^2," select a grid size, say 1 x 1 meter, randomly select several grid-sized areas within the experiment, count the number of hills within each grid area selected, and determine the average "Hills/m^2" value. Record this value under "Plant Pop."

"Plants/hill" is determined by counting the number of plants per hill. This count should be done before the plant starts to tiller. Record this value under "Plant Count."

__Note 7__: When cultivar, row spacing, plant count, or seed depth is a treatment factor, and so indicated on Form F, then use separate rows on Form M for the plot(s) receiving each combination of cultivar, row spacing, plant count, or seed depth.

__Note 8__: On the facing page of Form K (p.32) is the list of field implements and their codes. However, many field implements listed by one name in this appendix may have a different name in other countries. If your implement is not listed, if you use code "21" (animal drawn), or if you are uncertain as to which field implement to select, then write "99" in the "Imp. Code" column and sketch and/or describe the implement in the "Comments" section.

FORM M
Planting

Method of Planting (1 = Broadcast; 2 = Sowing by row; 3 = Transplant): _____

*Planting or Transplanting dd/mm/yy	*Plot(s)	*Cultivar	*Row Spacing (cm)	*Plant Count	*Plant Pop. (pl./m^2)	*Seed Depth (cm)	Imp. Code
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COMMENTS:

FORM N

Fertilizers, Inoculants, and Amendments

Importance: The depth of incorporation of fertilizers, inoculants, and amendments will give an indication of the relative distribution of the nutrient sources in the soil to the seed. Indicating the material code identifies the chemicals used. The information contained in Form N identifies the sources used for fertilizer treatment described in Form F.

Note 1: If *all* plots have the same requested information, then write "99" under "Plot(s)."

Note 2: "Material Codes," "Placement Codes," and "Method Codes" are listed below. If the material used in the experiment is not listed in the "Material Codes" below, then write "99" in the "Mat. Code" column of Form N and enter the material used and its chemical formula (usually listed on the container) in the "Comments" section. If a "99" is entered for a placement or method code, describe the placement or method in the "Comments" section.

Note 3: The $CaCO_3$ equivalent of N-P-K fertilizers need not be recorded since it can be estimated for the material used.

Note 4: Use the column headed by "Other" for additional amendments (e.g., manure and crop residue applications); write the amendment used in the "Comments" section and record values in kg/ha.

Material Codes:

Material Name	Chemical Formula	Code	Material Name	Chemical Formula	Code
Ammonium nitrate	NH_4NO_3	01	Single superphosphate	$CaH_4(PO_4)_2+CaSO_4$	13
Ammonium sulfate	$(NH_4)_2SO_4$	02	Triple superphosphate	$CaH_4(PO_4)_2$	14
Ammonium nitrate-sulfate	$NH_4NO_3(NH_4)_2SO_4$	03	Liquid phosphoric acid	H_3PO_4	15
Anhydrous ammonia	NH_3	04	Potassium chloride	KCl	16
Urea	$CO(NH_2)_2$	05	Potassium nitrate	KNO_3	17
Diammonium phosphate	$(NH_4)_2HPO_4$	06	Potassium sulfate	K_2SO_4	18
Monoammonium phosphate	$NH_4H_2PO_4$	07	Calcitic limestone	$CACO_3$	19
Calcium nitrate	$Ca(NO_3)_2$	08	Dolomitic limestone	$CACO_3 + MgCO_3$	20
Aqua ammonia	NH_4OH	09	Rock phosphate	****	21
Urea ammonium nitrate solution	$CO(NH_2)_2+NH_4NO_3$	10	Green manure	****	22
Calcium ammonium nitrate solution	$Ca(NO_3)_2+NH_4NO_3$	11	Barnyard manure	****	23
Ammonium polyphosphate	****	12	Rhizobium	****	24
			Crop residue	****	25
			Calcium hydroxide	$Ca(OH)_2$	26
			Other	****	99

Placement Codes:

Placement	Code	Placement	Code
Broadcast, not incorporated	01	Foliar spray	06
Broadcast, incorporated	02	Bottom of hole	07
Banded on surface	03	On the seed	08
Banded beneath surface	04	Other	99
Applied in irrigation water	05		

Method Codes:

Method	Code	Method	Code
Hand	01	Other	99
Machine	02		

FORM N

Fertilizers, Inoculants, and Amendments

*Date dd/mm/yy	*Plot(s)	*Mat. Code	Pl. Code	Method Code	*Depth (cm)	*N	P	K	$CaCO_3$	Other
						(----------	----------	kg/ha	----------	----------)
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COMMENTS:

FORM O

Biocides and Hormones

Importance: The information contained in this form will assist in the interpretation of observed versus simulated crop performance and results.

Note 1: When *all* plots have the same requested information, then write "99" under "Plot(s)."

Note 2: If a product is used which is not listed below, then indicate this by writing "1999, 2999, or 3999" in the "Prod. Code" column of Form O. In this case, note the name of the product and its active ingredient(s), usually listed on the container, in the "Comments" section.

Herbicides Product Codes:

Common Name	Code	Common Name	Code
Alachlor, Metholachlor	1001	2,4,5-T	1007
Propanil	1002	Pendimethalin, Prowl	1008
Trifluralin	1003	Atrazine	1009
Dalapon	1004	Diquat	1010
MCPA	1005	Paraguat	1011
2,4-D	1006	Other (specify)	1999

Insecticides Product Codes:

Common Name	Code	Common Name	Code
Carbaryl, Sevin, Septene	2001	DDT	2014
Malathion, Mercaptothion	2002	BHC, HCH	2015
Naled	2003	Chlordane	2016
Dimethoate	2004	Heptachlor	2017
Fenthion	2005	Toxaphene	2018
Diazinon, Basudin	2006	Aldrin	2019
Ethion, Diethion	2007	Dieldrin	2020
Oxydemeton-methyl	2008	Endrin, Nendrin	2021
Azinphos-Methyl	2009	Methomyl, Lannate	2022
Phosphamidon	2010	Thiotex	2023
Mevinphos	2011	Furadan	2024
Methyl Parathion	2012	Endosulfan	2025
Parathion	2013	Other (specify)	2999

Fungicides Product Codes:

Common Name	Code	Common Name	Code
Captan	3001	Mancozeb	3005
Benomyl	3002	Tilt	3006
Zineb	3003	Other (specify)	3999
Maneb	3004		

FORM O

Biocides and Hormones

Date dd/mm/yy	Plot(s)	Prod. Code	Amount Active Ingred. Applied (kg AI/ha)	Target
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COMMENTS:

FORM P

Irrigation

Importance: These data become the record of the water management tactics used and will help determine the effects of these tactics on crop growth and development.

Note 1: If the crop in the experimental plot is grown under lowland conditions, such as rice or taro, then complete **none** of the columns on Form P and write "Lowland Crop" in the "Comments" section.

Note 2: If an experimental plot is not irrigated, then complete **none** of the columns on Form P, and write "Rainfed" in the "Comments" section.

Note 3: When *all* plots have the same requested information, then write "99" under "Plot(s)."

Note 4: The "Amount" of water recorded should be the amount received at the experiment. If sprinkler or drip irrigation is used, then the volume flow, measured with a flow meter at the source, is the value to be reported.

Note 5: Some experiments are irrigated to prevent water stress, but the amount of irrigation water is not measured. In this case, write "-9" in the "Amount" column. It is, however, strongly suggested that when experiments are irrigated, the amount of water be measured. This is because, if the water amount is unknown, such experiments may not be successfully simulated.

Note 6: When an irrigation method other than those listed below is used, then write "99" in the "Method Code" column and note the method in the "Comments" section.

Method Codes:

Method	Code	Method	Code
Furrow	01	Sprinkler	04
Alternating furrows	02	Drip or Trickle	05
Flood	03	Other (Specify)	99

FORM P
Irrigation

*Date dd/mm/yy	*Plot(s)	*Amount (mm) (1 inch = 25.4 mm)	Method Code
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COMMENTS:

FORM Q
Crop Damage

Importance: The type and extent of crop damage have a considerable effect on crop growth and development and ultimately on yield.

Note 1: Observation of the plot should be made weekly to check for damage. Use this form only when damage occurs.

Note 2: Type of damage codes and tissue damage codes are listed below. If damage is caused by a factor not listed below, or if the damaged tissue is not listed below, then write "99" in the appropriate column and note the "Type" or the "Tissue" in the "Comments" section.

Note 3: Percentage estimates of "Plant Loss" and "Necrotic Area" should be done visually. Indicate in the "Comments" section any unusual event or circumstance.

Note 4: If a plot experiences more than seven episodes of damage, then duplicate Form Q as often as necessary to include all crop damage events.

Type of Damage Codes:

Pest and/or Disease	Code	Pest and/or Disease	Code
Assimilate sappers	01	Stand Reducers	07
Leaf senescence accelerators	02	Tissue consumers	08
Light stealers	03	Tissue disrupters	09
Metabolic diverters	04	Translocation disrupters (stranglers)	10
Photosynthesis rate reducers	05	Turgor reducers	11
Resource competitors	06	Other (specify)	99

Tissue Damage Codes:

Plant Tissue	Code	Plant Tissue	Code
Secondary stems	01	Seed (or grain)	15
Cob	02	Stem	16
Corm	03	Stover	17
Cormel	04	Straw	18
Ear	05	Tiller leaf	19
Ear leaf	06	Tiller leaf sheath	20
Hull	07	Tiller stem	21
Husk	08	Tuber	22
Leaf blade	09	Whole above ground plant	23
Leaf sheath	10	Petiole and leaf blade	24
Panicle	11	Whole above ground tiller	25
Petiole	12	Whole above ground primary plant	26
Pod	13	Main stem	27
Root	14	Other (specify)	99

FORM Q
Crop Damage

Date dd/mm/yy	Plot(s)	Type of Dam.Code	Tissue Dam.Code	% Plant Loss	% Necrotic Area
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COMMENTS:

FORM R-1 & R-2

Introduction

Importance: The data supplied on Forms R-1 and R-2 are used in model testing and validation. Use Form R-1 (p.49) to record the dates at which the vegetative (V) and reproductive (R) growth stages are attained. Record harvest measurements for specified V- and R-stages on Form R-2. The data supplied on Form R-2 will be used for model validation by comparing these measured responses with simulated ones.

Read these notes before using Forms R-1 and R-2

Note 1: Forms R-1 and R-2 should be completed together. Several of the dates required for Form R-1 are also the required biomass sampling dates for Form R-2.

Note 2: On the facing page (p.48) of Form R-1, the crop V- and R-stages for which dates must be recorded are given, as well as a brief description of each stage. These stages comprise only the minimum data set of dates required; additional growth stage dates may be recorded. A complete listing of each crop's V- and R-growth stages will be found on the facing pages of the crop-specific R-2 forms (see Note 4 below).

Note 3: Use Form R-1 for any IBSNAT crop. Record, by plot, the V- and R-stage crop-specific codes in the spaces provided on Form R-1 and the dates on which these occurred. Record both V- and R-growth stage dates concurrently. V-stage observation can be discontinued if determinate growth results in no further increases in V-stage.

Note 4: Form R-2 has been made crop specific. That is, there is a Form R-2 for one specific crop or group of crops. On each facing page of these crop-specific R-2 forms is a table listing the complete biomass and final harvest growth stage codes for that crop (or group of crops), with descriptions of each. Also on this table, the required MDS biomass and final harvest stages are marked, and the required (those which must be done) and desired (those which may be done) harvest components listed. Since biomass and final harvest sampling are lengthy and detailed processes, collaborators may wish to sample only a few carefully chosen treatments of large experiments.

Note 5: If crop data are already available to the collaborator in computer form, i.e., on floppy disk(s), then they can be sent to IBSNAT on floppy disk(s) rather than re-encoding the data onto Forms R-2. This is adequate even if the ordering of the data is somewhat different from that in Forms R-2. However, to ensure correct input into the IBSNAT data base, the procedures listed below **must** be followed.

1) The data must be in ASCII format.
2) If a collaborator includes a comment in the ASCII file, then this comment must start with an asterisk (see example on p.47). However, this comment will not be retrieved to the data base file.
3) Each group of data must have column heads which identify the data under the heads (see example).
   a) Four heads - date, plot, vstage, rstage - must be in this order.
   b) The heads, code=1, code=2, code=3, etc., used to designate the harvest codes in Form R-2, may be in any order, but the order must be specified on an instruction sheet submitted with the disk(s).
4) Each data item must be separated by 1 or more spaces (see example).
5) Dates must be in international format (i.e., dd/mm/yy).
6) If there is a missing data item, then a "#" must be used to indicate the missing item (see example).

Example:

Following are data collected for soybean experiment UFIU7901.

*1st group of data follows. Data collected for stem weight (code=10) and LAI (code=13).

date	plot	vstage	rstage	code=10	code=13
12/06/79	1	V2	#	2.1	0.1
12/06/79	2	V2	#	2.1	0.2
26/06/79	1	V5	#	10.7	0.5
26/06/79	2	V6	#	15.8	0.7

*2nd group of data follows. Final harvest data.

date	plot	vstage	rstage	code=1	code=2	code=3
27/09/79	1	#	R8	16.0	#	822.0
27/09/79	2	#	R8	16.0	24.7	610.5

Note 6: See Technical Report 2 for recommended biomass and final harvesting procedures for each IBSNAT crop.

FORM R-1 - Phenological Growth Stage Components

<u>Note 1</u>: The introductory notes to Forms R-1 and R-2 (p.46) must be read before this form is used.

<u>Note 2</u>: When a code is marked with an asterisk (*), then a concurrent biomass or final harvest sampling is required to be done on or near this date (check the appropriate R-2 form).

Growth Stage Code	Description
Maize (Ritchie and Hanway 1982)	
VE	50% of plants with some part visible at soil surface
V6*	50% of plants with collar of sixth leaf visible
R1*	50% of plants with some silks visible outside husks
R6*	50% of plants at physiological maturity
Grain Sorghum, Wheat, Rice, Barley, & Millet (Zadoks et al. 1974)	
10	First leaf through coleoptile or 50% plant emergence
13*	3 leaves unfolded or 50% of the main tiller with 3 fully extended leaves
65*	Flowering halfway or 50% of the main tiller at some stage of antethesis
94*	Overripe, straw dead and collapsing, or end of grain matter accumulation
Soybean & Dry Bean †(Fehr et al. 1971)	
V0	50% of plants with some part visible at soil surface
V4*	50% of plants with 4 nodes on main stem beginning with unifoliate node
R1	50% of plants with one flower at any node
R4*	50% of plants with a pod 2.0 cm long at one of the 4 uppermost nodes with a completely unrolled leaf *(see p. 56 for definition of unrolled leaf)*
R6*	50% of plants with a pod containing full size green beans at one of the 4 uppermost nodes with a completely unrolled leaf
R7*	50% of plants with pods yellowing; 50% of leaves yellow - physical maturity
R8*	50% of plants with 95% of pods brown - harvest maturity

† For dry bean, the phenological growth stages are defined as for soybean (Fehr et al. 1971).

Growth Stage Code	Description
Peanut (Boote 1982)	
VE	50% of plants with some part visible at soil surface
V4*	50% of plants with 4 developed nodes on the main stem
R1	50% of plants with 1 open flower at any node
R2	50% of plants with 1 elongated peg (gynophore)
R4*	50% of plants with full pod
R6	50% of plants with full seed
R7	50% of plants beginning maturity
R8*	50% of plants at harvest maturity
Aroid	
V0	50% of plants have visible leaf tip‡
V1	50% of plants have 1 fully opened leaf
V3*	50% of plants have 3 fully opened leaves
V4	50% of plants have 4 fully opened leaves
S	50% of plants have suckers above ground
R7*	50% of plants have only 2 or 3 active leaves remaining on plant (harvest maturity)

‡ The leaves of 5 plants/treatment could be marked to keep track of the total number of leaves produced.

Growth Stage Code	Description
Cassava	
VE*	50% of plants with at least 1 shoot on the planting stick more than 1 cm in length
V1*	50% of plants with at least 1 apical meristem
V(n)*	50% of plants with at least n apical meristems
R1*	50% of plants flowering
R7*	50% of plants at harvest maturity
Potato	
VE	50% of plants with some part visible at the soil surface
T1*	Tuber initiation
T2*	T1 + 20 days
T3*	T1 + 40 days
T4*	Date when green canopy cover reaches 20% of the maximum achieved (harvest maturity)

FORM R-1
Phenological Growth Stage Components

*Date dd/mm/yy	*Plot(s)	*Vegetative Growth Stage	*Reproductive Growth Stage
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COMMENTS:

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Maize

Note: Biomass harvests should occur at approximately stages V6, R1, and R4. Final harvest should occur as soon after stage R6 as possible. In the table below, growth stage codes marked with a "b" are the required biomass harvest sampling dates; the growth stage code marked with an "f" is the required final harvest sampling date. Additional harvest data may be reported on Form R-2.

Growth Stage Codes	Description (Ritchie and Hanway 1982)	Harvest Code Required	Harvest Code Desired
Vegetative			
VE	50% of plants with some part visible at soil surface		
V1	50% of plants with collar of 1st leaf visible		
V2	50% of plants with collar of 2nd leaf visible		
V3	50% of plants with collar of 3rd leaf visible		
V4	50% of plants with collar of 4th leaf visible		
V5	50% of plants with collar of 5th leaf visible		
V6[b]	50% of plants with collar of 6th leaf visible	1-3	8-10,12-15
V(n)	50% of plants with collar of n leaf visible		
VT	50% of plants with last branch of tassel visible but silks not yet visible		
Reproductive			
R1[b]	50% of plants with some silks visible outside husks	1-3	7-10, 13-15
R2	50% of plants in "blister" stage - endosperm is abundant clear fluid - often 10-14 days after R1		
R3	50% of plants in "milk" stage - kernels yellow on outside and inner fluid milky - often 18-22 days after R1		
R4[b]	50% of plants in "dough" stage - endosperm with pasty consistency - often 24-28 days after silking	1-3	4-11, 13-15
R5	50% of plants in "dent" stage - shelled cob dark red in color - dent beginning to form in top of kernel		
R6	50% of plants at physiological maturity - brown or black abscission layer visible at base of embryo when kernel sectioned longitudinally, and husks no longer green - often 55-65 days after R1		
f	Final harvest should be taken shortly after R6	1-3, 5-7	4, 8-15
R7	50% of plants at harvest maturity		

Harvest Code	Component	Units	Harvest Code	Component	Units
1	Plant population of harvest area	plants/m2	9	Leaf sheath weight (dry)	g/m2
2	Area harvested	m2	10	Stem + tassel weight (dry)	g/m2
3	Above ground biomass (dry)	g/m2	11	Cob + shuck weight (dry)	g/m2
4	Seed weight (undried)	g/m2	12	Root weight (dry)	g/m2
5	Seed weight (dry)	g/m2	13	Leaf area index	m2/m2
6	Seed number	seeds/m2	14	Leaf number	
7	Ear number	ears/m2	99	Other (specify)	
8	Leaf blade weight (dry)	g/m2			

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Maize

*Date dd/mm/yy	*Plot	*V-Stage	*R-Stage	*Harvest Codes (1) #/m²	(2) m²	(3) g/m²	(4) g/m²	(5) g/m²	(6) seed/m²	(7) ears/m²
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*Harvest Codes (continued) (8) g/m²	(9) g/m²	(10) g/m²	(11) g/m²	(12) g/m²	(13) m²/m²	(14)	(Other)

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Grain Sorghum, Wheat, Rice, Barley, and Millet

Note: Biomass harvests should occur at stages 13, 65, and 85. Final harvest should occur as soon after physiological maturity as possible - any time between stages 92-94. In the table below, growth stage codes marked with a "b" are the required biomass harvest sampling dates; the growth stage code marked with an "f" is the required final harvest sampling date. Additional harvest data may be reported on Form R-2.

Growth Stage Codes	Description (Zadoks et al. 1974)	Harvest Codes Required	Harvest Codes Desired
Vegetative			
Germination			
00	Dry seed		
01	Start of imbibition		
02	---		
03	Imbibition complete		
04	---		
05	Radicle emerged from seed coat		
06	---		
07	Coleoptile emerged from seed coat		
08	---		
09	Leaf just at coleoptile tip		
Seedling growth			
10	First leaf through coleoptile		
11	First leaf unfolded		
12	2 leaves unfolded		
13[b]	3 leaves unfolded	1-3,8-10,13,14	12
14-19	4-9 or more leaves unfolded		
Tillering			
20	Main shoot only		
21	Main shoot and 1 tiller		
22	Main shoot and 2 tillers		
23-29	Main shoot and 3 to 9 or more tillers		
Stem elongation			
30	Pseudo-stem erection (winter cereals only)		
31	1st node detectable		
32	2nd node detectable		
33-36	3rd to 6th node detectable		
37	Flag leaf just visible		
38	---		
39	Flag leaf ligule just visible		
Booting			
40	---		
41	Flag leaf sheath extending		
42	---		
43	Boots just visibly swollen		
44	---		
45	Boots swollen		
46	---		
47	Flag leaf sheath opening		
48	---		
49	First awns visible		
Reproductive			
Emergence			
50	---		
51	First spikelet of ear just visible		
52	---		

Growth Stage Codes	Description (Zadoks et al. 1974)	Harvest Codes Required	Desired
Emergence (continued)			
53	1/4 of ear emerged		
54	---		
55	1/2 of ear emerged		
56	---		
57	3/4 of ear emerged		
58	---		
59	Emergence of ear completely		
Flowering			
60	---		
61	Beginning of flowering (not easily detectable in barley)		
62	---		
63	---		
64	---		
65[b]	Flowering halfway	1-3,8-10,13,14	12
66	---		
67	---		
68	---		
69	Flowering complete		
Milk development			
70	–		
71	Seed coat water ripe		
72	---		
73	Early milk		
74	---		
75	Medium milk. Increase in solids of liquid endosperm notable when crushing the seed between fingers		
76	---		
77	Late milk		
78	---		
79	---		
Dough development			
80	---		
81	---		
82	---		
83	Early dough		
84	---		
85[b]	Soft dough (fingernail impression not held)	1-3,5,8-11,13,14	4,6,7,12
86	---		
87	Hard dough (fingernail impression held, head losing chlorophyll)		
88	---		
89	---		
Ripening			
90	---		
91	Seed coat hard (difficult to divide by thumbnail)		
92 }	Seed coat hard (can no longer be dented by thumbnail)		
93 } f[†]	Seed coat loosening in daytime	1-3,5,7-11[†]	4,6,12-14
94 }	Overripe, straw dead and collapsing		
95	Seed dormant		
96	Viable seed giving 50% germination		
97	Seed not dormant		
98	Secondary dormancy induced		
99	Secondary dormancy lost		

† For the final harvest, determine the growth stage code (92, 93, or 94) which most closely corresponds to the growth stage of the plant at physiological maturity and record this code on Form R-2.

(Continued...)

FORM R-2 - Growth Analysis Harvest and Final Yield Components for Grain Sorghum, Wheat, Rice, Barley , and Millet (continued)

Harvest Code	Component	Units	Harvest Code	Component	Units
1	Plant population of harvest area	plants/m2	9	Leaf sheath weight (dry)	g/m2
2	Area harvested	m2	10	Stem weight (dry)	g/m2
3	Above ground biomass (dry)	g/m2	11	Panicle rachis weight (dry)	g/m2
4	Seed weight (undried)	g/m2	12	Root weight (dry)	g/m2
5	Seed weight (dry)	g/m2	13	Leaf area index	m2/m2
6	Seed number	seeds/m2	14	Leaf number	
7	Panicle number	panicles/m2	99	Other (specify)	
8	Leaf blade weight (dry)	g/m2			

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Grain Sorghum, Wheat, Rice, Barley, and Millet

*Date dd/mm/yy	*Plot	*V-Stage	*R-Stage	*Harvest Codes (1) #/m²	(2) m²	(3) g/m²	(4) g/m²	(5) g/m²	(6) seed/m²	(7) panicle/m²
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*Harvest Codes (continued) (8) g/m²	(9) g/m²	(10) g/m²	(11) g/m²	(12) g/m²	(13) m²/m²	(14)	(Other)

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Soybean and Dry Bean

Note: Biomass harvests should occur at stages V4, R4, R5, R6, and R7. Final harvest should be made at stage R8. In the table below, growth stage codes marked with a "b" are the required biomass harvest sampling dates; the growth stage code marked with an "f" is the required final harvest sampling date. Additional harvest data may be reported on Form R-2.

Growth Stage Codes	Description (Fehr et al. 1971)† ‡	Harvest Codes Required	Harvest Codes Desired
Vegetative			
V0	50% of plants with some part visible at soil surface		
V1	50% of plants with completely unrolled leaf at unifoliated node		
V2	50% of plants with completely unrolled leaf at 1st node above the unifoliated node		
V3	50% of plants with 3 nodes on main stem beginning with the unifoliated node		
V4[b]	50% of plants with 4 nodes on main stem beginning with the unifoliated node	1-3	8-10,13
V(n)	50% of plants with n nodes on main stem beginning with the unifoliated node		
Reproductive			
R1	50% of plants with one flower at any node		
R2	50% of plants with flower at node immediately below the uppermost node with a completely unrolled leaf		
R3	50% of plants with a pod 0.5 cm long at one of the four uppermost nodes with a completely unrolled leaf		
R4[b]	50% of plants with a pod 2.0 cm long at one of the four uppermost nodes with a completely unrolled leaf	1-3	7-11,13
R5[b]	50% of plants with beans beginning to develop (can be felt when pod is squeezed) at one of the four uppermost nodes with a completely unrolled leaf	1-3	7-11,13
R6[b]	50% of plants with a pod containing full-size green beans at one of the four uppermost nodes with a completely unrolled leaf	1-3	7-11,13
R7[b]	50% of plants with pods yellowing ; 50% of leaves yellow - physiological maturity	1-3,5	6-11,13
R8[f]	50% of plants with 95% of pods brown - harvest maturity	1,2,5,6	3,7-11,13

† Only development of the main stem is considered by this system; branches are ignored. A leaf is considered completely unrolled when the leaf at the node immediately above it has unrolled sufficiently so the two edges of each leaflet are no longer touching. At the terminal node on the main stem, the leaf is considered completely unrolled when the leaflets are flat and similar in appearance to older leaves on the plant.

‡ For dry bean, the phenological growth stages are defined as for soybean (Fehr et al. 1971).

Harvest Code	Component	Units	Harvest Code	Component	Units
1	Plant population of harvest area	plants/m2	9	Petiole weight (dry)	g/m2
2	Area harvested	m2	10	Stem weight (dry)	g/m2
3	Above ground biomass (dry)	g/m2	11	Empty shell weight (dry)	g/m2
4	Seed weight (undried)	g/m2	12	Root weight (dry)	g/m2
5	Seed weight (dry)	g/m2	13	Leaf area index	m2/m2
6	Seed number	seeds/m2	14	Nodule weight (dry)	g/m2
7	Pod number	pods/m2	99	Other (specify)	
8	Leaf blade weight (dry)	g/m2			

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Soybean and Dry Bean

				*Harvest Codes						
*Date dd/mm/yy	*Plot	*V-Stage	*R-Stage	(1) $\#/m^2$	(2) m^2	(3) g/m^2	(4) g/m^2	(5) g/m^2	(6) $seed/m^2$	(7) $pods/m^2$
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*Harvest Codes (continued)							
(8) g/m^2	(9) g/m^2	(10) g/m^2	(11) g/m^2	(12) g/m^2	(13) m^2/m^2	(14) g/m^2	(Other)

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Peanut

Note: Biomass harvests should occur at approximately stages V4, R4, three to four weeks after R4, and six to eight weeks after R4. Final harvest should be made at stage R8. In the table below, growth stage codes marked with a "b" are the required biomass harvest sampling dates; the growth stage code marked with an "f" is the required final harvest sampling date. Additional harvest data may be reported on Form R-2.

Growth Stage Codes	Description (Boote 1982)	Harvest Codes Required	Harvest Codes Desired
Vegetative			
VE	50% of plants with some part visible at soil surface		
V1	50% of plants with 1 developed node on the main axis (its tetrafoliate unfolded and its leaflets flat)		
V2	50% of plants with 2 developed nodes on the main axis		
V3	50% of plants with 3 developed nodes on the main axis		
V4[b]	50% of plants with 4 developed nodes on the main axis	1-3	8-10,13
V(n)	50% of plants with n developed nodes on the main axis		
Reproductive			
R1	50% of plants beginning bloom. 50% of plants with 1 open flower at any node		
R2	50% of plants beginning peg. 50% of plants with 1 elongated peg (gynophore)		
R3	50% of plants beginning pod. 50% of plants with 1 peg in soil with turned swollen ovary at least twice the width of the peg		
R4[b]	Full pod. 50% of plants with 1 fully-expanded pod, to dimensions characteristic of the cultivar	1-3,5	6-11,13
R5†	Beginning seed. 50% of plants with 1 fully-expanded pod with cotyledon growth visible when pod cut in cross section with razor blade (past liquid endosperm phase)		
R6†	Full seed. 50% of plants with 1 pod with seeds filling cavity of pod when fresh	1-3,5†	6-11,13
R7†	Beginning maturity. 50% of plants with 1 pod showing visible natural coloration or blotching of inner pericarp coloration		
R8[f]	Harvest maturity. 50% of plants with 2/3 to 3/4 of all developed pods having testa or pericarp coloration	1-3,5-7	8-11,13
R9	Over-mature pod. 50% of plants with 1 undamaged pod showing orange-tan coloration of the testa and/or natural peg deterioration		

† Two biomass harvests need to be taken after harvest stage R4: one taken 3-4 weeks after R4, and one taken 6-8 weeks after R4. For each of these biomass harvests, determine the growth stage code (R5, R6, or R7) which most closely corresponds to the growth stage of the plant and record this code on Form R-2.

Harvest Code	Component	Units	Harvest Code	Component	Units
1	Plant population of harvest area	plants/m2	9	Petiole weight (dry)	g/m2
2	Area harvested	m2	10	Stem weight (dry)	g/m2
3	Above ground biomass (dry)	g/m2	11	Empty shell weight (dry)	g/m2
4	Seed weight (undried)	g/m2	12	Root weight (dry)	g/m2
5	Seed weight (dry)	g/m2	13	Leaf area index	m2/m2
6	Seed number	seeds/m2	14	Nodule weight (dry)	g/m2
7	Pod number	pods/m2	99	Other (specify)	
8	Leaf blade weight (dry)	g/m2			

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Peanut

*Date dd/mm/yy	*Plot pods/m^2	*V-Stage	*R-Stage	*Harvest Codes (1) #/m^2	(2) m^2	(3) g/m^2	(4) g/m^2	(5) g/m^2	(6) seed/m^2	(7)
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*Harvest Codes (continued) (8) g/m^2	(9) g/m^2	(10) g/m^2	(11) g/m^2	(12) g/m^2	(13) m^2/m^2	(14) g/m^2	(Other)

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Aroid

Note: Biomass harvests should occur at approximately stages V3, V8, V11, and V25. By growth stage V25, above ground production begins to decline. Final harvest should be made at stage R7 (harvest maturity). All biomass harvests should consist of at least 6 plants/plot. For final harvest, additional plants/plot would be desirable. In the table below, growth stage codes marked with a "b" are the required biomass harvest sampling dates; the growth stage code marked with an "f' is the required final harvest sampling date. Additional harvest data may be reported on Form R-2.

Growth Stage Codes	Description	Harvest Codes Required	Harvest Codes Desired
V0	50% of plants have 1 visible leaf tip		
V1	50% of plants have 1 fully opened leaf		
V2	50% of plants have 2 fully opened leaves		
V3[b]	50% of plants have 3 fully opened leaves	1,2,3,5,6,8-11,13	4,7,12
V4-V7	50% of plants have 4-7 fully opened leaves		
V8[b]	50% of plants have 8 fully opened leaves	1,2,3,5,6,8-11,13	4,7,12
V9-V10	50% of plants have 9-10 fully opened leaves		
V11[b]	50% of plants have 11 fully opened leaves	1,2,3,5,6,8-11,13	4,7,12
V12-V24	50% of plants have 12-24 fully opened leaves		
V25[b]	50% of plants have 25 fully opened leaves	1,2,3,5,6,8-11,13	4,7,12
S	50% of plants have suckers above ground		
R7[f]	50% of plants have only 2 or 3 active leaves remaining on plant (approximately 10-11 months after planting)	1,2,3,5,6,8-11	4,7,12,13

Harvest Code	Component	Units	Harvest Code	Component	Units
1	Plant population of harvest area	plants/m2	8	Cormel weight (dry)	g/m2
2	Area harvested	m2	9	Cormel number	cormels/m2
3	Above ground biomass (dry)	g/m2	10	Leaf weight (dry)	g/m2
4	Corm weight (undried)	g/m2	11	Petiole weight (dry)	g/m2
5	Corm weight (dry)	g/m2	12	Root weight (dry)	g/m2
6	Corm number	corms/m2	13	Leaf area	cm^2
7	Cormel weight (undried)	g/m2	99	Other (specify)	

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Aroid

*Date	*Plot	*V-Stage	*R-Stage	*Harvest Codes						
dd/mm/yy				(1) #/m^2	(2) m^2	(3) g/m^2	(4) g/m^2	(5) g/m^2	(6) corms/m^2	(7) g/m^2
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*Harvest Codes (continued)						
(8) g/m^2	(9) cormels/m^2	(10) g/m^2	(11) g/m^2	(12) g/m^2	(13) cm^2	(Other)

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Cassava

Note: Biomass harvests should occur at approximately stages VE, V1, V2, V(n), and R1. Final harvest should be made at stage R7. In the table below, growth stage codes marked with a "b" are the required biomass harvest sampling dates; the growth stage code marked with an "f" is the required final harvest sampling date. Additional harvest data may be reported on Form R-2.

Growth Stage Codes	Description	Harvest Codes Required	Harvest Codes Desired
VE^b	50% of plants with at least 1 shoot on the planting stick more than 1 cm in length	1,2,3,5,6,8-12	4,7,13,14
$V1^b$	50% of plants with at least 1 apical meristem	1,2,3,5,6,8-12	4,7,13,14
$V2^b$	50% of plants with at least 2 apical meristems	1,2,3,5,6,8-12	4,7,13,14
$V(n)^b$	50% of plants with at least n apical meristems	1,2,3,5,6,8-12	4,7,13,14
$R1^b$	50% of plants flowering	1,2,3,5,6,8-12	4,7,13,14
$R7^f$	50% of plants at harvest maturity	1,2,3,5,6,8,9	4,7,10-13

Harvest Code	Component	Units	Harvest Code	Component	Units
1	Plant population of harvest area	plants/m2	9	Usable tuber number	tubers/m2
2	Area harvested	m2	10	Leaf weight (dry)	g/m2
3	Above ground biomass (dry)	g/m2	11	Petiole weight (dry)	g/m2
4	Total tuber weight (undried)	g/m2	12	Stem weight (dry)	g/m2
5	Total tuber weight (dry)	g/m2	13	Feeder root weight (dry)	g/m2
6	Total tuber number	tubers/m2	14	Leaf area	cm^2
7	Usable† tuber weight (undried)	g/m2	99	Other (specify)	
8	Usable tuber weight (dried)	g/m2			

†Usable tubers are defined as tubers over 200 g (undried).

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Cassava

*Date dd/mm/yy	*Plot	*V-Stage	*R-Stage	*Harvest Codes (1) #/m²	(2) m²	(3) g/m²	(4) g/m²	(5) g/m²	(6) tubers/m²	(7) g/m²
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*Harvest Codes (continued) (8) g/m²	(9) tubers/m²	(10) g/m²	(11) g/m²	(12) g/m²	(13) g/m²	(14) cm²	(Other)
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FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Potato

Note: Biomass harvests should occur at approximately stages T1, T2, and T3. For biomass harvests, take a sampling of eight plants per plot, and from these eight, chose a representative subsample of two plants for measurements. Final harvest should be made after T4 has been reached. For the final harvest, a sampling of 40 plants per plot should be used. Use a representative tuber sample of 4 kg to determine dry matter content of tubers (harvest code #16). In the table below, growth stage codes marked with a "b" are the required biomass harvest sampling dates; the growth stage code marked with an "f" is the required final harvest sampling date. Additional harvest data may be reported on Form R-2.

Growth Stage Codes	Description	Harvest Codes Required	Harvest Codes Desired
Vegetative			
VE	50% of plants with some part visible at soil surface		
V1	50% of plants with 1 developed node on the main axis		
V2	50% of plants with 2 developed nodes on the main axis		
V(n)	50% of plants with n developed nodes on the main axis		
Reproductive			
T1[b]	Tuber initiation. 50% of plants have at least one tuber $\geq$ 1 cm in diameter	3,6-15,17-19	4,5
T2[b]	T1 + 20 days	3,6-15,17-19	4,5
T3[b]	T1 + 40 days	3,6-15,17-19	4,5
T4[f]	Green canopy cover reaches 20% of the maximum achieved (harvest maturity)	1-3,10-16	

Harvest Code	Component	Units	Harvest Code	Component	Units
Biomass Sample (2 plants) / Final Harvest (40 plants)					
1	Plant population of harvest area	plants/m2	11	Tuber weight (5-30 mm, dry)	g/m2
2	Area harvested	m2	12	Tuber number (5-30 mm)	tubers/m2
3	Number of main stems	stems/m2	13	Tuber weight (>30 mm, undried)	g/m2
4	Main stem length	cm			
5	Number of auxiliary branches > 30 cm	branches/m2	14	Tuber weight (>30 mm, dry)	g/m2
			15	Tuber number (>30 mm)	tubers/m2
6	Leaf weight (undried)	g/m2	16	Tuber dry matter content	%
7	Leaf weight (dry)	g/m2	17	Leaf area index	m2/m2
8	Stem weight (undried)	g/m2	18	Ground cover	%
9	Stem weight (dry)	g/m2	19	Plant maturity rating (see table below)	
10	Tuber weight (5-30 mm, undried)	g/m2	99	Other (specify)	

The following codes should be used in describing maturity (Regel and Sands 1983).

Maturity Rating	Name	Code	Leaf and Stalk Condition
0	Tops dead	TD	Plant tops are dead, stalks are dry
1			Stalks are slightly sappy
2			Sappy stalks, with a few yellow leaves
3	Golden leaf	GL	Leaves are golden yellow
4			Plants are yellow with a tinge of green
5			Plants are yellow with obvious green visible
6			Plants are 50% green and yellow
7	Yellow-green	YG	Plants are green with obvious yellow visible
8			Plants are green with tinge of yellow
9	Dark green leaf	DG	Plants are green with first evidence of yellow appearing
10			Absolutely no evidence of yellowing, leaves are green, growth is lush

FORM R-2

Growth Analysis, Harvest, and Final Yield Components for Potato

*Date dd/mm/yy	*Plot	*V-Stage	*R-Stage	*Harvest Codes (1) #/m²	(2) m²	(3) stem/m²	(4) cm	(5) branches/m²	(6) g/m²	(7) g/m²	(8) g/m²	(9) g/m²
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*Harvest Codes (continued)

(10) g/m²	(11) g/m²	(12) tubers/m²	(13) g/m²	(14) g/m²	(15) tubers/m²	(16) %	(17) m²/m²	(18) %	(19) M.R.	Other

FORM S
Plant Nutrient Concentrations

Importance: For experiments where fertility was a treatment factor, these data indicate the nutrient status of the crop at time of harvest and are used to interpret simulation results and validate the crop model.

Note 1: This form should be used only when soil fertility was a treatment factor.

Note 2: The nutrients recorded on this form should be reported as percent concentrations of N, P, or K. Additional nutrients analyzed may be identified on Form S.

Note 3: Plant components and their codes are listed below. For each tissue component analyzed, use the appropriate component code. If any plant tissue analyzed is not listed below, then write "99" in the "Component Code" column and describe the tissue in the "Comments" section.

Note 4: See Technical Report 2 for recommended procedures for tissue sampling and preparation, and nutrient analysis of plant samples.

Plant Component Codes:

Plant Tissue	Code	Plant Tissue	Code
Secondary stems	01	Seed (or grain)	15
Cob	02	Stem	16
Corm	03	Stover	17
Cormel	04	Straw	18
Ear	05	Tiller leaf	19
Ear leaf	06	Tiller leaf sheath	20
Hull	07	Tiller stem	21
Husk	08	Tuber	22
Leaf blade	09	Whole above ground plant	23
Leaf sheath	10	Petiole and leaf blade	24
Panicle	11	Whole above ground tiller	25
Petiole	12	Whole above ground primary plant	26
Pod	13	Main stem	27
Root	14	Other (specify)	99

FORM S
Plant Nutrient Concentrations

Date dd/mm/yy	Plot(s)	Component Code	Nutrient Concentration N (%)	P (%)	K (%)	-- (%)	-- (%)	-- (%)	-- (%)
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COMMENTS:

APPENDIX

Institute Codes

ID	Institute Name
AC	Arab Center for Studies of Arid Zones and Dry Lands, Syria (ACSAD)
AI	Agency for Agricultural Research and Development, Indonesia (AARD)
AP	A.P. Agricultural University, India
AT	Asian Vegetable Research and Development Center, Taiwan (AVRDC)
CA	Centro Agronomico Tropical de Investigacion y Ensenanza, Costa Rica (CATIE)
CC	Centro Internacional de Agricultura Tropical, Colombia (CIAT)
CH	National Chung-Hsing University, Taiwan
CL	North Central Conservation Research Lab., USDA-ARS
CO	Cornell University
CP	Centro Internacional de la Papa, Peru (CIP)
CR	Center for Soil Research, Indonesia (CSR)
CS	Commonwealth Scientific and Industrial Research Organization, Australia (CSIRO)
CV	Centro Nacional de Investigaciones Agropecuarias, Venezuela
DN	Department of Scientific and Industrial Research, New Zealand (DSIR)
DT	Department of Agriculture, Thailand (DOA)
EB	Empresa Brasileira de Pesquisas Agropecuaria, Brazil (EMBRAPA)
ER	Economic Research Service (ERS)
FA	Food and Agriculture Organization, United Nations (FAO)
FF	Food and Fertilizer Technology Center for the Asian & Pacific Region, Taiwan (FFTC/ASPAC)
FN	Fondo Nacional de Investigaciones Agropecuarias, Venezuela (FONIAP)
GA	University of Georgia
GT	Grassland, Soil and Water Research Laboratory (ARS)
GU	Gujarat Agricultural University, India
HA	Haryana Agricultural University, India
IA	Institut National de la Recherche Agronomique, Yaounde, Cameroon (INRA)
IB	International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT)
IC	Indian Council for Agricultural Research (ICAR)
ID	Instituto de Investigacion Agropecuaria de Panama (INIAP)
IE	International Center for Agricultural Research in Dry Areas, Syria (ICARDA)
IF	International Fertilizer Development Center (IFDC)
IN	Institut National de la Recherche Agronomique, Toulouse, France (INRA)
IR	International Rice Research Institute, Philippines (IRRI)
IS	International Soybean Program (INSOY)
IT	International Crops Research Institute for the Semi-Arid Tropics, India (ICRISAT)
IU	Iowa State University
KK	Khon Kaen University, Thailand
LC	Lincoln College, New Zealand
LU	Louisiana State University
MA	Malaysian Agricultural Research & Development Institute (MARDI)
MI	Ministry of Primary Industries, Fiji (MPI)
MP	Marathwada Agricultural University, India
MS	Michigan State University
MU	Mississippi State University
NB	National Bureau of Soil Survey and Land Use Planning, India (NBSS/LUP)
NC	North Carolina State University
NI	Nitrogen Fixation by Tropical Agricultural Legumes (NifTAL)
NO	National Oceanographic and Atmospheric Administration (NOAA)
OK	Oklahoma State University
OR	Office de la Recherche Scientifique et Technique Outre-Mer, France (ORSTOM)
OS	Oregon State University
PA	Pakistan Agricultural Research Council (PARC)

ID	Institute Name
PC	Philippines Council for Agriculture and Resources Research and Development (PCARRD)
PP	Peanut Production, Disease and Harvesting Research, USDA-ARS
PR	Purdue University
PU	Punjab Agricultural University, India
QD	Queensland Department of Primary Industry, Australia
QU	University of Queensland, Australia
SC	Soil and Crop Evaluation Project (SCEP)
SP	University of South Pacific, Fiji
TA	Texas A & M University, College Station
TH	Land Development Department, Thailand (LDD)
TN	Tamil Nadu Agricultural University, India
UB	University of Burundi
UC	University of Guelph, Canada
UF	University of Florida
UG	University of Guam
UH	University of Hawaii
UI	University of Illinois
UJ	University of Jordan
UM	University of Melbourne
UN	University of Nebraska
UP	University of Puerto Rico
US	Utah State University
UZ	University of Zambia
WS	Washington State University

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