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TECHNICAL REPORT 2

Field & Laboratory Methods for the Collection of the IBSNAT Minimum Data Set

for the Decision Support System for Agrotechnology Transfer (DSSAT V.2.1)

International Benchmark Sites Network for Agrotechnology Transfer

IBSNAT, the International Benchmark Sites Network for Agrotechnology Transfer, is a group consisting of the contractor (the University of Hawaii) and several collaborators. Together they have created a prototype network of national, regional, and international agricultural research centers for the purpose of developing, validating, and using a scientific method for the effective transfer of agrotechnology among and within countries in the tropics and sub-tropics.

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PREFACE

Technical Report 2, *Field and Laboratory Methods for the Collection of IBSNAT Minimum Data Set* was developed as a quick reference guide for users of Technical Report 1, *Experimental Design and Data Collection Procedures for IBSNAT.* Field procedures and laboratory methods are outlined to provide easy access to information the user may require in collecting the minimum data set to validate and calibrate IBSNAT crop simulation models.

Field procedures and descriptions related to the layout of plots are only recommendations. We use illustrations to depict areas within experiment plots that the user would need to collect the complete minimum data set. The experimental design and the area available to the user will necessarily dictate the actual layout.

We have also developed flow charts describing steps the user should be aware of during intermediate biomass harvests and the final harvest for each of the crops to complete Forms R-1 and R-2.

Laboratory methods for soil and plant analyses are standard procedures we encourage users to adopt. Only with standardized methods will we be able to compare results. If you plan to use other methods, please submit a copy of the procedures with Forms I and S.

Technical Report 2 is being produced in a loose-leaf format to allow IBSNAT to send you updates relative to changes that may be incorporated in Technical Report 1. With this in mind, the version number and date of this edition is printed at the bottom outside margin of every page. When updated material is sent to users, the edition number and date of its pages will change sequentially to reflect their hierarchic order. It is strongly suggested that the registration form on page 67 be completed and sent to IBSNAT to ensure the receipt of all future versions. Graphical displays depicting various growth stages for each crop are planned, and will be included as updates to Technical Report 2.

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CHAPTER 1

RATIONALE & PURPOSE: IBSNAT EXPERIMENTS

An IBSNAT experiment can be an independent or adjunct part of any planned field experiment that will allow for the collection of the minimum data set described in Technical Report 1. It should not be different from agronomic experiments being conducted at research stations today, except in the frequency of biomass harvests required for Form R. These will require monitoring the crop's phenological development, daily weather, and crop and soil management inputs. Because of the destructive sampling required for biomass harvesting, adjustments to plot size will most likely be necessary. **Plot sizes for modeling experiments tend to be larger than those for other agronomic experiments.**

In principle, grain yield alone is sufficient to test the crop models. Nevertheless, biomass information is collected during stages of crop development as part of the minimum data set (MDS). With this information we hope to increase our understanding of the relationship between plant growth and development, and final yield.

It is anticipated that the complete minimum data set will permit a validation of crop model simulation with observed field measurements at various intermediate phenological stages of growth and at final harvest. The IBSNAT crop models are process-based growth models that compute photosynthesis on a daily basis and partition the supply of carbohydrates to the root, stem, leaf, and reproductive organs in ratios governed by the crop's phenological program. As Technical Report 2 is a reference document for Technical Report 1, it attempts to answer many of the "how" questions associated with methods needed to determine the data and information for the MDS forms. The procedures discussed should provide researchers with sufficient information to help them plan and manage experiments that will yield accurate minimum data sets in the most resource-efficient manner.

General Considerations for IBSNAT Experiments

An IBSNAT experiment requires that measurements of dry matter production be taken at different phenological stages of growth, and thus necessitates the systematic destruction of plants within a finite population. Therefore, the variability of the population within the experimental unit must be minimized if the growth data are to represent the development of a crop from emergence to maturity. The many causes of variance in field experimentation can be grouped in the following general categories: mechanical errors, plant competition effects, and soil heterogeneity. The researcher must be able to cope with each of these causes in order to ensure that a satisfactory level of uniformity among plants will exist within the plot.

Table 2 lists recommended or acceptable plot size dimensions, row spacing, plant density, etc. This list should be used only as a *guide*.

Despite all the precautions a researcher may take, some degree of variability will undoubtedly remain in the plant population within a plot as well as among plots of replicated treatments. The researcher must, therefore, develop a good sampling technique that will enable him to collect precise data to achieve the objectives of the experiment.

Sampling and processing of harvested plant materials are both labor intensive and time consuming. The researcher needs to critically evaluate the available resources and be able to fit the experiment to the capabilities of the research station with the overall goal of maintaining a high degree of precision at reasonable cost.

CHAPTER 2

FIELD METHODS

1) **FORM C—Daily Weather**
   Selection and installation of weather instruments
   Location & layout of weather instruments

2) **FORM H—Experimental Plots**
   Estimation of dry-weight crop residue

3) **FORM J-1 & J-2—Soil Water Contents**
   Volumetric moisture content
   Bulk density
      core method
      clod method
   Field measurements for DUL and LL

4) **FORM R-1 & R-2—Growth Stage and Yield Components**
   Procedures for biomass harvest
   Procedures for final harvest
   Plot Diagram and Final Harvest for MAIZE
   Plot Diagram and Final Harvest for SORGHUM
   Plot Diagram and Final Harvest for RICE and WHEAT
   Plot Diagram and Final Harvest for CASSAVA
   Plot Diagram and Final Harvest for AROID
   Plot Diagram and Final Harvest for POTATO
   Plot Diagram and Final Harvest for SOYBEAN and DRY BEAN
   Plot Diagram and Final Harvest for PEANUT

FORM C-1: Daily Weather Data

Form C-1 is used to record daily weather that is required to complete the MDS forms. Form C-2 (additional daily weather) is to be used to record additional weather that may be useful to the experiment. The information in Form C-2 **is not required** to complete the MDS forms. A list of instruments needed to record data in Form C-2 can be found in Appendix A.

In order to complete these forms, reliable instrumentation located in a representative and unobstructed position is required. The following paragraphs should provide each user with information to help select, locate, and install these instruments.

Selection and Installation of Weather Instruments

The required minimum weather data are daily records of rainfall, maximum and minimum air temperatures, and solar radiation. Instruments used to measure these data should be monitored regularly and the data recorded daily. This is especially critical during the crop growth period—from the time the seed is sown (or when preplant soil samples are taken) until final crop harvest.

Selection

Automatic recording weather stations and manually read weather instruments are now commonly available. Either system is sufficient to collect the MDS. Battery-operated recorders must be closely monitored to ensure continuous recording of data, as failure can result in irreversible loss of data. Installation of a manually maintained station as a back-up to an automatic one is recommended to minimize loss of data.

The following table lists instruments and sensors normally available for either type of weather station:

Table 1: Weather Instruments & Sensors.

Parameter	Automatic	Manual
Rainfall	Tipping, bucket, 1mm	Standard 8-inch rain gauge with metric dipstick
Air temperature	Thermocouple sensors	Max/min thermometers
Solar radiation	Silicon cell pyranometer	Sunshine hour recorder or pyroheliometer

For manually maintained instruments, it is essential to record events at nearly the same time each day. At readily accessible sites, the instruments should be read and data recorded as the first activity of the day. For remote sites, the instruments may be read at the end of the working day.

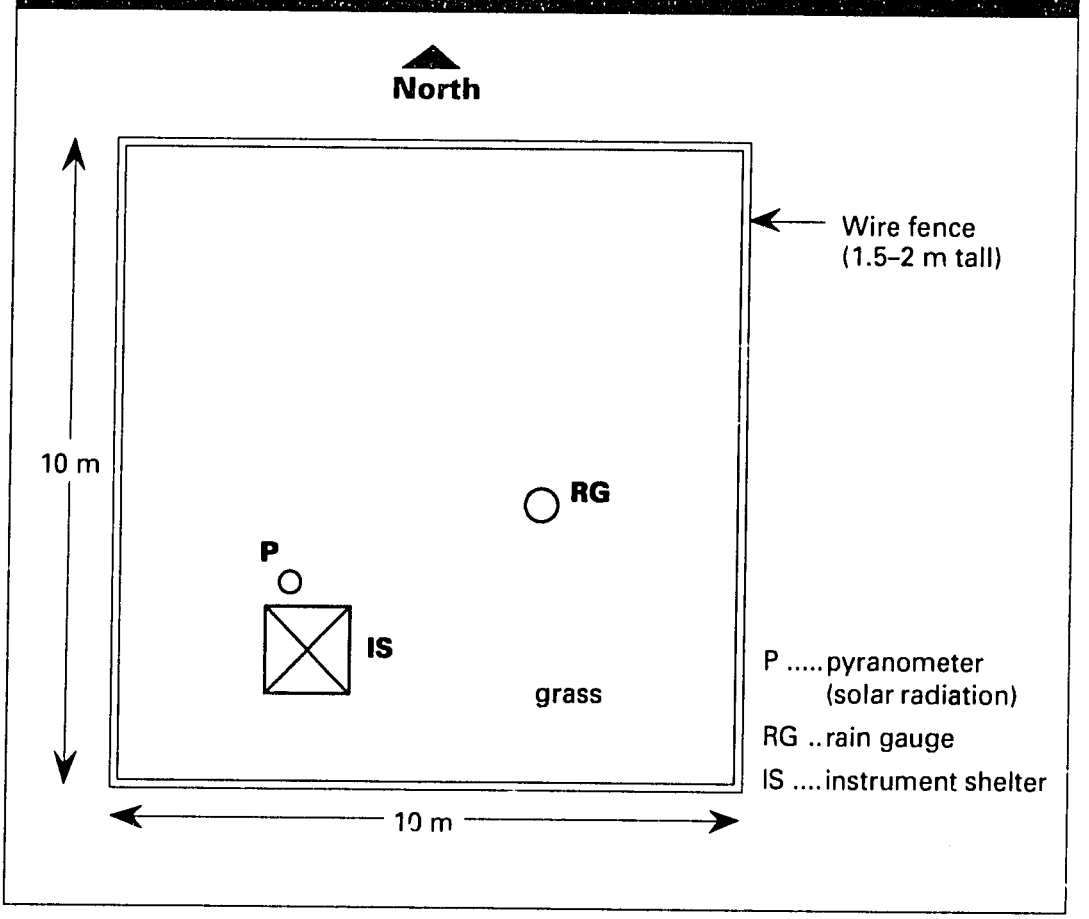
Location and Layout of Weather Station

If an existing weather station that records the minimum weather data set is available at the experimental site, the distance from that station to the experiment plots should be noted and recorded in Form D of Technical Report 1.

If no weather station exists, select an area that is most representative of the experimental site. The weather station site should be on as level ground as is possible to find, and planted with grass. Avoid locations where natural or man-made structures may obscure sunlight. As a general rule, the weather station should be positioned at a distance ten times the height of the obstruction.

An example of layout and installation of a weather station is shown in Figure 1. An area of at least 100 m^2 should be allotted for the installation of the station.

Figure 1. Suggested layout of instruments at a weather station.



Installation

Max/min thermometers and thermographs should be housed in a well-ventilated instrument shelter. It is best to have the door to the instrument shelter open to the north or south to minimize direct sunlight on the thermometers. Height of the shelter should be at least 1.25 m above the ground. Legs of the shelter should be secured on a concrete footing or otherwise well-anchored to prevent vibrations.

Rainfall

The rain gauge should be mounted on level ground or a level platform with a concrete footing. For tipping bucket rain gauges, the electrical lead to the event recorder should be sufficiently insulated and buried as a safety precaution. The event recorder should be housed in an instrument shelter.

Solar radiation

Solar radiation instruments, and sunshine duration recorders should be mounted on a well-anchored level platform. Both must be positioned in a location clear of any east-west obstructions or shadows.

FORM H: Experimental Plots

Estimation of Dry-weight Crop Residue

Data on initial crop residue is reported as part of the minimum data set. It is used in the nitrogen and water balance subroutines of the crop models. The procedure for estimating this variable is described below.

1. Just before plowing, measure ten 1 m^2 sections, uniformly distributed across the experimental area.

2. From each 1 m^2 sampling area, collect all aboveground residue and weigh. Determine th average weight of all ten samples. This is the average fresh weight measurement in the formula in Equation 1 (below). Be sure that residue does not include soil.

3. From each of the ten samples, obtain a subsample of 100–200 g. Weigh these, and place a marked bag.

4. Oven dry each residue subsample at 70°C for 24 hours or more until a constant weight is obtained.

5. Determine average moisture content (M.C.) of each of the subsamples by the following:
   Equation 1:

$$\text{M.C.} = \frac{\text{fresh weight} - \text{dry weight}}{\text{fresh weight}}$$

   NOTE: The value of M.C. should be <1.

6. Determine moisture content of the ten subsamples.

7. Express residue amount in kg/ha, on a dry basis by the following:
   Equation 2:

$$\underset{(\text{kg/ha})}{\text{Crop residue}} = (\text{average fresh weight}/\text{m}^2)\,(1 - \text{Average M.C.})\,(10{,}000).$$

FORMS J-1 and J-2: Soil Water Contents

Volumetric Water Content

The following procedure should be used to determine volumetric soil water content.

1. Collect a core sample or auger sample from each soil layer two weeks before planting.

2. Thoroughly mix and composite the auger samples in one bag for each layer.

3. Take a duplicate set of subsamples from the composite. Weigh (W_i) both sets of samples in soil moisture cans.

4. Oven dry the samples at 105°C for 24 hours or until a constant weight (W_d) is obtained.

5. Calculate the gravimetric moisture content (θ_g) as follows:
   $$\theta_g = [(W_i - W_d)/W_d]$$

6. Determine the bulk density separately and convert gravimetric moisture content into volumetric moisture content (θ_v), as follows:
   $$\theta_v = (\rho_b/\rho_w) \times \theta_g$$
   where ρ_b is the bulk density and ρ_w is the density of water equal to 1.

Bulk Density

Core Method

A core sampler can be a single cylindrical tube or a tube with several cylindrical rings of known dimensions. The sampler can be driven mechanically or manually into the soil either horizontally or vertically. Extruded soil from core sampler or soils and rings are weighed and oven-dried to constant weight at 105°C. The oven-dry weight divided by the volume of the core sampler or cylindrical ring is the bulk density usually expressed in g/cm^3. This method should not be used for wet (e.g., aquic, histic) or dry, sandy soils.

Clod Method

Natural clods about one inch in diameter are coated with saran and weighed in air, then in water, using the Archimedes principle to determine the soil volume.

APPARATUS:
Beam balance accurate to 0.01 g; beaker or container to accommodate clod while being weighed in water.

REAGENT:
Methyl ethyl ketone solvent; Dow Saran S310 resin (as an alternative, paraffin can be used). Saran-solvent ratios of 1:6 and 1:7 are used, dependent on porosity of the soil. Coating solution: fill a weighed container to 3/4 of its total volume. From the weight of solvent, calculate the weight of resin to obtain derived resin-solvent ratio and add to solvent. Mix vigorously under an exhaust hood; solution is highly volatile and flammable, so store in metal cans tightly closed to prevent evaporation.

PROCEDURE:

1. Tie approximately 30 cm of fine thread around each clod and weigh (W_i).

2. Dip in coating solution several times until the clods are fully coated. Allow to solidify between each coating.

3. Weigh coated clods in air (W_{cp}).

4. Weigh coated clods in water (W_{cw}) that are hanging from balance pan and suspended in water. Make sure that during weighing the clod is fully submerged in water but not resting at the bottom of the water container. Remove or dislodge air bubbles sticking to the side of the clod during submergence. If bubbles continuously appear out of the clod while submerged, the clod is not fully coated with the saran. Discard clod and start all over again with new clod.

5. Carefully peel off saran coating, weigh and dry clod at 105°C. Weigh dry clod and calculate moisture factor (MF) of clod as follows:

$$MF = 1 + \frac{\text{wet weight - dry weight}}{\text{dry weight}}$$

where W_f = fresh weight of clod, and M.C. = % moisture content.

7. The bulk density, ρ_b, is then calculated by the following formula:

$$\rho_b = \frac{W_d}{\frac{W_{cp} - W_{cw}}{\rho w} - \frac{W_{cp} - W_c}{\rho p}}$$

where W_d = clod dry weight
W_{cp} = weight of clod and wax in air
W_{pw} = weight of clod and wax in water
W_f = weight of clod in air
ρw = density of water at temperature of determination
ρp = density of resin (about 0.9 g/cubic centimenter).

ADAPTED FROM:

SCS, USDA. 1984. Soil survey laboratory methods and procedures for collecting soil samples. 1984. *In* Soil Survey Investigation Report No. 1. U.S. Gov. Print. Office, Washington, D.C.

Field Measurements for Drained Upper Limit (DUL) and Lower Limit (LL)

Existing IBSNAT crop simulation models make use of soil water parameters as a measure of plant-extractable water. The drained upper limit (DUL) is defined as the highest field measured water content of a soil after it has been wetted and allowed to drain until drainage has ceased (i.e., less than 0.1 to 0.2% change in water content per day). DUL is analogous to the definition of field capacity. Another parameter is called the lower limit (LL) which is the lowest field measured water content of soil when plants have stopped extracting water (i.e., near premature death or become dormant due to water stress); the LL is analogous to the permanent wilting point. Traditionally, these parameters are measured in the laboratory with a pressure plate apparatus to obtain a relationship between the pressure applied and soil moisture retained under this pressure, a moisture release curve.

PROCEDURE:

The procedures for field measurement of soil water at DUL and LL are as follows:

1. Grow a crop in the field during a period when rainfall is least likely to occur. Apply

sufficient fertilizer and irrigation water to allow the crop to attain full growth and normal development. A minimum plot size of 10 x 10 m is recommended. Recommended crops are maize, sunflower, sorghum, wheat, and barley.

2. At about two weeks before flowering or silking withdraw irrigation and let the plants extract water until they exhibit severe drought stress or are near death.
   NOTE: It is important, during this period, to minimize or prevent any addition of water by rainfall. Plastic sheets or shelter should be available.

3. Determine volumetric soil water content every 10- 20 cm to a depth of 2 m, if bedrock is not limiting. Soil water can be determined either by a neutron probe or gravimetrically with auger samples. A minimum of four sample locations for a neutron probe or 10 sampling holes for auger samples is recommended. A separate pit, as near as possible to the experimental plot, must be dug to collect soil samples for bulk density measurements.

4. After determining the lower limit (LL) of extractable water, remove plants and irrigate the plot until the entire profile is saturated. If sprinklers or drip irrigation is used, saturation can be estimated visually by observing ponding or a slowing of water intake in fine textured soils. For course-textured soils, volumetric water content at field saturation for each depth or layer should be determined upon cessation of irrigation. For fine textured soils, sampling should be initiated only after any ponded water has drained.

5. Cover plot with plastic.

6. Determine the water content at each depth or layer after allowing the soil to drain for several days until the water content becomes stable or changes from 0.1 to 0.2% one day. For coarse-textured soils, DUL is usually attained after 2 days, while in fine-textured soils 10-14 days may be required. This is called the drained upper limit (DUL).

If field measurements are not possible, data from moisture release curves may be used as a first approximation. Another alternative would be to use field measurements made elsewhere on a similar soil. Similar soils mean similarly classified soils that have either the same soil series name or same phase and soil family.

REFERENCE:

Ratliff, L. F., J.T. Ritchie, and D.K. Cassel. 1983. Field measured limits of soil water availability as related to laboratory-measured properties. J. Soil Sci. 47:770-75.

Ritchie, J. T. 1981. Soil water availability. Plant and Soil 58:327-38.

FORMS R-1 & R-2: Growth Stage and Yield Components

Two types of sampling or harvest procedures are described in this section: (1) biomass harvest at recommended growth stages, and (2) final harvest to determine crop yield. Both types of harvest data are used in validating simulated crop model outputs.

In most instances, there will be three or four biomass harvests before the final harvest. In Table 2, the recommended physical dimensions of designated MDS plots are provided for each crop. The biomass harvests correspond to selected vegetative and reproductive stages of growth (Table 3).

The recommended MDS plot is of sufficient size to accommodate the requirements of both biomass and final harvests. Final harvest procedure flow charts and plot diagrams in this section, provide harvesting guides and recommended plot and subplot size for each crop.

Table 2. Recommended row dimensions and harvest information.

(Researchers may modify these dimensions and numbers as needed).

crop	no. of rows	row spacing (m)	plants/ m-row	plants/ha ($x10^3$)	no. of biomass harvests	biomass and harvest rows	biomass plot lengths (m)	final harvest plot lengths (m)	no. of plants: biomass harvest	no. of plants: final harvest
Maize	4	0.67	4	59.7	3	2	1.0	9.0	8	72
Sorghum	4	0.67	9	134	3	2	1.0	3.6	9	65
Wheat & Rice	15	0.2	50	2500	3	5	.50	1.5	75	250
Soybean & Dry Bean	4	0.67	18	269	5	2	1.0	5.0	36	129
Peanut	4	0.67	5	74.6	2	2	1.0	5.0	10	50
Cassava	8	1.0	1	10.0	5	6	1.0	1.0	6	6
Aroid	6	0.6	2	33.3	4	4	0.6	3.0	4	24
Potato	6	0.9	4	44.4	3	4	0.5	2.5	8	40

Procedure for Biomass Harvest

To harvest all aboveground biomass, cut the plant with a sharp knife as close to the ground as possible. Weigh harvested material, place material in a paper bag, and oven-dry at 70°C to constant weight. Record data in Form R-2. Since respiration can reduce plant weight, oven dry the harvested material immediately after harvesting, or if that is not possible, place in a cooler, cold container, or a refrigerator until it can be dried. For crops with thick stems or

Table 3: Growth stages for biomass harvest.

Crop	Harvest Number	Growth Stages: Code	Descriptions
Maize	1st	V6	50% of plants with collar of 6th leaf visible.
	2nd	R1	50% plants with some silks visible outside husks.
	3rd	R4	50% plants in "dough" stage—endosperm with pasty consistency—often 24-28 days after silking.
Sorghum, wheat, & rice	1st	13	3 leaves unfolded.
	2nd	65	Flowering half-way.
	3rd	85	Soft dough (fingernail impression not held).
Soybean & dry bean	1st	V4	50% of plants with 4 nodes on main stem beginning field with unifoliate node.
	2nd	R4	50% of plants with a pod 2.0 cm long at one of the four uppermost nodes with a completely unrolled leaf.
	3rd	R5	50% of plants with beans beginning to develop at one of the four uppermost nodes with a completely unrolled leaf.
	4th	R6	50% of plants containing full size beans at one of the four uppermost nodes with completely unrolled leaf.
	5th	R7	50% of plants with pods yellowing; 50% of leaves yellow–physiological maturity.
Peanut	1st	V4	50% of plants with 4 developed nodes on the main axis.
	2nd	R4	Full pod. 50% of plants with one fully-expanded pod, to dimensions characteristic of the cultivar.
	3rd	R6†	Full seed. 50% plants have one pod with seeds filling cavity of pod when fresh.
Cassava	1st	VE	50% of plants with at least 1 shoot greater than 1 cm in length on the planting stick.
	2nd	V1	50% of plants with at least 1 apical meristem.
	3rd	V2	50% of plants with at least 2 apical meristems.
	4th	V(n)	50% of plants with at least n apical meristems.
	5th	R1	50% of plants flowering.
Aroid	1st	V3	50% of plants have 3 fully opened leaves.
	2nd	V8	50% of plants have 8 fully opened leaves.
	3rd	V11	50% of plants have 11 fully opened leaves.
	4th	V25	50% of plants have 25 fully opened leaves.
Potato	1st	T1	Tuber initiation. 50% plants have at least one tuber greater or equal to 1 cm in diameter.
	2nd	T2	T1 + 20 days
	3rd	T3	T1 + 40 days

† *NOTE: Two biomass harvests must be taken after R4: one taken 3-4 weeks after R4, and one taken 6-8 weeks after R4. See Technical Report 1, p. 58.*

woody tissues, chop the stems into smaller pieces (2-5 cm) before oven drying. For further details, consult the following section before conducting biomass sampling during the reproduction (V&R) stages.

Procedure for Final Harvest

Steps for final harvest include harvestable plant identification, harvesting, and plant preparation and drying. Most crops have a unique set of data to be collected. The preparation of plant samples for each crop is described in the flow charts on the proceeding pages. Harvestable plant identification and harvesting procedures are similar for all crops and are also described on the flow charts.

1. Before harvest, the harvestable plants must be identified and harvest areas determined.

2. Harvestable plants adjacent to border plants within the harvest row should be tagged so as to clearly demark the harvestable row. Refer to the plot diagrams on the following pages for identification of border and harvest plants. Multiplying the total length of all harvested rows by the space between rows gives the harvest area of the plot.

3. Once harvestable rows are marked and harvest area determined, harvesting may proceed.

Table 4: Final harvest for each crop.

Crop	Growth Stages: Code	Descriptions
Maize	After R6	50% of plants with black layer at the base of the seed. Also in the absence of a black layer, grains become shiny and translucent.
Sorghum	92-94†	Soon after 80% of grains are hard and difficult to break with fingernails or teeth.
Rice and wheat	92-94†	70-80% of grains are brown which may or may not be associated with browning of the leaves.
Soybean and dry bean	R8	95% of pods are dry and brown.
Peanut	R8	70-80% of pods have inner pericarp darkening (or show light-brownish color of mesocarp when outside of pod is scratched). Pods are very firm when pressed between thumb & forefinger. Leaves may or may not be senescing.
Aroid	R7	50% of plants have only 2 or 3 active leaves remaining on plant (approximately 10-11 months after planting).
Cassava	R7	50% of plants at harvest maturity.
Potato	T4	Green canopy cover reaches 20% of the maximum achieved (harvest maturity).

† *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. See Technical Report 1, p. 53.*

In harvesting, plants between and including tagged plants, should be collected. Cut all plants at ground level. Count the plants as they are being cut, and record the total number of plants harvested for plant population determination. To calculate plant population of the plot, divide the number of plants harvested by the harvest area. When all plants have been removed from the plot, preparation of plant samples may be executed according to the appropriate flow chart for that crop.

Final Harvest Procedure for MAIZE

Bracketed numbers in bold are Technical Report 1 Harvest Codes

For each plot: Determine plants and area to be harvested. Cut plants in harvest area at ground level. Remove ears leaving husk intact on plant.

Ears

Calculate ear number (ears/m²) **[7]** by dividing number of ears by harvest area (12 · 96 m²) and record in Form R2. Enter total ear weight (undried).

Select a subsample of 10 representative ears for dry weight and seed number determination. Record ear subsample weight (undried).

Remove seed from cob of subsample and log seed subsample weight (undried). Count three sets of 100 seeds and note the average 100 seed weight (undried). Calculate and record seed number **[6]**.

$$\text{seed no. (seed/m}^2) = \frac{\text{ear wt. (undried)} \times \dfrac{\text{seed subsamp. wt. (undried)}}{\text{ear subsamp. wt. (undried)}} \times \dfrac{100}{\text{100 seed wt.}}}{\text{harvest area}}$$

Dry seed and cob subsamples to constant weight at 70°C (approximately 7 days). Record seed and cob subsample weights (dry) separately.

Seed

Calculate and note seed weight (dry) **[5]**.

$$\text{seed wt. dry (g/m}^2) = \frac{\text{ear wt. (undried)} \times \dfrac{\text{seed subsample wt. (dry)}}{\text{ear subsample wt. (undried)}}}{\text{harvest area}}$$

Cob

Calculate & record cob weight (dry).

$$\text{cob wt. dry (g/m}^2) = \frac{\text{ear wt. (undried)} \times \dfrac{\text{cob subsample wt. (dry)}}{\text{ear subsample wt. (undried)}}}{\text{harvest area}}$$

Stover

Divide number of plants by harvest area (12 · 96 m²) and record under plant population of harvest area (plants/m²) **[1]**. Components into leaf blade, leaf sheath, husk, and stem.

Select a well-mixed, 500 g subsample of leaf blade. Record the leaf blade subsample weight (undried).

Oven dry the leaf blade to constant weight at 70°C. Record leaf blade subsample weight (dry).

Calculate and record leaf blade weight (dry) **[8]**.

$$\text{leaf blade wt. dry (g/m}^2) = \frac{\text{leaf blade wt. (undried)} \times \dfrac{\text{leaf blade subsample wt. (dry)}}{\text{leaf blade subsample wt. (undried)}}}{\text{harvest area}}$$

Calculate and record aboveground biomass (dry) **[3]**.

$$\text{aboveground biomass dry (g/m}^2) = \text{seed wt. (dry)} + \text{stover wt. (dry)}$$

Measure leaf area using leaf area meter for green leaf blades only from 10 representative plants. Record leaf area (cm^2). Calculate and record LAI **[13]**.

$$LAI = \frac{\text{leaf area } (cm^2) \times \text{plant population } (plants/m^2)}{10 \text{ plants} \times 10{,}000\ cm^2/m^2}$$

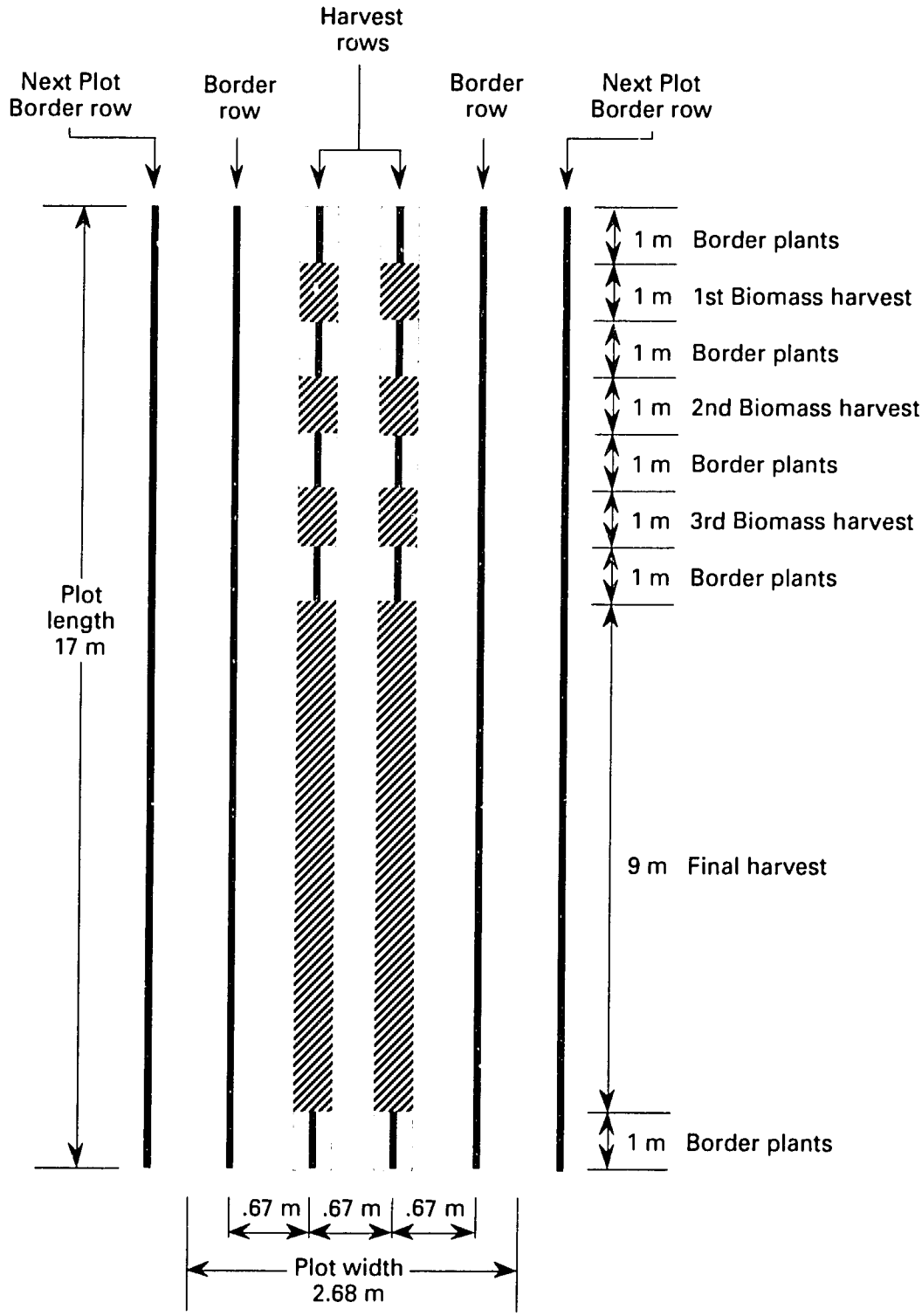
Separate all plants into the following plant components: leaf blade, husk, leaf sheath, and stem (includes tassel).

Repeat the last 3 steps for leaf sheath (dry) weight **[9]**, stem (dry) weight **[10]**, and husk (dry) weight.

Calculate and record stover weight (dry).

$$\text{stover wt. dry } (g/m^2) = \text{leaf blade wt. (dry)} + \text{leaf sheath wt. (dry)} + \text{stem wt. (dry)} + \text{(cob + husk) wt. (dry)}$$

Plot diagram of harvest area for MAIZE



Final Harvest Procedure for SORGHUM

Bracketed numbers in bold are Technical Report 1 Harvest Codes.

Measure area to be harvested. Count plants as you harvest. Cut plants at base as near to the ground as possible.

↓

Identify and count plants and area to be harvested. Calculate plant population of harvest area (plants/m²) **[1]** and record.

$$\text{plant population (plants/m}^2) = \frac{\text{no. of plants harvested}}{\text{harvest area}}$$

↓

Weigh and log panicle and stover weights (undried) after separation.

↓ Panicle

Calculate and record panicle number (panicles/m²) **[7]** by dividing number of panicles by harvest area.

↓

Select a subsample of 10 representative panicles for dry weight and seed number determination. Log panicle subsample weight (undried).

↓

Remove seed from rachis of subsample and record seed subsample weight (undried). Count 1000 seeds, weigh, and log weight.

↓

Calculate and record the seed number **[6]**.

$$\text{seed no. (seed/m}^2) = \frac{\text{panicle wt. (undried)} \times \text{seed subsamp. wt. (undried)} \times \text{1000 seeds}}{\text{panicle subsamp. wt. (undried)} \times \text{1000 seed wt.}}$$

harvest area

↓

Stover ↓

Select a subsample of 10 representative stalks for dry weight determination. Log subsample weight (undried).

↓

Separate subsample into leaf blades, leaf sheaths, and stems. Oven dry each subsample at 70°C. Record each subsample weight separately.

↓

Panicle

Stover

Calculate and record leaf blade (dry) **[8]**, leaf sheath (dry) **[9]**, and stem (dry) **[10]** weights.

$$\text{leaf blade wt. dry } (g/m^2) = \frac{\text{stover wt. (undried)} \times \dfrac{\text{leaf blade subsample wt. (dry)}}{\text{stover subsample wt. (undried)}}}{\text{harvest area}}$$

$$\text{leaf sheath wt. dry } (g/m^2) = \frac{\text{stover wt. (undried)} \times \dfrac{\text{leaf sheath subsample wt. (dry)}}{\text{stover subsample wt. (undried)}}}{\text{harvest area}}$$

$$\text{stem wt. dry } (g/m^2) = \frac{\text{stover wt. (undried)} \times \dfrac{\text{stem subsample wt. (dry)}}{\text{stover subsample wt. (undried)}}}{\text{harvest area}}$$

Dry seed and rachis subsamples to constant weight at 70°C (approximately 7 days). Log seed and rachis subsample weights (dry) separately.

Seed

Calculate & record seed weight (dry) **[5]**.

$$\text{seed wt. dry } (g/m^2) = \frac{\text{panicle wt. (undried)} \times \dfrac{\text{seed subsample wt. (dry)}}{\text{panicle subsample wt. (undried)}}}{\text{harvest area}}$$

Rachis

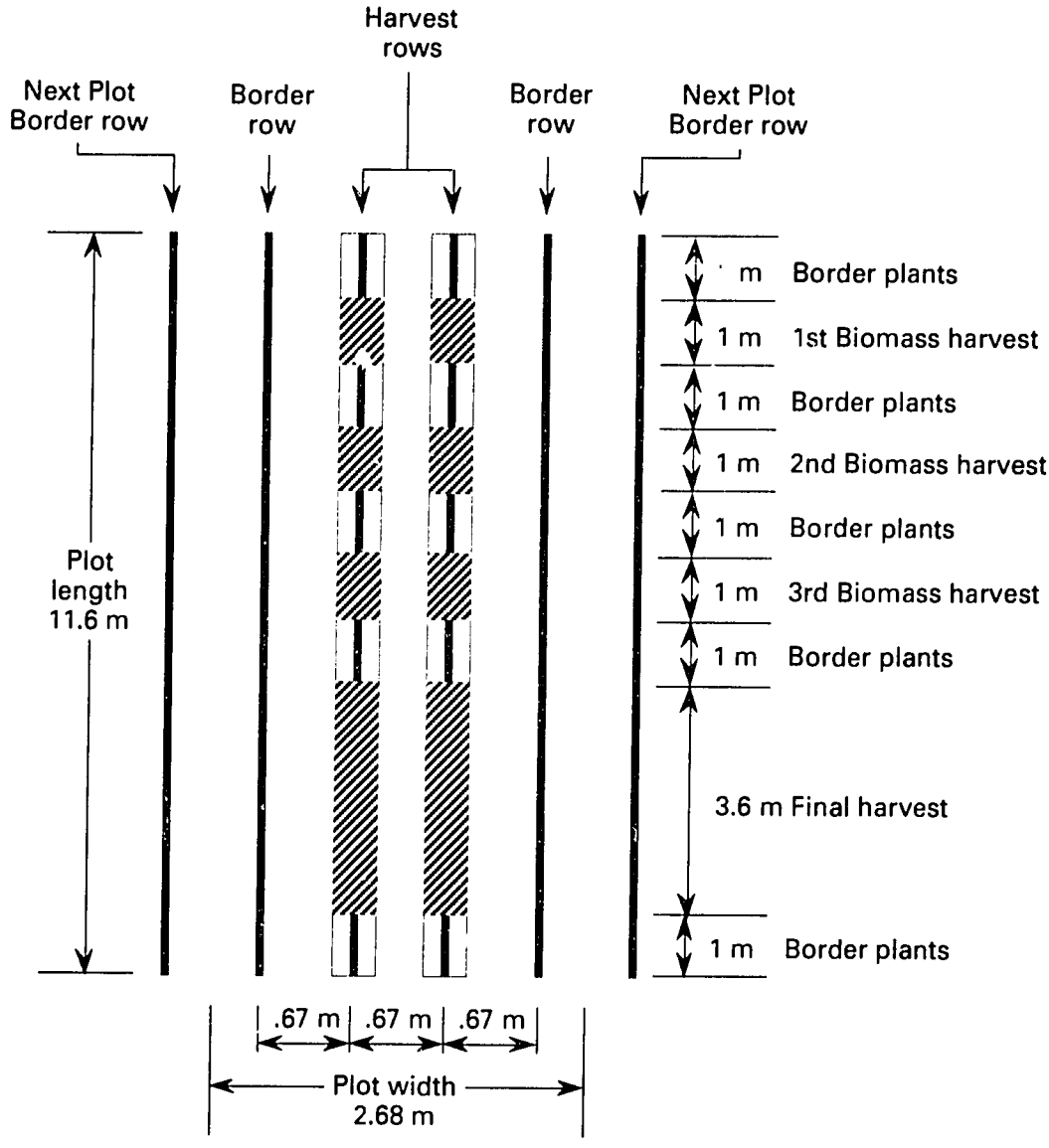
Calculate and record rachis weight (dry) **[11]**.

$$\text{rachis wt. dry } (g/m^2) = \frac{\text{panicle wt. (undried)} \times \dfrac{\text{rachis subsample wt. (dry)}}{\text{panicle subsample wt. (undried)}}}{\text{harvest area}}$$

Calculate and record aboveground biomass (dry) **[3]**.

$$\text{above ground biomass dry } (g/m^2) = \text{seed wt. (dry)} + \text{rachis wt. (dry)} + \text{leaf blade wt. (dry)} + \text{leaf sheath wt. (dry)} + \text{stem wt. (dry)}$$

Plot diagram of harvest area for SORGHUM



Final Harvest Procedure for RICE/ WHEAT

Bracketed numbers in bold are Technical Report 1 Harvest Codes.

Identify plants and area to be harvested. Cut plants in harvest area to ground level and log the number of plants harvested.

↓

Calculate and record plant population of harvest area (plants/m²) **[1]**.

$$\text{plant population (plants/m}^2) = \frac{\text{no. of plants harvested}}{\text{harvest area}}$$

↓

Select a subsample of 10 representative plants and log the number of panicles. Calculate panicle number (panicle/m²) **[7]** and record.

$$\text{panicle number (panicle/m}^2) = \frac{\text{plant population x no. of panicles in subsample}}{10}$$

↓

Remove seeds from all (including sub-sample) panicle rachises.

↓

Seed

Log the seed weight (undried).

↓

Count 1000 seeds and log weight (undried). Calculate and record seed number **[6]**.

$$\text{seed no. (seed/m}^2) = \frac{\text{seed wt. (undried)} \times \frac{\text{1000 seeds}}{\text{1000 seed wt. (undried)}}}{\text{harvest area}}$$

↓

Stover

Log stover weight (undried). Select and weigh 10 representative plants for the subsample. Log stover subsample weight (undried).

↓

Separate the subsample into leaf blades, leaf sheaths, stems, and panicle rachises. Oven dry stover components to constant weight at 70°C. Weigh and record dry weight of the leaf blade, leaf sheath, stem, and panicle rachis subsample weights (dry).

↓

Seed

Select a subsample of seed, approximately 1/8 of seed weight (undried), log seed subsample weight (undried). Oven dry to constant weight at 70°C (approximately 7 days). Log seed subsample weight (dry).

Calculate and log seed weight (dry) **[5]**.

$$\text{seed wt. dry (g/m}^2\text{)} = \frac{\text{seed wt. (undried)} \times \frac{\text{seed subsample wt. (dry)}}{\text{seed subsample wt. (undried)}}}{\text{harvest area}}$$

Stover

Calculate and record leaf blade (dry) **[8]**, leaf sheath (dry) **[9]**, stem (dry) **[10]**, and panicle rachis (dry) **[11]** weights.

$$\text{leaf blade wt. dry (g/m}^2\text{)} = \frac{\text{stover wt. (undried)} \times \frac{\text{leaf blade subsample wt. (dry)}}{\text{stover subsample wt. (undried)}}}{\text{harvest area}}$$

$$\text{leaf sheath wt. dry (g/m}^2\text{)} = \frac{\text{stover wt. (undried)} \times \frac{\text{leaf sheath subsample wt. (dry)}}{\text{stover subsample wt. (undried)}}}{\text{harvest area}}$$

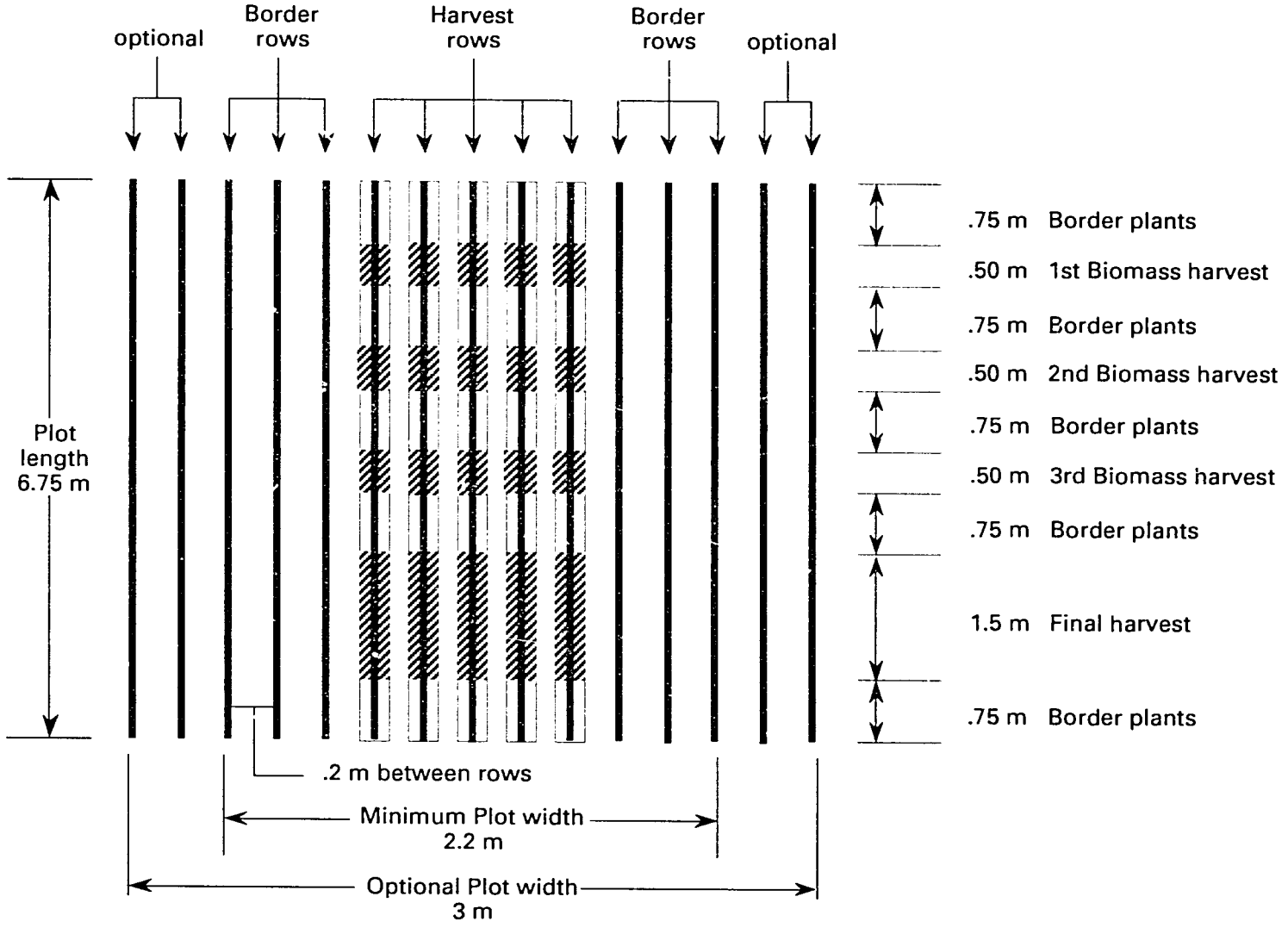
$$\text{stem wt. dry (g/m}^2\text{)} = \frac{\text{stover wt. (undried)} \times \frac{\text{stem subsample wt. (dry)}}{\text{stover subsample wt. (undried)}}}{\text{harvest area}}$$

$$\text{panicle rachis wt. dry (g/m}^2\text{)} = \frac{\text{stover wt. (undried)} \times \frac{\text{panicle rachis subsample wt. (dry)}}{\text{stover subsample wt. (undried)}}}{\text{harvest area}}$$

Calculate and record aboveground biomass (dry) **[3]**.

$$\text{above ground biomass dry (g/m}^2\text{)} = \text{leaf blade wt. (dry)} + \text{leaf sheath wt. (dry)} + \text{stem wt. (dry)} + \text{panicle rachis wt. (dry)} + \text{seed wt. (dry)}$$

Plot diagram* of harvest area for RICE and WHEAT



Optional border rows can be utilized for destructive sampling to determine panicle initiation data, grain filling rate, etc.

*This is a sample plot layout. The experimenter may change the dimensions, row spacing, etc. as appropriate to the specific experiment.

Final Harvest Procedure for CASSAVA

Bracketed numbers in bold are Technical Report 1 Harvest Codes.

Identify and determine the number of plants and area to be harvested. Harvest tubers and aboveground biomass from the designated area. Separate above ground biomass from the tubers.

Tubers

Wash soil off tubers. Count tubers. Calculate tuber number by dividing harvest area by total tuber number (tubers/m²) **[6]**.

$$\text{tuber number (tubers/m}^2) = \frac{\text{no. of tubers harvested}}{\text{harvest area}}$$

Separate "usable" tubers (undried, weighing over 200 g) from smaller ones.

Usable Tubers

Count number of usable tubers, divide by harvest area and record usable tuber number (tubers/m²) **[9]**.

Log usable tuber weight (undried).

Chop tubers into 2 cm pieces and mix well.

Select a usable tuber subsample (undried) of approximately 2 kilos and log weight.

Over dry the subsample at 70°C to constant weight. Record usable tuber subsample weight (dry).

Small Tubers

Log small tuber weight (undried). Chop tubers into small pieces and mix well.

Select a small tuber subsample (undried) of approximately 2 kilos and log weight.

Oven dry the subsample at 70°C to constant weight. Record small tuber subsample (dry) weight.

Calculate and log small tuber weight (dry) per unit area.

$$\text{small tuber wt. dry (g/m}^2) = \frac{\text{small tuber wt. (undried)} \times \dfrac{\text{small tuber sub-sample wt. (dry)}}{\text{small tuber subsample (undried)}}}{\text{harvest area}}$$

Aboveground Biomass

Aboveground Biomass

Calculate plant population of harvest area (plants/m²) **[1]**.

$$\text{plant population (plants/m}^2) = \frac{\text{no. of plants harvested}}{\text{harvest area}}$$

Record aboveground biomass weight (undried). Chop biomass and mix well.

Select approximately 1/8 of the aboveground biomass as a subsample and log its weight.

Oven dry the subsample to constant weight at 70°C. Log aboveground biomass subsample subsample weight (dry).

Calculate and record aboveground biomass (dry) **[3]**.

$$\text{aboveground biomass wt. dry (g/m}^2) = \frac{\text{aboveground biomass wt. (undried)} \times \frac{\text{aboveground biomass subsample wt. (dry)}}{\text{aboveground biomass subsample wt. (undried)}}}{\text{harvest area}}$$

Small Tubers

Usable Tubers

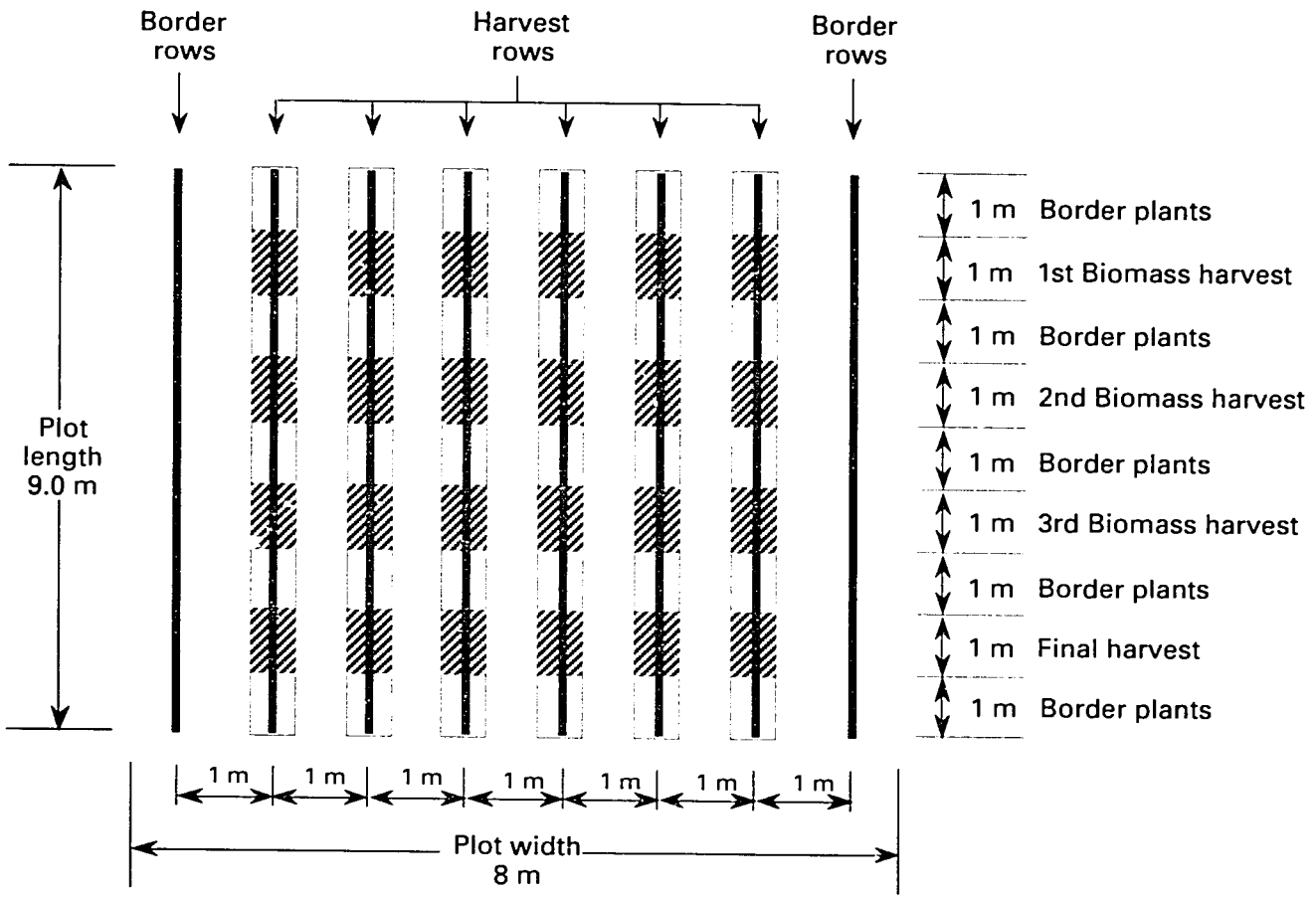
Calculate and record usable tuber weight (dry) **[8]**.

$$\text{usable tuber wt. dry (g)} = \frac{\text{usable tuber wt. (undried)} \times \frac{\text{usable tuber subsample wt. (dry)}}{\text{usable tuber subsample wt. (undried)}}}{\text{harvest area}}$$

Calculate and record total tuber weight (dry) **[5]**.

$$\text{total tuber wt. dry (g)} = \text{usable tuber wt. (dry)} + \text{small tuber wt. (dry)}$$

Plot diagram of harvest area for CASSAVA



Final Harvest Procedure for AROID

Bracketed numbers in bold are Technical Report 1 Harvest Codes.

Identify plants and area to be harvested Count plants and calculate plant population of area harvested (plants/m²) **[1]**. Record plant population of harvest area.

$$\text{plant population} = \frac{\text{no. of plants harvested}}{\text{harvest area}}$$

Remove plants from harvest area. Wash soil from corms and cormels and drain until water completely evaporates from the plants.

Separate corms, cormels, petioles, and leaves.

Petioles & Leaves

Corms

Count the corms. Calculate and record corm number (corms/m²) **[6]**.

Weigh the corms and log the corm weight.

Chop the corms and mix well. Select a corm subsample (undried) of approximately 2000 g and log its weight.

Oven dry the corm subsample to constant weight at 70°C. Log the corm subsample weight (dry).

Calculate and record corm weight (dry) **[5]**.

$$\text{corm wt. dry (g/m}^2\text{)} = \frac{\text{corm wt. (undried)} \times \dfrac{\text{corm subsample wt. (dry)}}{\text{corm subsample wt. (undried)}}}{\text{harvest area}}$$

Cormels

Count the cormels. Calculate and record cormel number (cormels/m²) **[9]**.

Weigh the cormels and log cormel weight (undried).

Chop the cormels and mix well. Select a cormel subsample (undried) of approximately 2000 g and log its weight.

Oven dry the cormel subsample to constant weight at 70°C. Log the cormel subsample weight (dry).

Calculate and record cormel weight (dry) **[8]**.

$$\text{cormel wt. dry (g/m}^2\text{)} = \frac{\text{cormel wt. (undried)} \times \dfrac{\text{cormel sub-sample wt. (dry)}}{\text{cormel subsample wt. (undried)}}}{\text{harvest area}}$$

Petioles

Weigh petioles and log petiole weight (undried).

Chop the petioles and mix well.

Select a subsample 1/8 of the petiole weight (undried). Log petiole subsample weight (undried).

Oven dry the petiole subsample to constant weight at 70°C. Log the corm subsample weight (dry).

Calculate and record petiole weight (dry) **[11]**.

$$\text{petiole wt. dry } (g/m^2) = \frac{\text{petiole wt. (undried)} \times \dfrac{\text{petiole subsample wt. (dry)}}{\text{petiole subsample wt. (undried)}}}{\text{harvest area}}$$

Leaves

Weigh leaves and log leaf weight (undried).

Chop the leaves and mix well.

Select a subsample 1/8 of the leaf weight (undried). Log leaf subsample weight (undried).

Oven dry the leaf subsample to constant weight at 70°C. Log the leaf subsample weight (dry).

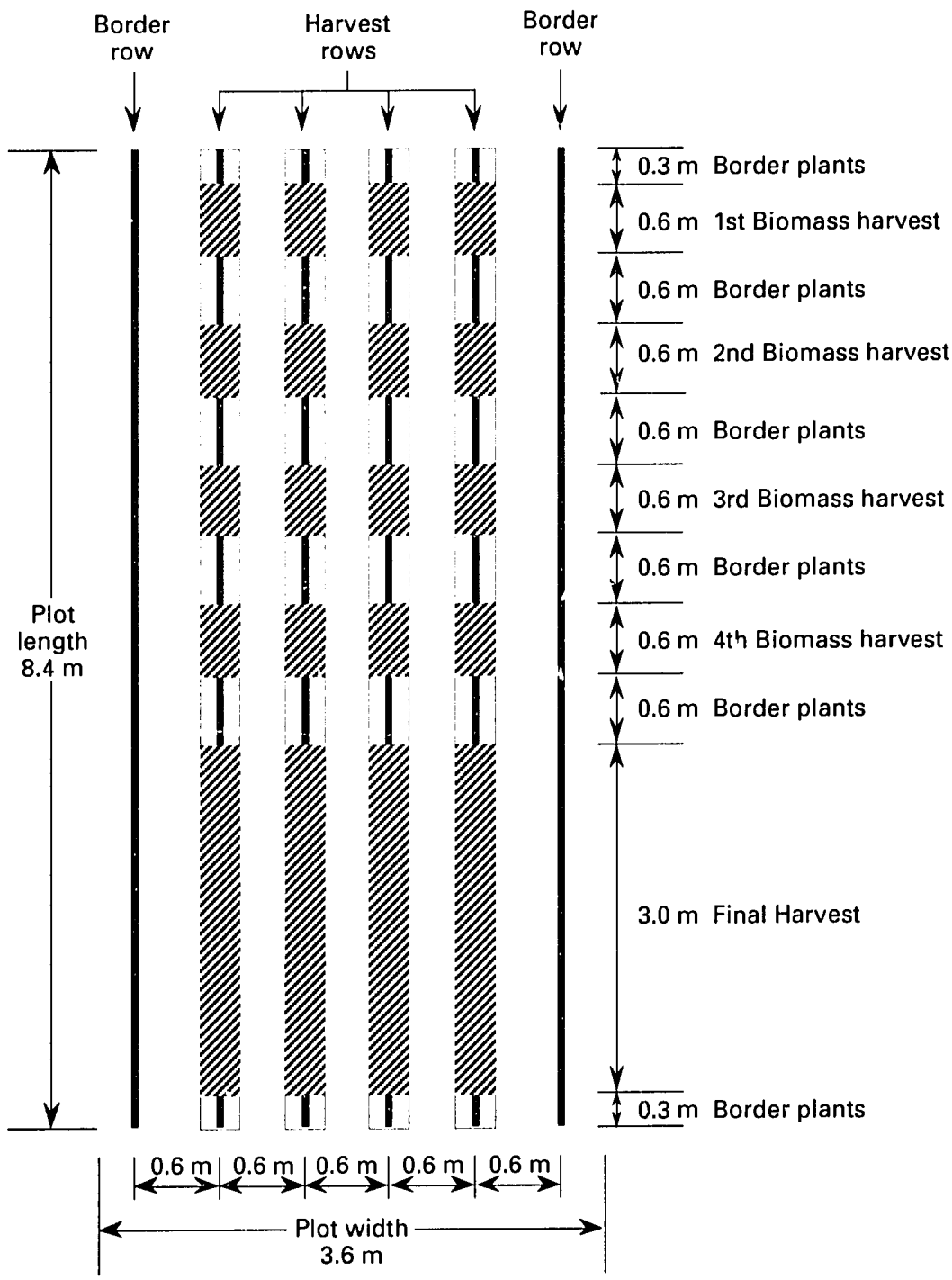
Calculate and record leaf weight (dry) **[10]**.

$$\text{leaf wt. dry } (g/m^2) = \frac{\text{leaf wt. (undried)} \times \dfrac{\text{leaf subsample wt. (dry)}}{\text{leaf subsample wt. (undried)}}}{\text{harvest area}}$$

Calculate and record aboveground biomass (dry) **[3]**.

$$\text{aboveground biomass wt. dry } (g/m^2) = \text{petiole wt. (undried)} + \text{leaf wt. (undried)}$$

Plot diagram of harvest area for AROID



Final Harvest Procedure for POTATO

Bracketed numbers in bold are Technical Report 1 Harvest Codes.

Identify plants and area to be harvested. Cut plants in harvest area at ground level. Log the total number of plants harvested and how many of those were main stems. Calculate the plant population **[1]** and the number of main stems in the harvest area **[3]**.

↓

Collect all tubers >5 mm in diameter and discard balance of underground plant parts. Separate tubers into two size categories, those 5-30 mm in diameter and those >30 mm. Count and weigh both categories and log data.

5-30 mm ↓ ↓ >30 mm

Calculate tuber number for both size categories **[12, 15]** by dividing numbers of tubers in each category by the harvest area. Calculate tuber weight (undried) for both categories **[10, 13]** by dividing tuber weight in each category by the harvest area.

↓ ↓

Determine dry tuber weight of each category. Either oven dry a 2 kg representative sample of fresh tubers to constant weight at 70°C <u>or</u> determine the specific gravity of about 4 kg of fresh tubers.

↓ ↓

Determine specific gravity of tubers. To do this, take 4 kilograms of tubers. Clean and air dry them. Weigh the tubers. Hang basket to hold the tubers in water. Tare the basket. Put the potatos in the basket and weigh underwater. The formula for specific gravity is:

$$\text{specific gravity} = \frac{\text{air dry wt.}}{\text{air dry wt.} - \text{underwater wt.}}$$

(NOTE: Specific gravity is usually 1.09)

↓ ↓

5-30 mm | >30 mm

Calculate tuber weight (dry) for the two categories **[11, 14]** using the appropriate formula shown below.

$$\text{tuber wt dry (g/m}^2\text{)} = \frac{\text{tuber wt (undried)} \times \text{tuber subsample wt (dry)}}{\text{harvest area} \times \text{tuber subsample wt (undried)}}$$

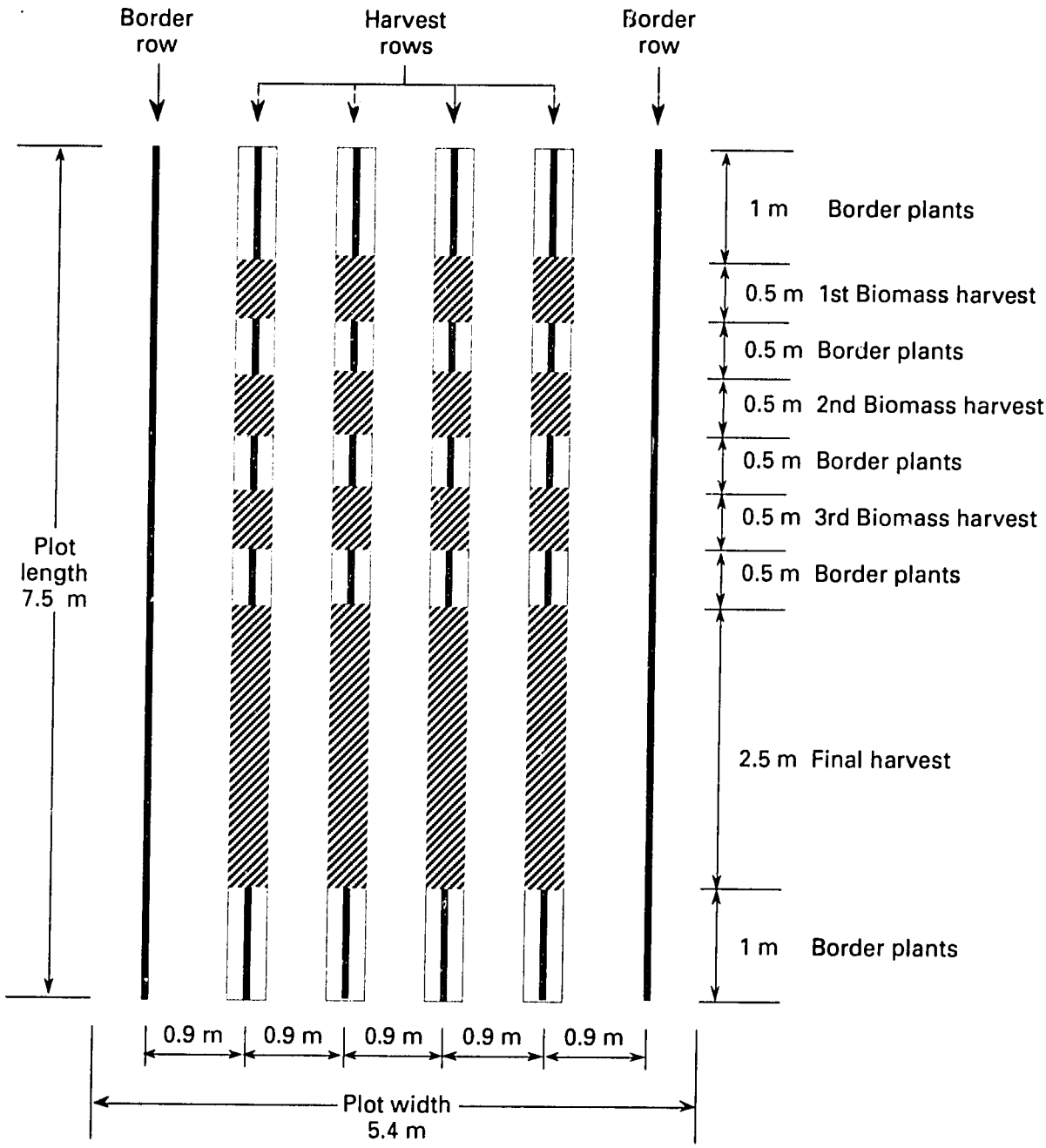
$$\text{tuber dry wt.} = \frac{\frac{\text{\% solids}}{100} \times \text{tuber wt. (undried)}}{\text{harvest area}}$$

$$\text{\% solids} = 214.9206 + 218.1852 \times \text{specific gravity}$$

Calculate and record the tuber dry matter content **[16]**.

$$\text{tuber dry matter content (\%)} = \frac{\text{tuber wt. dry} \times 100}{\text{tuber wt. undried}}$$

Plot diagram of harvest area for POTATO



Alternatively, plot length can be shortened and plot dimensions made more square by using 6 or 8 row plots. Biomass sampling would then be carried in two outer rows (i.e., rows 2 and 7) and final harvesting in the center rows (i.e., rows 4 and 5).

Final Harvest Procedure for SOYBEAN and DRY BEAN

Bracketed numbers in bold are Technical Report 1 Harvest Codes.

Mark and measure the length of the rows. Mark plots clearly for final harvest. Identify plants and area to be harvested. Harvest plants by cutting exactly at ground level. Count the plants as you harvest them.

↓

Calculate plant population of harvest area. (plants/m^2)

$$\text{plant poplulation} = \frac{\text{no. of plants}}{\text{harvest area}}$$

↓

Remove pods from stem.

↓

Stems

Log stem weight (undried).

↓

Chop stems and mix well. Select a subsample about 1/8 of total mass. Log the weight of stem subsample (undried).

↓

Dry stem subsample to constant weight at 70° C. Log stem subsample weight (dry).

Pods

Log pod weight (undried).

↓

Select 300 pods as a subsample and log the pod subsample weight (undried).

↓

Dry seeds and shells to constant weight at 70° C. Separate seeds from shells of subsample. Log seed and shell subsample weight (dry) separately.

↓

Count 300 seeds from the seed subsample (dry) and log the 300 seed weight.

Formulas for soybean and dry bean calculations:

$$\text{stem weight (dry) (g/m}^2\text{) [10]} = \frac{\text{stem weight (undried)} \times \frac{\text{stem subsample weight (dry)}}{\text{stem subsample weight (undried)}}}{\text{harvest area}}$$

$$\text{pod weight (dry) (g/m}^2\text{)} = \frac{\text{pod weight (undried)} \times \frac{\text{seed subsample weight (dry)} + \text{shell subsample weight (dry)}}{\text{pod subsample weight (undried)}}}{\text{harvest area}}$$

$$\text{shelling percentage} = \frac{\text{seed subsample weight (dry)}}{\text{seed subsample weight (dry)} + \text{shell subsample weight (dry)}} \times 100$$

$$\text{seedweight (dry) (g/m}^2\text{) [5]} = \text{pod weight (dry)} \times \frac{\text{shelling percentage}}{100}$$

$$\text{empty shell weight (dry) (g/m}^2\text{) [11]} = \text{pod weight (dry)} \times \frac{\text{shell subsample weight (dry)}}{\text{seed subsample weight (dry)} + \text{shell subsample weight (dry)}}$$

$$\text{seed number (seed/m}^2\text{) [6]} = \text{seed weight (dry)} \times \frac{300 \text{ seed}}{300 \text{ seed weight (dry)}}$$

$$\text{pod number (pod/m}^2\text{) [7]} = \text{pod weight (dry)} \times \frac{300 \text{ pods}}{\text{seed subsample weight (dry)} + \text{pod subsample weight (dry)}}$$

$$\text{seeds per pod} = \frac{\text{seed number}}{\text{pod number}}$$

$$\text{seed size} = \frac{300 \text{ seed weight (dry)}}{300 \text{ seeds}}$$

$$\text{aboveground biomass (dry) [3]} = \text{stem weight (dry)} + \text{pod weight (dry)}$$

$$\text{harvest index} = \frac{\text{seed weight (dry)}}{\text{aboveground biomass (dry)}}$$

Final Harvest Procedure for PEANUT

Bracketed numbers in bold are Technical Report 1 Harvest Codes.

Mark and measure the final harvest rows. Havest plants within the rows and count them as they are collected. Log the number of plants harvested and the harvest area.

↓

Separate the aboveground parts and pods from the roots.

Aboveground Parts

Log the aboveground parts weight (undried).

↓

Chop the aboveground parts and mix well. Select subsample about 1/8 of the total mass. Log the weight of aboveground subsample (undried).

↓

Dry aboveground subsample at 70° C to constant weight. Log aboveground subsample weight (dry).

Pods

Wash pods and air dry until water completely evaporates from the pod's surface.

↓

Log pod weight (undried).

↓

Select 300 pods as a subsample and log the pod subsample weight (undried).

↓

Dry seeds and shells at 70° C to constant weight. Separate seeds from shells. Log seed and shell subsample weight (dry) separately.

↓

Count 300 seeds from the seed subsample (dry) and log the 300 seed weight.

Formulas for peanut calculations:

$$\text{aboveground biomass (dry) (g/m}^2\text{) [3]} = \frac{\text{aboveground part weight (undried)} \times \frac{\text{aboveground subsample (dry)}}{\text{abovegound subsample (undried)}}}{\text{harvest area}} + \text{pod weight}$$

$$\text{pod weight (dry) (g/m}^2\text{)} = \frac{\text{pod weight (undried)} \times \frac{\text{seed subsample weight (dry)} + \text{shell subsample weight (dry)}}{\text{pod subsample weight (undried)}}}{\text{harvest area}}$$

$$\text{shelling percentage} = \frac{\text{seed subsample weight (dry)}}{\text{seed subsample weight (dry)} + \text{shell subsample weight (dry)}} \times 100$$

$$\text{seedweight (dry) (g/m}^2\text{) [5]} = \text{pod weight (dry)} \times \frac{\text{shelling percentage}}{100}$$

$$\text{empty shell weight (dry) (g/m}^2\text{) [11]} = \text{pod weight (dry)} \times \frac{\text{shell subsample weight (dry)}}{\text{seed subsample weight (dry)} + \text{shell subsample weight (dry)}}$$

$$\text{seed number [6]} = \text{seed weight (dry)} \times \frac{\text{300 seed}}{\text{300 seed weight (dry)}}$$

$$\text{pod number [7]} = \text{pod weight (dry)} \times \frac{\text{300 pods}}{\text{seed subsample weight (dry)} + \text{shell subsample weight (dry)}}$$

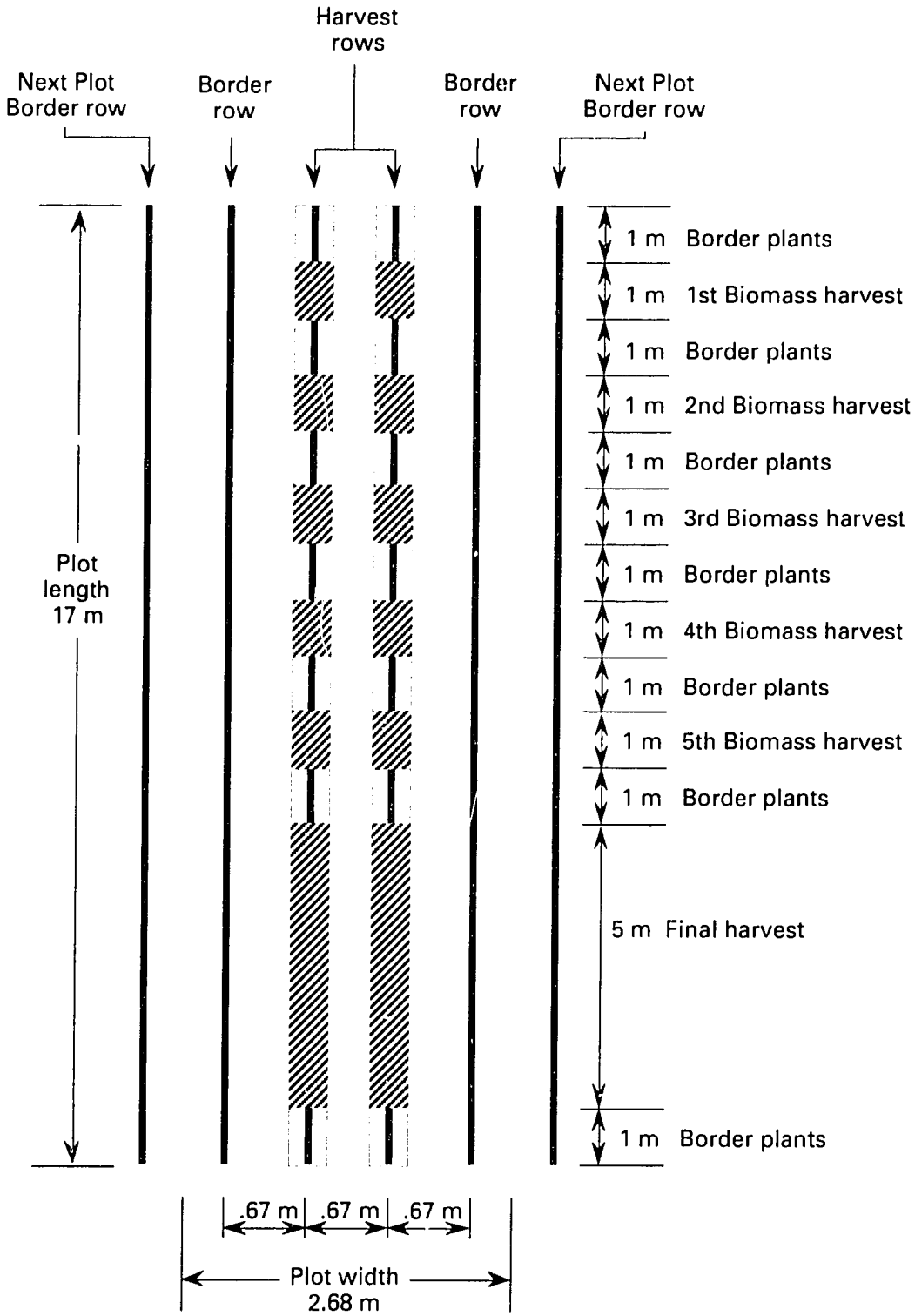
$$\text{seeds per pod} = \frac{\text{seed number}}{\text{pod number}}$$

$$\text{seed size} = \frac{\text{300 seed weight (dry)}}{\text{300 seeds}}$$

$$\text{pod harvest index} = \frac{\text{pod weight (dry)}}{\text{aboveground biomass (dry)}}$$

NOTE: For peanut, "aboveground biomass" refers to everything except the roots. This term does refer to the peanut pods even though those are not literally above the ground.

Plot diagram of harvest area for SOYBEAN, PEANUT, and DRY BEAN



CHAPTER 3

LABORATORY METHODS

5) **FORMS I-1 & I-2—Soil Fertility Measurements**
   Preplant soil sampling
   Post-harvest soil sampling
   Soil moisture factor determination
   Soil pH determination
      1:1 soil to H_2O & 1:1 soil to 1N Potassium Chloride (KCl)
   KCl-extractable Nitrate and Ammonium Nitrogen
   Extractable Potassium analysis
   Phosphorus Determination
      P extraction: modified Truog
      P determination: Murphy and Riley
   KCl-extractable Acidity & Aluminum

6) **FORM S—Plant Nutrient Concentrations**
   Tissue sampling and preparation
   Nutrient analysis of plant samples
   Total Nitrogen (Micro-Kjeldahl)
   P and K determination
      Phosphorus determination
      Potassium determination

FORMS I-1 and I-2: Soil Fertility Measurements

Preplant Soil Sampling

1. For each experimental plot, a representative number of samples from the surface layer (0–15 cm) and at least one set of subsurface samples from each layer should be taken. These samples should be taken from a cross-section of the experimental plot at least two weeks before planting. For example, for a 4 m x 8 m plot, eight surface samples should be collected, mixed thoroughly, and a representative subsample should be retained for analysis. Use an auger to collect the subsurface samples at depths of 15–30, 30–50, 50–75, and 75–100 cm.

2. Samples from each layer should be mixed thoroughly and subsampled (200 g) for soil chemical analysis.

3. Samples from soils classified as Andepts should not be air dried. Dehydration results in irreversible changes in soil chemical and physical properties.

4. Field moist soil samples for NO_3-N and NH_4-N determinations should be stored in a cooler and refrigerated. Samples should be analyzed within a week.

Post-harvest Soil Sampling

For experiments where soil fertility or applied fertilizer are variables, post-harvest surface soil samples are required to obtain residual fertilizer levels. These soil samples need to be collected from the experimental plot by the following procedure.

1. Collect the samples within a two week period after the final harvest.

2. For experiments with four rows (two harvest and two border rows), collect the samples within the plot harvest area, four subsamples between rows and another four subsamples within the row. These subsamples should be evenly distributed within the final harvest area for each plot.

3. For each plot, mix all eight subsamples and retain about 500 g as the final sample for that plot.

4. Place the samples in a plastic bag, seal, label the bag according to date, plot and replicate number, and place in a second plastic bag.

5. Samples from soils classified as Andepts should not be dried.

6. Soil samples for NO_3-N and NH_4-N determination should be refrigerated after collection and analyzed as soon as possible.

7. Samples should then be air-dried and passed through a 2 mm sieve.

Soils Moisture Factor Determination Procedure

All soil data are reported on oven-dry basis; consequently, the moisture factor should be determined.

PROCEDURE:

1. Weigh 10 g soil into a weighed Aluminum dish.

2. Place in an oven at 105°C for 24 hours.

3. Weigh dried sample and Aluminum dish.
   CALCULATION:
   Sample + Al dish - Al dish = weight of dry sample.

$$\text{Moisture Factor} = \frac{\text{moist sample weight}}{\text{dry sample weight}}$$

Repeat the above for air-dried soil samples as well.

Soil pH Determination

1:1 Soil to H_2O and 1:1 Soil to 1N Potassium Chloride (KCl) Slurry

APPARATUS:
pH meter; 50-ml beakers.

PROCEDURE:

1. Weigh 20 g of air-dried composite soil sample into each of two 50-ml beakers.

2. Add 20 ml distilled water to one beaker, stir vigorously, let stand one hour, then read pH with a pH meter. Record this as pH in a 1:1 soil:water.

3. Add 20 ml 1N KCl to the remaining beaker, stir vigorously, let stand one hour, then read pH with a pH meter. Record this as pH in 1:1 soil:1N KCl.

KCl-extractable Nitrate and Ammonium Nitrogen

APPARATUS:
Kemmerer Hallet nitrogen distillation unit; 100-ml sample flask with side arm; 50-ml Erlenmeyer flasks; 50-ml plastic tube; Whatman No. 5 filter paper.

REAGENTS:

1. Potassium Chloride (KCl), 2N.
2. Magnesium Oxide (MgO-Heavy)—ignited at 650°C for one hour.
3. Devarda alloy—ground to a fine powder.
4. Mineral oil.
5. 2% boric acid (H_2BO_3).
6. Sulfamic acid (NH_2SO_3H)—dissolve 2 g in 100 ml water. Store the solution in a refrigerator or at 7°C.
7. Mixed indicator—3 ml of 0.1% methyl red and 15 ml of 0.1% brom cresol green diluted to 1 liter with ethanol.
8. Standard sulfuric acid (H_2SO_4), 0.005N.

PREPARATION:

1. Weigh 3 g of soil sample into 50-ml plastic tube.
2. Add 30 ml of 2N KCl.
3. Cap and shake for one hour.
4. Filter with Whatman No. 5 filter paper.
5. Pipette 25 ml aliquot into sample flask.

DETERMINATION OF NITROGEN:

1. Add 1 ml NH_2SO_3H into the aliquot and swirl a few seconds to destroy nitrite in extract.
2. Add 1 ml mineral oil to sample to prevent foaming during distillation.
3. Add 0. 2 g of MgO to sample.
4. Place 50-ml Erlenmeyer flask, which contains 5 ml of 2% H_2BO_3 and 3 drops of mixed indicator, at the end of distillation unit.
5. Cap sample flask with side arm with ground glass cover.
6. Attach sample flask to distillation unit.
7. Distill 30 ml into boric acid solution. Set aside for NH_4-N determination. Titrate NH_4-N with standardized 0.005N H_2SO_4.
8. Stop distillation by removing side arm clamp of unit (do not turn off heating unit).
9. Remove ground glass cover of sample flask.
10. Add 0.2 g Devarda alloy.
11. Immediately replace ground glass cover and distill 30 ml into 50 ml flask containing 2% boric acid with 3 drops of mixed indicator. Set aside for NO_3-N determination. Titrate with 0.005N H_2SO_4.
12. Correct for blank.

CALCULATIONS:

mgN = 1 ml of 0.005N H_2SO_4 x 70

REFERENCE

Page, A.L., R.H. Miller, and D.R. Keeney. 1982. Nitrogen-inorganic forms. p. 643-698. *In* Methods of soil analysis. No. 9, part 2. American Society of Agronomy Inc., and Soil Science Society of America Inc., Madison, Wisconsin.

Extractable Potassium Analysis

The following procedure applies not only for the determination of ammonium acetate extractable K but also for ammonium acetate extractable Ca, Mg, and Na.

APPARATUS:

Atomic Absorption 7 or flame photometer; Buchner funnel (Coors No.1); 250-ml suction flask; 100-ml volumetric flask; 125-ml Erlenmeyer flask; 500-ml volumetric flask; Whatman No. 42 filter paper.

REAGENTS:

1. Ammonium acetate (CH_3COONH_4), 1N, pH 7.0.
   - Mix 68 ml ammonium hydroxide (NH_4OH), specific gravity 0.90, and 57 ml 99.5% acetic acid (CH_3COOH) per liter of solution desired.
   - Cool, dilute to volume with water, and adjust to pH 7.0 with CH_3COOH or NH_4OH.
   - Optionally, prepare from CCH_3COONH_4 reagent salt and adjust pH.

2. Standards
   - Stock standard = 100 ppm
   - Working standard = 10, 20, 30 ppm.

PROCEDURE:

1. Weigh 10 g air-dried <2-mm soil into a 125-ml Erlenmeyer flask and add 15 ml CH_3COONH_4 solution.

2. Cover with stopper, shake the flask for several minutes, and allow to stand 18 hours or more.

3. Transfer contents of the flask to a Buchner funnel attached to suction flask (Coors No.1) fitted with moist Whatman No. 42 filter paper.

4. Filter, using suction.

5. Leach with additional 75 ml CH_3COONH_4, adding small amounts. Minimize leaching time to less than one hour.

6. Transfer leachate to a 100-ml volumetric flask and dilute volume with distilled water.

7. Retain CH_3COONH_4 extract for analysis of exchangeable cations—Ca, Mg, Na, K.

DETERMINATION OF K:

- Flame Photometer
- Atomic Absorption

8. Compare absorption of samples at 766.5 nm on flame photometer, or atomic absorption at 383 (visual), with that of the standard solution to determine the amount of exchangable K.

ADAPTED FROM:

SCS, USDA. 1972. Soil survey laboratory methods and procedures for collecting soil samples. *In* Soil Survey Investigation Report No. 1. U.S. Gov. Print. Office, Washington, D.C.

Phosphorus Determination

P Extraction: Modified Truog

APPARATUS:

Spectrophotometer; 4-liter volumetric flask; 2-liter volumetric flask; 1-liter volumetric flask; 200-ml volumetric flask; 25-ml volumetric flask; dark pyrex bottle; 125-ml plastic bottle; 50-n graduated test tubes; Whatman No. 42 filter paper.

REAGENTS:

1. Extracting solution, 0.02N sulfuric acid (H_2SO_4) and 0.03% ammonium sulfate ($NH_4)_2SO_4$. Mix 2.22 ml concentrated H_2SO_4 and 12 g ($NH_4)_2SO_4$.
   Dilute to 4 liters.
2. Ascorbic acid reagent (see followir g page, Murphy and Riley, Reagent B, for method of preparation).
3. Standard should be made with Extraction solution.

PROCEDURE:

1. Weigh 1 g soil sample (oven-dried) into 125-ml plastic bottle.
2. Add 100 ml of extracting solution.
3. Shake for 1/2 hour.
4. Filter with Whatman's No. 42 filter paper.
5. Save leachate for P determination. Prepare a blank with extracting solution.

P DETERMINATION:

Proceed as in Murphy and Riley (see below for procedure).

REFERENCE:

Ayres, A.S. and Hagihara, H.H. 1952. Available phosphorus in Hawaiian soil profiles. Hawaiian Planters' Record 54:81-99.

P Determination: Murphy and Riley

REAGENTS:

1. Standard P solution: 5 to 10 ppm solution in extracting solution.
2. Reagent A:
   - Dissolve 12 g of ammonium molybdate [$(HN_4)_6Mo_7O_{21} : 4H_2O$] in 250 ml of distilled water.
   - In 100 ml distilled water dissolve 0.2908 g of antimony potassium tartrate.
   - Pour both of the dissolved reagents into a 2000-liter volumetric flask, then add 1000 ml of 5N sulfuric acid (H_2SO_4), mix thoroughly, and fill to volume. Store in a dark pyrex bottle in a cool and dark compartment.
3. Reagent B:
   - Dissolve 1.056 g ascorbic acid in 200 ml of Reagent A and mix.
     NOTE: Reagent B should be prepared daily.

PROCEDURE:

1. Pipette suitable aliquot into 25-ml or 50-ml volumetric flask.
2. Dilute to 20 ml with H_2O.

3. Add 4 ml of Reagent B to develop color.

4. Fill to volume and mix thoroughly.

5. After 20 minutes read optical density. Use any suitable spectrophotometer and read at 850-nm wavelength.

PREPARATION OF STANDARD CURVE:

1. Pipette aliquots of P solution containing from 5–40 µg of P into 50-ml graduated tubes.
2. Add 4 ml of Reagent B, dilute to 50 ml, and read absorbance as stated above.

CALCULATIONS:

$$\text{ppmP} = \frac{\text{micrograms of standard}}{\text{absorbance of standard}} \times \frac{\text{total volume of extractant}}{\text{weight of sample} \times \text{Aliquot of extract}} \times \text{moisture factor}$$

REFERENCE:

Murphy, J. and J.P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta 27: 31–36.

KCl-extractable Acidity and Aluminum

For soils with pH <5.5, aluminum saturation is reported on Form I as a percent of effective cation exchange capacity.

APPARATUS:

7-1/2 cm. Buchner funnels; 250-ml suction flask; 125-ml Erlenmeyer flasks; Whatman No. 42 filter paper.

REAGENT:

1. Potassium chloride (KCl), 1N
   - Standard Sodium hydroxide (NaOH): 0.05 N NaOH
   - Standard Sulfuric acid (H_2SO_4) 0.05N
2. Potassium fluoride (KF), 1N

PROCEDURE:

1. Weigh 10 g soil samples into 125-ml Erlenmeyer flasks.

2. Add 50 ml 1N KCl to each flask, mix several times, and let stand for 30 minutes.

3. Filter through moistened Whatman No. 42 filter paper in Buchner funnel, with suction flask.

4. Leach each sample as rapidly as possible with about five 9 ml portions of KCl, using the first to help transfer the remaining soil in the Erlenmeyer flasks to the Buchner funnels.

5. Add 3 drops phenolphthalein to the leachate in the suction flask.

6. Titrate with standard NaOH to a pink color that persists for 30 seconds or more.

7. Correct for a KCl blank to obtain KCl-extractable acidity.

8. To obtain KCl extractable aluminum, add 10 ml KF to filtrate and titrate with standard H_2SO_4 until the pink color disappears.

9. Set aside while other samples are titrated and then complete to a lasting colorless end point.

10. Correct for blank.

CALCULATIONS:

$$\text{Acidity (meq/100g)} = \frac{\text{ml NaOH}}{\text{g sample}} \times \text{N of NaOH} \times 100 \times \text{moisture factor}$$

$$\text{Al (meq/100g)} = \frac{\text{ml } H_2SO_2}{\text{g sample}} \times \text{N of } H_2SO_4 \times 100 \times \text{moisture factor}$$

ADAPTED FROM:

SCS, USDA. 1984. Soil survey laboratory methods and procedures for collecting soil samples. *In* Soil Survey Investigation Report No. 1. U.S. Govt. Printing Office, Washington, D.C.

FORM S: Plant Nutrient Concentrations

Tissue Sampling and Preparation

PROCEDURE:

1. Finely chop (1-2 cm) approximately 1 to 10 kg of aboveground biomass except seeds.
2. Mix chopped plant material thoroughly (approximately 400 g is required for plant analysis).
3. Oven dry plant material at 70°C for 24 hours or more. A constant weight must be attained.
4. Set aside 50 to 100 g for nutrient analysis.
5. Grind plant samples separately in a stainless steel mill, if possible.
6. Store samples in screw-cap botties and analyze within two months.
7. Procedure for determination of Moisture Factor.
   - Weigh 5 gm of plant tissue into a weighed, Al dish.
   - Place in oven 105°C for 5 hours.
   - Weigh the oven dry sample and the Al dish.

CALCULATION:

Sample + Al dish − Al Dish = weight of dry sample

$$\text{Moisture Factor} = \frac{\text{moist sample wt.}}{\text{dry sample wt.}}$$

Procedures for Nutrient Analysis of Plant Samples

The following procedures are recommended to obtain the plant nutrient concentrations. If other methods are used, please send a copy with your data set.

Total Nitrogen (Micro-Kjeldahl)

APPARATUS:

100-ml Kjeldahl flask; distillation flask; 40-mesh screen.

REAGENTS:

1. Concentrated sulfuric acid (H_2SO_4) 36N.
2. Potassium sulfate mixture: 10 parts powdered potassium sulfate (K_2SO_4) + 1 part fine crystal ferrous sulfate (Fe_2SO_4) + 1/2 part cupric sulfate ($CuSO_4 \cdot 5H_2O$).
3. Sodium hydroxide (NaOH) 50%: 500 g of NaOH/1 liter of distilled water.
4. Boric acid (H_2BO_3), 2% aqueous solution: 20 g/liter of distilled water.
5. Standard sulfuric acid (H_2SO_4), 0.05N: 1.39 ml/liter of distilled water.
6. Brom cresol green-methyl red indicator: Dissolve 0.20 g each of brom cresol green and methyl red indicators in 95% ethyl alcohol and dilute to 200 ml with ethyl alcohol.

PROCEDURE:

1. Weigh 0.2 g ground aboveground biomass except for seeds (or 0.2 g of seed).
2. Transfer the tissue sample into an 100-ml Kjeldahl flask.

3. Add 5 g potassium sulfate mixture, 2 ml distilled H_2O and 3 ml concentrated sulfuric acid (H_2SO_4). Swirl until the plant material is fully in contact with the reagent. Let stand 18 hours.

4. Heat gently for 5 minutes, watch the mixture carefully to avoid frothing, and then digest at full heat.

5. Continue digestion for one hour after the solution has cleared.

6. Cool and transfer solution into distillation flask with about 40 ml of distilled water.

7. Add 10 ml sodium hydroxide (NaOH), then distill off 30 ml into 5 ml of 2% boric acid (H_2BO_3) with 3 drops of mixed indicator.

8. Titrate with standard 0.05N sulfuric acid (H_2SO_4) until the first faint pink appears.

9. Run a blank and titrate to the same end point.

CALCULATION:

$$N\ (pct.) = \frac{\text{ml } H_2SO_4 \text{ sample} - \text{ml } H_2SO_4 \text{ of blank}}{\text{g sample}} \times \text{normality of Acid} \times 1.4 \times \text{moisture factor}$$

REFERENCE:

Page, A.L., R.H. Miller, and D.R. Keeney. 1982. Regular Kjeldahl method. p. 612-616. *In* Methods of soil analysis. Part 2, number 9. American Society of Agronomy Inc. and Soil Science Society of America Inc. Madison, Wisconsin.

P and K Determination

APPARATUS:

Spectrophotometer; atomic absorption or flame photometer; 100-ml Kjeldahl flask; 100 volumetric flask.

REAGENTS:

HNO_3 : $HClO_4$ as a 2:1 mixture.

conc. Nitric acid (HNO_3) : Perchloric acid ($HClO_4$) as a 2:1 mixture.

PROCEDURE:

1. Weigh 0.5 g ground aboveground biomass except for seeds and place in a 100-ml Kjeldahl flask.

2. Add 15 ml of HNO_3: $HClO_4$ solution. Let stand 18 hours.

3. Digest sample until the solution is white. Caution: do <u>not</u> evaporate until dry—$HClO_4$ fumes and organic matter can cause an explosion!

4. Cool, transfer solution to a 100-ml volumetric flask, and fill to volume.

Phosphorus Determination

Continue with P Determination Murphy and Riley: Procedure and Preparation of Standard Curve (page 44).

Potassium Determination

REAGENTS:

1. Stock standard potassium: 1.907 gm of KCl diluted to 1 liter or 1000 ppm.
2. Working potassium standard: 1–100 ppm.
3. Dilute sample to 1:10.
4. Determine potassium with flame photometer or atomic absorption.

CALCULATION:

1. Prepare standard curves for mg/ml K against % transmission or absorbance. For a 1:100 plant:solution ratio

$$\frac{\text{mg/ml in final solution x dilution factor}}{100} = \%K$$

For example: For 10 x dilution: $\frac{\text{mg/ml}}{10} = \%K$

REFERENCE:

Chu, A.E. 1990. Personal communication. Dept. of Agronomy and Soil Science, University of Hawaii.

GLOSSARY

aboveground biomass: Biomass that is above the ground, not buried. (NOTE: For peanut, aboveground biomass includes pod weight even though pods are not above the ground.)

anthesis: The action or period of opening of a flower. The start of flowering.

apical meristem: The growing point, composed of meristematic tissue, at the tip of the root or shoot in a vascular bundle.

biomass: Total dry weight of all plants in a particular area or plot.

black layer: A dark, suberized membrane that develops around the base of corn kernels at physiological maturity.

canopy: A formation of leaves and branches affording a cover of foliage.

coleoptile: The sheath enclosing the apical meristem and leaf primordia of the grass embryo; often interpreted as the first leaf.

corm: An enlarged, lower stem where photosynthate is stored; usually underground.

cormel: The corm of a sucker arising from the main corm.

dry weight: The weight of material after water is completely removed.

dough stage: A developmental stage that begins when the kernel's endosperm becomes of pasty consistency.

ear leaf: The leaf directly beneath an ear.

endosperm: A tissue containing stored food, that develops from the union of a male nucleus and the polar nuclei of the central cell; it is digested by the growing sporophyte either before or after the maturation of the seed; found only in angiosperms.

haulm (or halm): The stems or tops of cultivated plants such as peas, beans, potatoes, and cereals. Especially after the crop has been gathered.

internode: The region of a stem between two successive nodes.

leaf blade: The lamina-like portion of the leaf bounded by the leaf collar and tip.

leaf sheath: The portion of a leaf below the collar that forms part of the stalk.

Log vs Record: To "log" means to temporarily note, as opposed to "record" which means to set down in writing.

mesocarp: The middle layer of the mature ovary wall, or pericarp, between the exocarp and the endocarp.

node: The part of a stem where one or more leaves are attached

panicle: An inflorescence, the main axis of which is branched, and whose branches bear loose flower clusters.

petiole: The stalk of the leaf.

pericarp: Fruit wall which develops from the mature ovary wall.

pod: A dry dehiscent seed vessel or fruit that is either monocarpellary (as a legume) or com-

posed of two or more carpels.

root: The usually descending axis of a plant, normally below ground, and serving to anchor the plant and to absorb and conduct water and minerals.

rachis: Main axis of spike; in compound leaves, the extension of the petiole corresponding to the midrib of an entire leaf.

senesce: To age and wither.

senescense: The phase of plant growth that extends from full maturity to actual death and is characterized by an accumulation of metabolic products, increase in respiratory rate, and a loss in dry weight, especially in fruits.

stover: The refuse of a field crop such as the stalks and leaves of corn after the ears are harvested. Used as a food for cattle. Also, hay stubble.

tare: The weight of a container that is deducted from the gross weight to obtain the net weight.

testa: The hard external coating or integument of a seed. Also called episperm.

tiller leaf blade: Leaf blade of a branch originating from the main stem's basal node.

tiller leaf sheath: Leaf sheath of a branch originating from the main stem's basal node.

tiller stem: Stem of a branch originating from the main stem's basal node.

tuber: An enlarged, short, fleshy underground stem, such as that of the potato.

wet weight: The weight of a material before it is dried.

APPENDIX A:

Form C-2: Optional weather data collection

Form C-2 asks for weather data not required by the minimum data set. The additional weather data collected 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.

Parameter	Instrument
Dry bulb temperature	Dry-bulb thermometer of a psychrometer
Wet bulb temperature	Wet-bulb thermometer of a psychrometer
Windrun	Anemometer

Dry bulb temperature

"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.

Wet bulb temperature

"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

"Windrun" is the measurement of wind movement during a 24-hour period, and is usually recorded with an anemometer.

APPENDIX B:

The following flow charts refer to harvest procedures for large plots of soybean, dry bean and peanut. A "large plot" may be defined as a plot that is so large as to require the assistance of a harvest combine or other such equipment to harvest the field.

Each of the flow charts is divided into areas of harvest. The first is a) the one meter area of the field and the other, b) is the rest of the field excluding the one meter area. Researchers who follow this large plot format need to gather data from both of these areas for input into the minimum data set.

Please note that for peanut only, "aboveground biomass" refers to not just that part of the plant that is above the ground, but to the pods below the ground as well. However, the roots of the peanut are not considered as part of aboveground biomass.

SOYBEAN and Dry BEAN Final harvest flow chart for large plot (excluding 1 meter area)

Bracketed numbers in bold are Technical Report 1 Harvest Codes.

From the remaining final harvest rows, harvest plants and thresh the pods. Log the harvested area. Dry the grain at 70°C to constant weight. Log the grain weight (dry). Recalculate seed, aboveground biomass, pod, empty shell dry weight, seed number, and pod number.

↓

Use the following equations in the given order.

↓

Seed weight (dry) (g/m²) **[5]** = $\frac{\text{seed weight (dry)}}{\text{harvest area}}$

Aboveground biomass (dry) (g/m²) **[3]** = $\frac{\text{seed weight (dry)}}{\text{harvest index*}}$

Pod weight (dry) (g/m²) = $\frac{\text{seed weight (dry)}}{\text{shelling percentage} \div 100\text{*}}$

Empty shell weight (dry) (g/m²) **[11]** = pod weight (dry) – seed weight (dry)

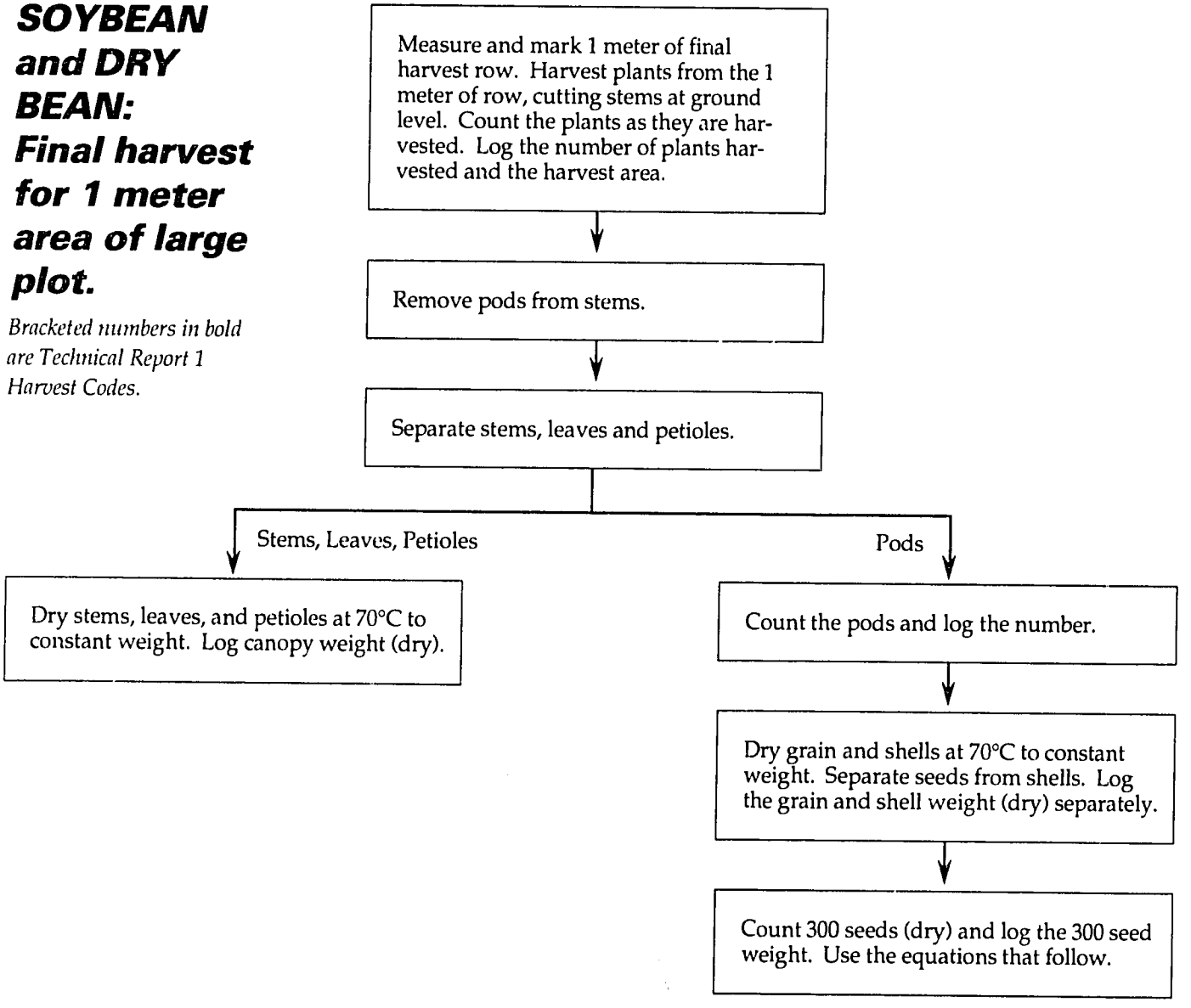
Seed number **[6]** = $\frac{\text{seed weight (dry)}}{\text{seed size*}}$

Pod number **[7]** = $\frac{\text{seed number}}{\text{seeds per pod}}$

* These two values are taken from the one meter area.

SOYBEAN and DRY BEAN: Final harvest for 1 meter area of large plot.

Bracketed numbers in bold are Technical Report 1 Harvest Codes.



Formulas for soybean and dry bean calculations:

$$\text{Plant population of harvest area [1]} = \frac{\text{number of plants}}{\text{harvest area}}$$

$$\text{seed weight (dry) (g/m}^2\text{) [5]} = \frac{\text{grain weight (dry)}}{\text{harvest area}}$$

$$\text{Empty shell weight (dry) (g/m}^2\text{) [11]} = \frac{\text{shell weight (dry)}}{\text{harvest area}}$$

$$\text{Pod weight (dry) (g/m}^2\text{)} = \text{seed weight (dry)} + \text{empty shell weight (dry)}$$

$$\text{Shelling percentage} = \frac{\text{seed weight (dry)}}{\text{pod weight (dry)}} \times 100$$

$$\text{Seed Number [6]} = \text{seed weight (dry)} \times \frac{\text{300 seeds}}{\text{300 seed weight}}$$

$$\text{Pod number [7]} = \frac{\text{number of pods}}{\text{harvest area}}$$

$$\text{Seeds per pod} = \frac{\text{seed number}}{\text{pod number}}$$

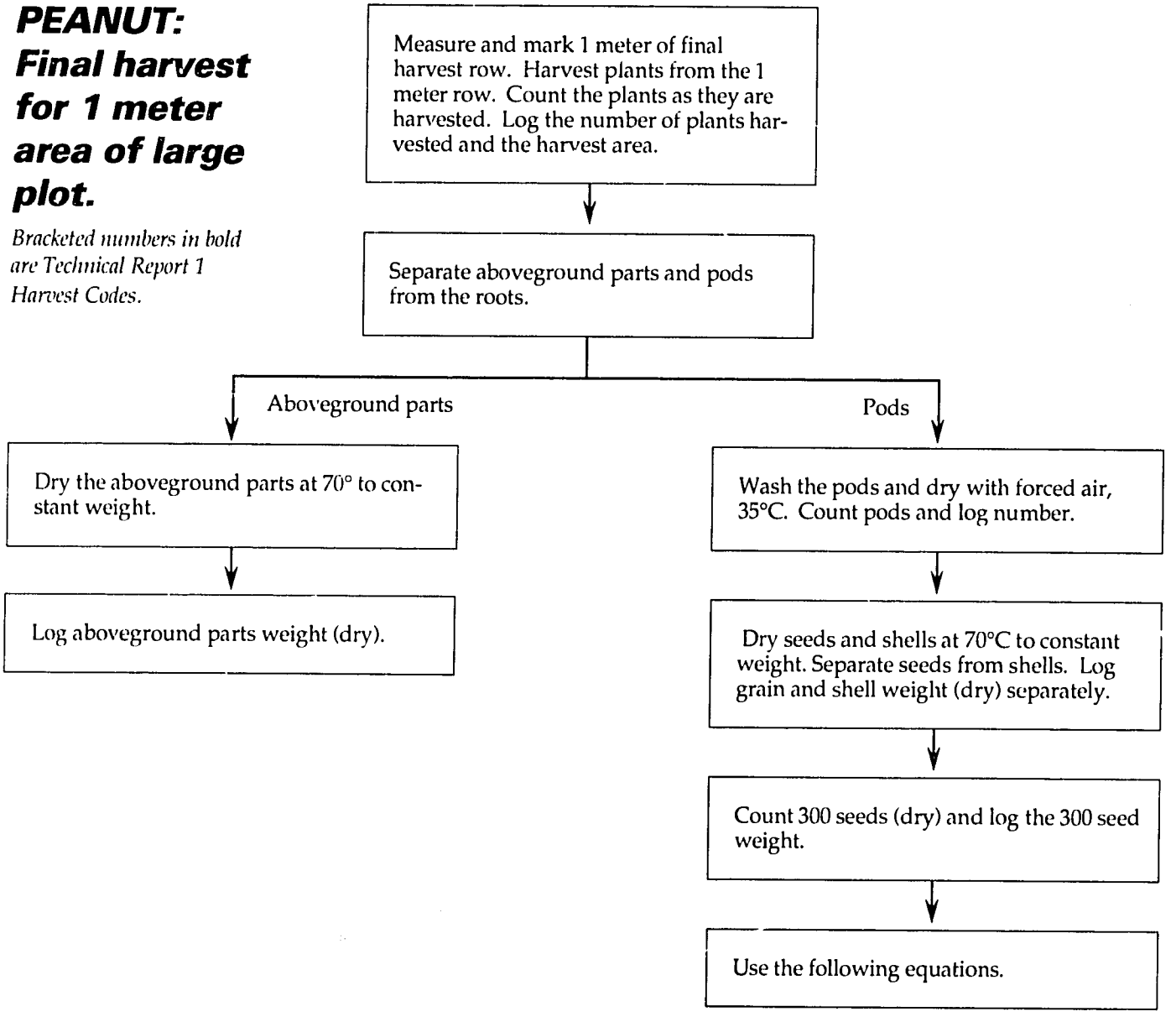
$$\text{Seed size} = \frac{\text{300 seed weight}}{\text{300 seeds}}$$

$$\text{Aboveground biomass (dry) (g/m}^2\text{) [3]} = \text{pod weight (dry)} + \frac{\text{stem, leaf, petiole weight (dry)}}{\text{harvest area}}$$

$$\text{Harvest index} = \frac{\text{seed weight (dry)}}{\text{aboveground biomass (dry)}}$$

PEANUT: Final harvest for 1 meter area of large plot.

Bracketed numbers in bold are Technical Report 1 Harvest Codes.



Formulas for peanut calculations:

$$\text{Plant population of harvest area [1]} = \frac{\text{number of plants}}{\text{harvest area}}$$

$$\text{Seed weight (dry) (g/m}^2\text{) [5]} = \frac{\text{seed weight (dry)}}{\text{harvest area}}$$

$$\text{Empty shell weight (dry) (g/m}^2\text{) [11]} = \frac{\text{shell weight (dry)}}{\text{harvest area}}$$

$$\text{Pod weight (dry) (g/m}^2\text{)} = \text{seed weight (dry)} - \text{empty shell weight (dry)}$$

$$\text{Aboveground biomass (dry) (g/m}^2\text{)[3]} = \frac{\text{aboveground parts weight (dry)} + \text{pod weight (dry)}}{\text{harvest area}}$$

$$\text{Shelling percentage} = \frac{\text{seed weight (dry)}}{\text{pod weight (dry)}} \times 100$$

$$\text{Seed Number [6]} = \text{seed weight (dry)} \times \frac{\text{300 seeds}}{\text{300 seed weight}}$$

$$\text{Pod number [7]} = \frac{\text{number of pods}}{\text{harvest area}}$$

$$\text{Seeds per pod} = \frac{\text{seed number}}{\text{pod number}}$$

$$\text{Seed size} = \frac{\text{300 seed weight}}{\text{300 seeds}}$$

$$\text{Pod Harvest Index} = \frac{\text{pod weight (dry)}}{\text{aboveground biomass (dry)}}$$

NOTE: for peanut, "aboveground biomass" refers to everything except the roots. This term does refer to the peanut pods even though those are not literally above the ground.

PEANUT: Final harvest for large plot (excluding 1 meter area).

Bracketed numbers in bold are Technical Report 1 Harvest Codes.

Harvest and thresh the pods from the remaining harvest rows. Log the harvested area. Dry the grain at 70°C to constant weight. Log grain weight (dry) Recalculate seed, aboveground biomass, pod, and empty shell weights, using the following equations.

$$\text{Seed weight (dry) (g/m}^2\text{) } \mathbf{[5]} = \frac{\text{seed weight (dry)}}{\text{harvest area}}$$

$$\text{Aboveground biomass (dry) (g/m}^2\text{) } \mathbf{[3]} = \frac{\text{seed weight (dry)}}{\text{harvest index*}}$$

$$\text{Pod weight (dry) (g/m}^2\text{)} = \frac{\text{seed weight (dry)}}{\text{shelling percentage*}} \div 100$$

$$\text{Empty shell weight (dry) (g/m}^2\text{) } \mathbf{[11]} = \text{pod weight (dry)} - \text{seed weight (dry)}$$

* These two values are taken from the one meter area.

APPENDIX C: Determination of Leaf Area Index

A method is outlined for collaborators who do not have a leaf area meter with which to measure leaf area index. Leaf area index is required for maize and for potato at the T1, T2, and T3 stages. For all other cultivars, leaf area index is only desired data, not required by the minimum data set.

Determination of Leaf Area Index

The leaf area index (LAI) is the leaf area subtended per unit of land area (Chang 1968). LAI is used as an indicator of plant growth and for evaluating assimilation and transpiration rates in plant physiological studies. LAI measurements provide indices of plant growth with time and are customarily used as inputs for crop simulation models. Because accurate measurements of LAI are required to develop and/or validate growth simulation models, it is important to select a method that can provide measurements of leaf are with reasonable confidence. This section briefly describes some of the methods currently available for measuring LAI.

Methods for measuring LAI

Leaf area measurements are both laborious and time consuming. The selection of a particular method to measure leaf area depends largely on the characteristics of leaves to be measured, the availability of time and equipment, and the degree of accuracy (Daughtry and Hollinger 1984). As a general rule, methods of measuring leaf area are classified into two categories: direct and indirect. In the direct methods, the area of leaves is measured using an area meter, whereas the indirect methods employ leaf area and leaf weight relationships to estimate leaf area.

Direct Methods

Leaf area meters are especially designed for precise and automatic area measurement. Area meters utilize an electronic method of rectangular approximation to measure leaf area of either attached or detached leaves (Hatfield et al. 1976). In the LI-3100 model, capabilities for either 0.1 or 1 mm2 area resolution are provided on the same instrument. As a leaf sample travels under the fluorescent light source, the projected image is reflected by a system of three mirrors to a solid-state scanning camera. Object width is sensed by the scanning camera; object length is determined by an attached encoding cord linked to the scanning beam. As the leaf sample passes under the light source, the accumulated area in cm^2 is digitally displayed. The errors of measurement with this type of area meter is probably less than 2% (Hatfield et al. 1976). In some cases, leaves tend to fold and wrinkle as they pass under the light source, causing some differences in the total area measured. However, these errors may be small compared to other sources of variation (Daughtry and Hollinger 1984).

Indirect Methods

In the absence of leaf area meters, leaf area measurements can be made by measuring the length and width of leaves. Leaf area per plant is calculated by multiplying the average number of leaves per plant (n) by the average length (L) and width (W) of a leaf by an area constant K:

$$LA = L \times W \times K \times n \qquad [1]$$

K is an empirically derived constant which is obtained by comparing leaf area measured

directly with a planimeter vs. leaf area obtained from length and width measurements. Equation [1] works well with short-statured crops.

Indirect methods also use relationships between leaf area and dry weight of leaves (LDW) to estimate leaf area:

$$LA = b_0 + b_1 \times LDW \qquad [2]$$

Equation [2] is obtained from experimental data using regression analysis between leaf area vs. leaf dry weight. Theoretically b_0 should be equal to zero and Equation [2] can be rewritten as follows:

$$LA = b_1 \times LDW \qquad [3]$$

A b_1 value of 223 cm^2/g is reported for taro (*Colocasia esculenta*), (Shih and Snyder 1984), whereas a relationship $LA = 0.396 + 0.680 \times LDW$, where b_1 is expressed in m^2/g is reported for corn (Daughtry and Hollinger 1984). The coefficient b_1 in Equation [3] varies with plant age, cultivars, and locations, thus some field testing to determine b_1 for a specific site and cultivar is required.

A variation of the above method employs the relationship between leaf area and leaf weight of a subsample to convert the weight of a large sample of leaves into leaf area. LA is calculated as follows (Daughtry and Hollinger 1984):

$$LA = (LA(S)/LDW(S)) \times LDW/n \qquad [4]$$

where LA(S) and LDW(S) are leaf area and leaf dry weight on a subsample of leaves, and LDW/n is the average leaf dry weight of n plants. This method uses a small number of plants to estimate leaf area per LDW, and a larger number of plants to estimate LDW.

Direct measurement of leaf area requires few plants, has the lowest coefficient of variation but requires approximately the same amount of time as indirect methods. Despite these limitations, indirect methods are the only choice where area meters are unavailable.

If you have access to a photocopy machine, here are two more ways to determine leaf area.

1. Photocopy the leaf onto graph paper and then determine the area by determining the area that the leaf covers on the graph paper.
2. Photocopy the leaf onto graph paper and send the photocopy to someone who does have a leaf area meter and they can measure it for you.

These methods may be helpful, but keep in mind that some photocopiers distort their images slightly. You may need to determine what the distortion is (if any) and accommodate your figures for this.

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