YIELD and YIELD COMPONENTS

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1. Introduction

Agronomic practices are evaluated using yield data so it is essential the yield information is representative and reliable. The purpose of this manual is to explain in practical terms how to obtain such data. The manual is divided into four sections. The first section assists in identifying the harvest area; the second and third sections explain some simple steps for obtaining grain yield in cereal crops and biomass yield in fodder crops. The final section discusses in greater detail small grain cereals and maize and the various yield components of these crops.

It is important to note that, in order to report the data correctly, all samples should be dried in a similar manner and all weights must be recorded in units of grams. In the description of the procedures, the samples are dried in an experimental oven, if you do not have access to such equipment, the samples can be air or sun dried. If all samples are dried in the same conditions until they reach a constant weight, the formulas that are described in the sections of this manual may be applied without any problems. However, keep in mind that your report should indicate whether the data were obtained with oven, air or sun drying.

The size of the samples used in this manual (e.g., 10 plants, 50 stems, 200 grains, etc) is indicative only. When possible, you may use larger samples (adjusting the calculations). It is not advisable to use a smaller sample size because of the potential increase in sample variation.

2. Determining the harvest area

The harvest area of the plot from which you determine the yield has to be representative of the entire plot. Some points to consider in achieving this include:

- The harvest area should be large enough to capture the variability within the field.
- Avoid taking samples at the edges (borders) of the plot, since they may not be representative for the whole plot due to a "border effect".
- It is important to consider the equipment that is available for this task. For example, if you have a combine harvester, you can choose a larger harvest area. When the work is done manually, harvest areas are usually small.
- Areas in which something outside a given treatment occurred, and that may affect the final yield (e.g., a spot in the field where there was insect damage if the damage is not general), cannot be considered as representative.

An example of a minimum harvest area per plot could be 3 rectangles of 3 meters in length and with a width of at least one bed (for beds) or half the width of the sowing machine (for flat planting). You can increase the dimensions if plots are large or within-plot variability is high. The dimensions of the harvest area should be representative for the field and form a unit that is repeatable within the field. Correctly calculating the harvest area is of utmost importance for a correct result.

Figure 1 illustrates what happens when the harvest area is determined to be a set surface instead of choosing representative dimensions depending on field conditions. In this example all harvest areas are measured with the same quadrat of 1 m². In the wheat field with a row distance of 0.20 cm this is a repeating measure and the number of rows are the same in each square. In the field with a row distance of 0.75 cm, this is not a representative measure and the number of rows are different in each square. If the square is harvested with one row, yield will be underestimated. If two rows are harvested, yield will be overestimated. Similarly, in the third portion of the figure where wheat is planted in two rows on beds, a 1 m² quadrat can cover two or four rows, resulting in an under- or overestimation of yield.
3. Determination of grain yield only

This procedure can be applied to any cereal crop.

3.1 Materials and Equipment

- Grain harvesting equipment (scythe, combine, etc.)
- 1 large bag per plot
- 1 envelope per plot
- Weighing scales
- Marker
- Oven
- Datasheets and pencil
- Map of the trial or farmer’s field

3.2 Preparation

- Label the bags with the corresponding specifications (name of the trial, identification of the plot and agricultural cycle). Attach one label to the bag and put an extra label inside the bag.
- Verify that the materials and equipment are in good condition, complete and ready to use.

3.3 Data collection (illustrated in Figure 2)

1. Determine the area that will be harvested. Record the width and length of the harvest area in the columns ‘Width’ and ‘Length’ on the datasheet below.
2. Harvest all the grain in the determined area. If necessary, clean it, then weigh the total grain and record the results in the column titled ‘Total grain weight’.
3. Take a sub-sample of approximately 200 g and place it in the labeled envelope; weigh the sub-sample and note the weight in the column ‘Fresh weight’. This data will serve to determine the moisture content of the harvested grain.
4. Place the sub-sample in the oven at a temperature of 75°C for 48 h or until it has a constant dry weight (dry grain), weigh it and record the result in the ‘Dry weight’ column.
5. Count 200 grains of the sub-sample and place them in a small envelope. Do not count broken kernels. The kernel sample should be counted taking the kernels as they come, and not selecting for better looking ones. Dry them in the oven at a temperature of 75°C for 24 h or until they are completely dry, weigh the grain and note the amount in the ‘Weight of 200 grains’ column.
3.4 Calculations
Firstly, determine the harvest area:

\[
\text{Area (m}^2\text{)} = \text{width} \times \text{length}
\]

To determine the dry grain yield, determine the moisture content in the ‘Total grain weight’:

\[
\text{Percentage moisture} = \frac{\text{Fresh weight of the subsample} - \text{Dry weight of the subsample}}{\text{Fresh weight of the subsample}} \times 100
\]

Moisture content (g) = Total grain weight × Percentage moisture

Then it is possible to calculate the dry yield in kg/ha:

\[
\text{Dry yield (kg/ha)} = \frac{\text{Total grain yield–Moisture content}}{\text{Area}} \times 10
\]

The yield can then be calculated for any percentage moisture, for example 12%:

\[
\text{Yield at 12\% H}_2\text{O (kg/ha)} = \frac{\text{Dry yield}}{100-12} \times \frac{100}{100}
\]

From the weight of the 200 grains, the thousand kernel weight and the number of grains per m² can be calculated:

Thousand kernel weight (g) = Weight 200 grains × 5

Number of grains per m² = \( \frac{\text{Dry yield}}{\text{Thousand kernel weight}} \times 0.1 \)

4. Determination of biomass yield for fodder crops
This procedure can be applied to any fodder crop.

4.1 Materials and Equipment
- Equipment to harvest plants (biomass), for example a sickle
- Rope to tie plants (for use on large crops, for example maize)
- 1 large bag for each plot (for use on smaller crops, for example barley and alfalfa)
- large brown paper bag for each plot (to contain 1 kg subsample)
- Weighing scales
- Marker
• Oven  
• Datasheets and pencil  
• Map of the trial or of the farmer’s field

4.2 Preparations

• Label the bags with the corresponding specifications (name of the trial, identification of the plot and agricultural cycle). Attach one label to the bag and put an extra one inside the bag.
• Verify that the materials and equipment are in good condition, complete and ready to use.

4.3 Data collection (illustrated in Figure 3)

1. Determine the area that will be harvested. Record width and length of the harvest area in the columns ‘Width’ and ‘Length’ in the datasheet below.
2. Harvest all the plants (collect all above ground biomass) in the determined area.
3. Weigh the fresh biomass (record this in the column ‘Total fresh weight’). If necessary, chop the plants with a machete (for example in the case of maize). Make sure not to lose leaves during the process, as this may influence later analyses.
4. Take a sub-sample of roughly 1 kg of the chopped plants, weigh it and record the weight in the column ‘Fresh weight sub-sample’.

5. Dry the sub-sample in the oven at a temperature of 75°C for 48 h or until it has a constant weight; weigh it (dry weight) and note the result in the ‘Dry weight sub-sample’ column.

4.4 Calculations

Firstly, calculate the harvested area in m²

\[
\text{Area} (m^2) = \text{Width} \times \text{Length}
\]

To calculate the dry biomass yield, first determine amount of moisture in the total fresh weight:

\[
\text{Percentage Moisture} = \frac{\text{Fresh weight of the subsample} - \text{Dry weight of the subsample}}{\text{Fresh weight of the subsample}}
\]

\[
\text{Moisture content (g)} = \text{Total fresh weight} \times \text{Percentage moisture}
\]

Then it is possible to calculate the dry biomass yield in kg/ha:

\[
\text{Dry matter biomass yield (kg/ha)} = \frac{\text{Total fresh weight} - \text{Moisture Content}}{\text{Area}} \times 10
\]

Figure 3. The procedure to obtain biomass from fodder crops.
5. Determination of grain yield and yield components

5.1 Small grain cereals: Step 1 – Obtaining and recording data for biomass

This measurement is taken approximately 10 days after maturity of the crop.

5.1.1 Materials and Equipment

- 1 large brown paper bag for each plot
- 1 envelope for each plot
- Sickle or scissors
- Weighing scales
- Oven
- Marker
- Single plant thresher
- Datasheet and pencil
- Map of the trial or the farmer’s field

5.1.2 Preparation

- Label the bags with the corresponding specifications (name of the trial, identification of the plot and agricultural cycle).
- Verify that the materials and equipment are in good condition, complete and ready to use.

5.1.3 Data collection (illustrated in Figure 4)

1. Outside the harvest area, randomly cut five bundles of stems using a sickle or scissors. Randomly select 10 stems from each bundle. You will select 50 stems in total.
2. Place the 50 stems in a large, previously labeled paper bag. Ensure not to lose any grains, stems or leaves during this process as this may alter results.
3. Put the bag containing the 50 stems into the oven at a temperature of 75°C for 48 h or until a constant dry weight is reached. Weigh them and record the results in column ‘Dry weight of 50 stems’ in the datasheet below.
4. After weighing the stems, thresh them in an individual plant thresher to separate the grain from the straw. Store the threshed straw in a bag, if you want to analyze the straw.
5. Place the grains in an envelope and dry them in an oven for 24 h at a temperature of 75°C, weigh them to determine the total dry weight and record the results in the column ‘Weight of grain of 50 stems’.

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Figure 4. The procedure to obtain the biomass of small grain cereals.
5.2 Small grain cereals: Step 2 - Obtaining and recording yield data

This protocol is executed during harvest.

5.2.1 Materials and Equipment

- 1 large material bag (the kind used at the markets) or one sack per plot
- Identification tags for each bag
- 1 big bag per plot
- 1 small envelope per plot (large enough to store 200 grains)
- Experimental combine harvester or a sickle and a 3 m U-shaped quadrat
- Oven
- Weighing scales
- Marker
- Datasheets and pencil
- Map of the experiment or farmer’s field

5.2.2 Preparation

- Label the bags with the corresponding specifications (name of the trial, identification of the plot and agricultural cycle). Attach one label to the bag and put an extra one inside the bag.
- Verify that the materials and equipment are in good condition, complete and ready to use.

5.2.3 Data collection (illustrated in Figure 5)

If you use a combine harvester: pay attention that the machine does not lose too much grain. Harvest all the grain in the harvesting area and place it in the bag. Clean the grain with the grain cleaning machine. Be sure not to use too much air to prevent loss of grain.

If you harvest by hand: harvest all the spikes in a representative area of the plot, demarcated with the help of the U-shaped quadrat. The spikes are placed in the large bag. Then they are threshed and the grain is collected.

1. In the field: measure the width and length of the harvested area and note them in the columns ‘Width’ and ‘Length’ in the datasheet below.
2. Thereafter, weigh all the grain. Note this down in the column ‘Total grain weight’.
3. Take a sub-sample (estimate approximately 200 g) and transfer it in the envelope. Weigh the sub-sample and record the weight in the ‘Fresh weight’ column. This data is taken to determine the moisture content of fresh grain.
4. Place the sub-sample in the oven at a temperature of 75 °C for 48 h or until it has a constant dry weight (dry grain). Weigh the sub-sample and record the weight in the ‘Dry weight’ column of the sub-sample column.
5. From the sub-sample, count 200 grains and put them in the small envelope. Do not count broken kernels.

Figure 5. The procedure to obtain yield for small grain cereals.
The kernel sample should be counted taking the kernels as they come, and not selecting for better looking ones. Put the grains in the oven to dry at a temperature of 75°C for 24 h or until completely dry. Weigh them and record the weight in the ‘Weight of 200 grains’ column.

### 5.2.4 Calculations

With the data of the 50 stems the harvest index can be calculated:

\[
\text{Harvest Index} = \frac{\text{Weight of grain of 50 stems}}{\text{Dry weight of 50 stems}} \times 100
\]

Then, the dry grain yield can be calculated:

\[
\text{Dry yield (kg/ha)} = \frac{\text{Total grain yield – Moisture content}}{\text{Area}} \times 10
\]

The yield can now be calculated for any percentage moisture, for example 12%:

\[
\text{Yield at 12% H}_2\text{O (kg/ha)} = \frac{\text{Dry yield}}{(100 – 12)} \times \frac{100}{100}
\]

Given that the harvest index is already calculated, it is also possible to determine biomass and residue yield:

\[
\text{Biomass Yield (kg/ha)} = \frac{\text{Dry yield}}{\text{Harvest Index}} \times 10
\]

Residue yield = Biomass yield – Dry yield

From the weight of the 200 grains, the thousand kernel weight and the number of grains per m² can be calculated:

\[
\text{Thousand kernel weight (g)} = \frac{\text{Dry yield}}{\text{weight 200 grains} \times 5}
\]

\[
\text{Grains per m²} = \frac{\text{Dry yield}}{\text{Thousand kernel weight} \times 0.10} \times 1,000
\]

From the data of the 50 stems, other yield components can also be calculated:

\[
\text{Biomass yield} = \frac{\text{Grains per m²}}{\text{Dry weight of 50 stems}} \times 0.10
\]

\[
\text{Grains per spike} = \frac{\text{Number of grains per m²}}{\text{Number of spikes per m²}}
\]

\[
\text{Dry weight per stem at maturity (g)} = \frac{\text{Dry yield of 50 stems}}{50}
\]

\[
\text{Dry grain weight per spike (g)} = \frac{\text{Weight of grain of 50 stems}}{50}
\]

In addition, if the number of days from emergence to physiological maturity (EM) and from anthesis to physiological maturity (AM) is known, two additional aspects of yield can be calculated:

\[
\text{Grain Production Rate (kg/ha/day)} = \frac{\text{Dry Yield}}{\text{AM}}
\]

\[
\text{Biomass production Rate (kg/ha/day)} = \frac{\text{Biomass Yield}}{\text{EM}}
\]

### 5.3 Maize: Step 1 – Obtaining and recording data for biomass

This measurement is taken approximately 10 days after maturity of the plants.

#### 5.3.1 Materials and Equipment

- One large brown paper bag for each plot
- 1 envelope for each plot
- Rope to tie plants together
- Sickle
- Weighing scales
- Marker
- Oven
- Machete
- Threshing machine (or equipment to thresh manually)
- Datasheets and pencil
- Map of the experiment or the farmer’s field
5.3.2 Preparation
- Mark the bags and envelopes with the corresponding specifications (name of trial, identification of plot, agricultural cycle).
- Verify that the materials and equipment are complete and ready to use.

5.3.3 Data collection (illustrated in Figure 6)
1. Cut 10 plants per plot at random, approximately 10 to 15 cm from the ground and outside of the harvest area.
2. Cut the ears but leave the husks with the plants.
3. Put the ears in the paper bags, place them in the oven at 75°C for 48 h or until they have a constant dry weight.
4. Weigh the dried ears (note weight in column ‘Dry weight ears’ in the datasheet below).
5. Thresh the ears and weigh the dry grain (note weight in column ‘Dry weight grain’).
6. Weigh 10 fresh plants without ears (note weight in the column ‘Total fresh weight of plants without ears’). Take five random plants and chop them with a machete. Be sure not to lose leaves during the process as this may alter the results.
7. Take a sub-sample of the chopped plants (approximately 1 kg), weigh it (fresh weight) and note the result in the column ‘Fresh weight sub-sample’ of plants without ears.
8. Put the sub-sample in the oven to dry at 75°C for 48 h or until it has a constant weight, weigh it (dry weight) and note the weight in the ‘Dry weight sub-sample’ column of plants without ears.

5.4 Maize yield: Step 2 – Obtaining and recording yield data
This protocol is executed during harvest.

5.4.1 Materials and Equipment
- 1 large material bag (the kind used at the markets) or one sack per plot
- Identification labels
- Defoliator
- 1 large envelope per plot
- 1 small envelope per plot (large enough to store 200 grains)
- Datasheets and pencil
- Map of the experiment or farmer’s field

Figure 6. The procedure to obtain maize biomass
• Weighing scales
• Oven
• U-shaped quadrat, if the harvest areas will be determined with quadrats

5.4.2 Preparation
• Label the bags with the corresponding specifications (name of the trial, identification of the plot and agricultural cycle). Attach one label to the bag and put an extra label inside the bag.
• Verify that the materials and equipment are in good condition, complete and ready to use.

5.4.3 Data collection (illustrated in Figure 7)
1. Determine the area that will be harvested. Note the width and length of the harvest area in the columns titled ‘Width’ and ‘Length’ in the datasheet below.
2. Harvest all the ears in the determined area.
3. If you are in an area where damage to ears by insects or disease is common, you can count and record the number of ears in good and bad condition in the columns ‘Number of good ears’ and ‘Number of bad ears’.
4. Remove the husks from the ears with the defoliator. If necessary, place the ears in the sun, so they can be dried and threshed.
5. After drying, weigh all ears (record this in the ‘Total ear weight’ column).
6. Thresh the ears and weigh the grain (record in the column ‘Total grain weight’).
7. Take a sub-sample (approximately 200 g), weigh it and record the result in the ‘Fresh weight sub-sample’ column. Then dry it in the oven at a temperature of 75°C for 48 h or until it has a constant dry weight.
8. Weigh the dry sub-sample and enter the result in the ‘Dry weight sub-sample’ column.
9. Count 200 grains at random and put them in an envelope. Do not count broken kernels. The kernel sample should be counted taking the kernels as they come, and not selecting for better looking ones. Dry them in the oven at 75°C for 24 h or until they are completely dry, weigh them and write the weight in the ‘Weight of 200 grains’ column.

Figure 7. The procedure to measure maize yield.
5.4.4 Calculations
With the data obtained from the 10 plants the Harvest Index can be calculated. Firstly, the dry weight of the 10 plants has to be determined, using the moisture content of the sub-sample of plants without ears.

\[
\text{Percentage of moisture in biomass} = \frac{\text{Fresh weight subsample} - \text{Dry weight subsample}}{\text{Fresh weight subsample}}
\]

Amount of moisture in biomass (g) = Fresh weight of 10 plants without ears × Percentage of moisture in biomass

Dry biomass of 10 plants without ears (g) = Fresh weight of 10 plants without ears - Amount of moisture in biomass (g)

Total biomass of 10 plants (g) = Dry biomass of 10 plants without ears + Dry weight of ears

\[
\text{Harvest index} = \frac{\text{Dry weight grain}}{\text{Total Biomass 10 plants}} \times 100
\]

Also, the ratio of grain and cob in the ears can be calculated:

\[
\text{Grain/cob ratio} = \frac{\text{Dry weight grain}}{\text{Dry weight of ears} - \text{Dry weight grain}} \times 100
\]

Then the grain yield and the biomass can be calculated using the same procedure:

\[
\text{Area (m}^2\text{)} = \text{Length} \times \text{Width}
\]

\[
\text{Percentage moisture} = \frac{\text{Fresh weight of the subsample} - \text{Dry weight of the subsample}}{\text{Fresh weight of the subsample}}
\]

\[
\text{Moisture content (g)} = \text{Total grain weight} \times \text{Percentage moisture}
\]

\[
\text{Dry yield (kg/ha)} = \frac{\text{Total grain yield} - \text{Moisture content}}{\text{Area}} \times 10
\]

The yield can now be calculated for any percentage moisture, for example 12%:

\[
\text{Yield at 12\% H}_2\text{O (kg/ha)} = \frac{\text{Dry yield}}{(100 - 12)} \times 100
\]

\[
\text{Biomass yield (kg/ha)} = \frac{\text{Dry yield}}{\text{Harvest Index}} \times 100
\]

The residue and cob yield can also be calculated:

\[
\text{Residue and cob yield (kg/ha)} = \text{Biomass yield} - \text{Dry yield}
\]

\[
\text{Cob yield (kg/ha)} = \frac{\text{Dry yield}}{\text{Grain/cob ratio}}
\]

\[
\text{Residue yield without cobs (kg/ha)} = \text{Residue and cob yield} - \text{Cob yield}
\]
With the weight of the 200 grains the thousand kernel weight and the number of grains/m² can be calculated, as in the previous protocols:

\[
\text{Thousand kernel weight (g)} = \text{Weight of 200 grams} \times 5
\]

\[
\text{Number of grains per m}^2 = \frac{\text{Dry yield}}{\text{Thousand kernel weight} \times 0.1} \times \frac{1,000}{1,000}
\]

With the number of good and bad ears and the data of the 10 plants other yield components can also be calculated:

\[
\text{Number of good ears per m}^2 = \frac{\text{Number of good ears}}{\text{Area}}
\]

\[
\text{Total number of ears per m}^2 = \frac{\text{Number of good ears} + \text{Number of bad ears}}{\text{Area}}
\]

\[
\text{Number of bad ears per m}^2 = \frac{\text{Number of bad ears}}{\text{Area}}
\]

\[
\text{Percentage of good ears} = \frac{\text{Number of good ears}}{\text{Number of good ears} + \text{Number of bad ears}} \times 100
\]

\[
\text{Percentage cob} = \frac{\text{Cob yield}}{\text{Biomass yield}} \times 100
\]
Appendix I: Worked Examples

This example shows the yield component calculations from a plot harvested at CIMMYT in El Batan, which was planted with bread wheat. To make the process easier, standard excel files are used in which you can calculate all components once the yield data are inserted.

1. Area (m²) = width × length = 1.5 m × 20.02 m = 30.03 m²

2. Percentage moisture = \( \frac{\text{Fresh weight of the subsample} - \text{Dry weight of the subsample}}{\text{Fresh weight of the subsample}} \) = \( \frac{200.44 \text{ g} - 188.43 \text{ g}}{200.44 \text{ g}} \) = 0.0599

3. Moisture content (g) = Total grain weight × Percentage moisture = 12,035 g × 0.0599 = 721 g

4. Dry yield (kg/ha) = \( \frac{\text{Total grain yield} - \text{Moisture content}}{\text{Area}} \) = \( \frac{12,035 \text{ g} - 722 \text{ g}}{30.03 \text{ m²}} \) × 10 = 3,767 kg/ha

5. Yield at 12% H₂O (kg/ha) = \( \frac{\text{Dry yield}}{100-12} \) = \( \frac{3,767 \text{ kg/ha}}{100} \) = 4,281 kg/ha

6. Thousand kernel weight (g) = \( \frac{\text{Weight of 200 grains}}{5} \) = 6.73 g × 5 = 34 g

7. Number of grains per m² = \( \frac{\text{Dry yield}}{\text{Thousand kernel weight}} \) × 0.1 = \( \frac{3,767 \text{ kg/ha}}{34 \text{ g}} \) × 0.1 = 11,080

8. Harvest index = \( \frac{\text{Weight of the grains of 50 stems}}{\text{Weight of 50 stems}} \) = \( \frac{67.13 \text{ g}}{159.03 \text{ g}} \) × 100 = 42.2

9. Biomass Yield (kg/ha) = \( \frac{\text{Dry yield}}{\text{Harvest Index}} \) × 100 = \( \frac{3,767 \text{ kg/ha}}{42.2} \) × 100 = 8,926 kg/ha

10. Residue yield (kg/ha) = Biomass yield – Dry yield = 8,926 kg/ha – 3,767 kg/ha = 5,159 kg/ha

11. Spikes per m² = \( \frac{\text{Biomass yield}}{\text{Dry weight of 50 stems}} \) × 0.1 = \( \frac{8,926 \text{ kg/ha}}{159.03 \text{ g}} \) × 0.10 = 281

12. Grains per spike = \( \frac{\text{Number of grains per m²}}{\text{Number of spikes per m²}} \) = \( \frac{11,080 \text{ grains per m²}}{281 \text{ spikes per m²}} \) = 39.4

13. Dry weight per stem at maturity (g) = \( \frac{\text{Dry Weight of 50 stems}}{50} \) = \( \frac{159.03 \text{ g}}{50} \) = 3.18 g

14. Dry grain weight per spike (g) = \( \frac{\text{Grain weight of 50 stems}}{50} \) = \( \frac{67.13 \text{ g}}{50} \) = 1.34 g

15. Grain Production Rate (kg/ha/day) = \( \frac{\text{Dry Yield}}{\text{AM}} \) = \( \frac{3,767 \text{ kg/ha}}{55} \) = 68 kg/ha/day

16. Biomass Production Rate (kg/ha/day) = \( \frac{\text{Biomass yield}}{\text{EM}} \) = \( \frac{8,926 \text{ kg/ha}}{119} \) = 75 kg/ha/day
For maize, the calculations are somewhat different; they are explained here using data from another plot of the same trial. The calculations that are identical as those for wheat have been omitted.

1. Percentage of moisture in biomass = \( \frac{\text{Fresh weight subsample} - \text{Dry weight subsample}}{\text{Fresh weight subsample}} = \frac{1,079 \text{ g} - 380.99 \text{ g}}{1,079 \text{ g}} = 0.646 \)

2. Amount of moisture in biomass (g) = Fresh weight of 10 plants without the ears × Percentage of moisture in biomass = 3,526 g × 0.646 = 2,278 g

3. Dry biomass of 10 plants without ears (g) = Fresh weight of 10 plants without the ears - Amount of moisture in biomass (g) = 3,526 g - 2,278 g = 1,248 g

4. Total biomass of 10 plants (g) = Dry biomass of 10 plants without ears + Dry weight of ears = 1,248 g + 915.5 g = 2,163.5 g

5. Grain/cob ratio = \( \frac{\text{Dry weight grain}}{\text{Dry weight of good ears} - \text{Dry weight grain}} = \frac{686.6 \text{ g}}{915.5 \text{ g} - 686.6 \text{ g}} = 3.00 \text{ g} \)

6. Residue and cob yield (kg/ha) = Biomass yield – Dry yield = 15,051 – 4,783 = 10,268 kg/ha

7. Cob yield (kg/ha) = \( \frac{\text{Dry yield}}{\text{Grain/cob ratio}} = \frac{4,783}{3} = 1,594 \text{ kg/ha g} \)

8. Residue yield without cobs (kg/ha) = Residue and cob yield – Cob yield = 10,268 – 1,594.43 = 8,674 kg/ha

9. Number of good ears per m² = \( \frac{\text{Number of good ears}}{\text{Area}} = \frac{228}{32.22 \text{ m}^2} = 7.08 \)

10. Total number of ears per m² = \( \frac{\text{Number of good ears} + \text{Number of bad ears}}{\text{Area}} = \frac{228 + 0}{32.22 \text{ m}^2} = 7.08 \)

11. Number of bad ears per m² = \( \frac{\text{Number of bad ears}}{\text{Area}} = \frac{0}{32.22 \text{ m}^2} = 0 \)

12. Percentage of good ears = \( \frac{\text{Number of good ears}}{\text{Number of good ears} + \text{Number of bad ears}} \times 100 = \frac{228}{228 + 0} \times 100 = 100 \)

13. Percentage cob = \( \frac{\text{Cob yield}}{\text{Biomass yield}} \times 100 = \frac{1,594}{15,051} \times 100 = 10.6 \)
Appendix II: Important factors to record and/or measure in agronomic experiments

Apart from the yield data and yield components described above, there are other data that need to be collected to allow comparison of agronomic practices or varieties in an experiment. A list of the most important data is given below.

- Date of seeding
- Date of 50% emergence: the day on which 50% of the seedlings have emerged. A visual estimate is usually adequate, as seedling emergence is normally fairly uniform. However, when accurate records are required, such as in a depth of seeding trial, at least 2 × 1 m lengths of row, selected at random, should be marked out in each plot at planting. Daily counts of number of emerged plants are made from the emergence of the first plants until the plant count remains constant for several days. The date of 50% seedling emergence is then the date on which half of the final number of plants had emerged. The mean of the two 1 m lengths of row is the emergence date for that plot. Report as days after seeding.
- Date and amount of all fertilizer applications and methods of application
- Date of irrigations, number of irrigations and stage of crop development on the date of each irrigation
- Plant population at emergence (usually 15–20 days after emergence begins):
  - Under some conditions (e.g. where tillering cannot compensate for weak plant stand), plant population may exert a considerable influence on yield, complicating the interpretation of treatment effect.
  - For small grain crops like wheat, barley, oats rice etc., make several counts of the emerged plants for 50 cm to 100 cm of row
  - For planting on the flat: Plant counting area = length of plant count × row width
  - For bed planting: Plant counting area = length of plant count × bed width
    number of rows per bed
  - Make at least 3 counts per plot
- Plant population in the spring for winter wheat:
  - Same as for plant population at emergence (provides an estimate of the current plant population in the spring following winter and an estimate of winter plant kill if plant counts were taken when the crop emerged during the previous fall before the onset of winter)
- Days from emergence to anthesis:
  - For small grain crops, anthesis occurs when at least 50% of the tillers have spikes with at least one anther showing
  - For crops like maize, anthesis occurs when at least 50% of the tassels have at least one anther showing: silking occurs when at least 50% of the ears have extruded silks
- Plant height:
  - Measure at least 5–10 randomly selected plants per plot
    - For small grain crops, measure to the top of the spike/panicle, not including the awns
    - For maize, measure to the tip of the tassel. Measure ear height to the level of the stalk node where the ear is attached
- Days from emergence to physiological maturity:
  - For small grain crops, physiological maturity occurs when at least 75% of the spikes/panicles and the peduncles have lost their green color
  - For maize, physiological maturity occurs when 75% of the ears have grain that has formed the black layer between the grain and the cob on the ears
- Grain fill days = Days to physiological maturity – days to anthesis.
- Lodging scores:
  - Most common lodging score for small grain crops (use 1–5 visual score looking at the area where the harvest for yield will occur)
    - 1 = no lodging
    - 2 = 25% lodging
    - 3 = 50% lodging
- 4 = 75% lodging
- 5 = 100% lodging

- Maize – count the number of lodged plants in the area to be harvested
- Take note if lodging is due to root lodging or due to stem/stalk breakage
- As edge plants are usually stronger than those inside the plot, only that part of the plot which will be harvested should be considered.
- You can also record the angle to the vertical of the lodged crop. Thus a crop that is lying flat on the ground has an angle of 90°. Sometimes a crop may lodge and then stand up again over a period of time. This should be recorded and the final angles taken as well as the one when lodging occurred.

- Date of harvest
- With the above information it is possible to calculate the following:
  - Biomass production rate = Total biomass yield / days to physiological maturity
  - Grain production rate for crop season = grain yield / days to physiological maturity
  - Grain production rate during grain fill period = grain yield / grain fill days
  - Kernel fill rate (mg/kernel/day = thousand kernel weight / grain fill days)
Appendix III: Procedure to determine hectoliter weight

Hectoliter weight is an important quality parameter for small grains that is relatively easy to measure.

Materials and Equipment (Figure 8)

- Weighing scales
- Container of known volume (1 liter)
- Funnel with stopper
- Datasheet and pencil
- Rod

Data collection

1. Weigh the one liter container on the scales.
2. Make sure the base of the apparatus is level.
3. Place the container under the funnel and place the funnel over the center of the container.
4. Place the tray beneath to collect the remainder of the grain.
5. Fill the funnel with grain.
6. Open the stopper of the funnel until the container is full.
7. Even off the excess grain by moving the rod over the container in a zigzag motion.

8. Weigh the container with the grain

**Important Notes**
- It is important that the procedure is carried out with clean grain.
- In the instance that a plot did not yield enough grain to fill a 1 liter container, smaller containers of 0.5 or 0.250 liters can be used. The result is then multiplied by 2 or 4, respectively, to obtain the 1 liter weight of the grain.
- The rod needs to have rounded edges, not square edges.

**Calculation**
Hectoliter weight (kg) = Measured 1 l weight (g) × 0.10
Appendix IV: Data sheets

Data Sheet – Grain Yield

Trial: ________________  Harvest Date: ________________  Crop: ________________

<table>
<thead>
<tr>
<th>Plot</th>
<th>Harvest area</th>
<th>Width (m)</th>
<th>Length (m)</th>
<th>Total grain weight (g)</th>
<th>Fresh weight (g)</th>
<th>Dry weight (g)</th>
<th>Weight of 2000 grains (g)</th>
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## Data Sheet – Fodder Crop Biomass

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<th>Plot</th>
<th>Harvest area</th>
<th>Sub-sample</th>
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## Data Sheet – Small Grain Biomass

Trial: ________________  Harvest Date: ________________  Crop: ________________

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<th>Dry weight of 50 stems (g)</th>
<th>Weight of grain of 50 stems (g)</th>
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### Data Sheet – Small Grain Yield

**Trial:** _______________  **Harvest Date:** _______________  **Crop:** _______________

<table>
<thead>
<tr>
<th>Plot</th>
<th>Harvest area</th>
<th>Sub-sample</th>
<th>Weight of 200 grains (g)</th>
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<tbody>
<tr>
<td></td>
<td>Width (m)</td>
<td>Total fresh weight (g)</td>
<td>Fresh weight (g)</td>
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<td>Length (m)</td>
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</table>
## Data Sheet – Maize Biomass

**Trial:** ________________  **Sampling Date:** ______________________________

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<thead>
<tr>
<th>Plot</th>
<th>Plants without ears</th>
<th>Ears</th>
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<td>Total fresh weight (g)</td>
<td>Fresh weight sub-sample (g)</td>
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Data Sheet – Maize Yield

Trial: ___________________        Harvest Date: ______________________________

<table>
<thead>
<tr>
<th>Plot</th>
<th>Harvest area</th>
<th>Sub-sample</th>
<th>Weight of 200 grains (g)</th>
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<tbody>
<tr>
<td></td>
<td>Width (m)</td>
<td>Length (m)</td>
<td>Number of good ears</td>
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