GUIDELINES FOR
YIELD ASSESSMENT
OF OPIUM GUM
AND COCA LEAF
FROM BRIEF FIELD VISITS

Scientific Section
and
Illicit Crop Monitoring Programme
ACKNOWLEDGEMENT

UNDCP’s Scientific Section and the Illicit Crop Monitoring Programme wish to express their thanks to the experts who participated in the Consultative Meeting on Methodologies for Yield Assessment of Illicit Narcotic Crops, held in Vienna, Austria, from 30 October to 3 November 2000, for their contribution to the contents of these Guidelines. They also wish to express their thanks to Dr. Mary Acock, senior consultant who drafted the background paper discussed at the meeting.

NATIONAL EXPERTS

Mr. Temur Aziz, Survey Expert, Islamabad, Pakistan

Mr. Fipop Chamnivikaipong, Director of Survey and Report Unit, Northern Narcotics Control Office, Chiangmai, Thailand

Mr. Kou Chansina, National Programme Director of PFU, LCDC, Vientiane, Laos

Mr. Humberto Chirinos, Technical Director, UNDCP Monitoring Project, UNDCP Country Office, Peru

Eng. Sayed Hassan, Senior Programme Officer, UNDCP Country Office, Afghanistan

Eng. Luis Jairo Meneses C., Agronomist, Bogota, Colombia

Mr. Rolando Pacheco, Regional Field Coordinator, DIRECO Office Cochabamba, Bolivia

Mr. Arnoldo Rios Salas, Director General PGR-FEADS, Mexico City, Mexico

Mr. Manindra Sarania, Inspector, Central Bureau of Narcotics, Guwahati, India

Dr. Sant Prasad Singh, Scientist and Head, Plant Breeding and Genetics Laboratory, National Botanical Research Institute, Lucknow, India

Mr. U Kyaw Yee*, Assistant Manager, Myanmar Agriculture Services, Yangon, Union of Myanmar

(* Participant invited but unable to attend)

INTERNATIONAL EXPERT (co-author of discussion paper)

Dr. Basil Acock, Plant physiologist, Acock Info L.L.P., Clemson, SC, USA
Glossary

This glossary provides definitions of terms as used in this paper.

Yield
The amount of material harvested per unit land area (e.g., kg/ha) per crop harvest.

Annual yield
The amount of material harvested per unit land area (e.g., kg/ha) per year.

Production
The total amount of material harvested from a stated land area per year (e.g., the amount per regional area per year; ‘production’ thus takes the number of harvests into account).

Number of lancings
Refers to the number of visits made to the same capsule for cutting.

Number of cuts
Refers to the number of single passes with a lancing knife on each capsule; each cut consists of several parallel lines, depending on the number of blades on the lancing tool.

NB. In those countries, e.g., Afghanistan and Mexico, where only one cut is made, the term ‘lancing’ is used also to refer to a ‘cut’, because there is no need to differentiate between the two.
TABLE OF CONTENTS

INTRODUCTION............................................................................................................................1

PART I
A. PRINCIPLES AND METHODS
   1. Principles of yield assessment .........................................................................................2
   2. Yield survey methods ........................................................................................................3
   2.1. Opium poppy ..............................................................................................................3
   2.2. Coca bush ....................................................................................................................3
   3. Choosing a method ...........................................................................................................4
   4. Resource requirements .....................................................................................................4
   4.1. Opium poppy ..............................................................................................................4
   4.1.1. Capsule volume method .........................................................................................4
   4.1.2. Capsule dry weight method ....................................................................................4
   4.2. Coca ............................................................................................................................5
   4.2.1. Actual harvest method ..........................................................................................5
   4.2.2. Light interception method .......................................................................................5
   4.2.3. Canopy subsample method .....................................................................................6

B. SELECTION OF FIELDS, PLOTS AND SAMPLES
   5. Selection of fields ............................................................................................................6
   6. Recording field location ....................................................................................................6
   7. Deciding on boundaries of field ......................................................................................6
   8. Random sampling of fields ...............................................................................................7
   8.1. "Transect method" .......................................................................................................7
   8.1.1. "Transect method" – modification A .......................................................................10
   8.1.2. "Transect method" – modification B .......................................................................10
   8.2. "Stone method" ........................................................................................................10
   8.3. Measuring the area sampled .......................................................................................10
   9. Subsampling ..................................................................................................................11
   9.1. Subsampling in the field .............................................................................................11
   9.2. Subsampling after removal of plant parts from the field .............................................11
   10. Deciding how many observations are needed .................................................................11
   11. Accuracy of measurements required ............................................................................13

C. TESTING AN OLD, OR ESTABLISHING A NEW CORRELATION
   12. General principles ..........................................................................................................13
   13. Selection of fields, plots and samples ..........................................................................13
   14. Collecting data to test or develop a correlation ...............................................................14
   15. Identifying an appropriate model for data analysis .......................................................14

D. DATA HANDLING
   16. Recording data in the field .............................................................................................16
   17. Labelling of samples .....................................................................................................17
   18. Entering data into computer files ..................................................................................17

E. GENERAL / OTHER ISSUES
   19. Handling of crop samples removed from the field .........................................................17
   20. The importance of moisture content in reporting yields ...............................................18
   22. Additional observations useful for interpreting results ...............................................19
   23. From yield to production ..............................................................................................19

PART II
A. OPIUM POPPY
   1. Growth of the crop ........................................................................................................20
   2. Recognizing when the crop is ready to be harvested ....................................................20
   3. Choosing a method .........................................................................................................21
   4. Measuring the area sampled ..........................................................................................22
5. Handling of crop samples.............................................................. 22
6. Yield survey methods for opium poppy.................................... 23
6.1. Capsule volume method..................................................... 23
6.1.1. Field procedure............................................................ 23
6.1.2. Post-field procedure..................................................... 24
6.1.3. Theory and calculations................................................ 25
6.1.3.1. Formula for yield calculation................................... 25
6.1.3.2. Projection of final capsule volume per square metre........ 26
6.1.4. Collecting data to develop and/or test a method................... 27
6.2. Capsule dry weight method................................................ 28
6.2.1. Field procedure............................................................ 28
6.2.2. Post-field procedure..................................................... 28
6.2.3. Theory and calculations................................................ 29
6.2.3.1. Formula for yield calculation................................... 29
6.2.3.2. Projection of final dry weight per square metre............. 30
6.2.4. Collecting data to develop and/or test a method................... 30

B. COCA
1. Growth of the crop ............................................................. 32
2. Recognizing when the leaves are ready for harvesting................ 32
3. Choosing a method............................................................. 33
4. Measuring the area sampled................................................ 33
5. Handling c/ leaf samples..................................................... 34
6. Yield survey methods for coca............................................. 34
6.1. Actual harvest method.................................................... 34
6.1.1. Field procedure............................................................ 35
6.1.2. Post-field procedure..................................................... 36
6.1.3. Theory and calculations................................................ 36
6.1.4. Collecting data to test the method................................... 36
6.2. Light interception method................................................ 37
6.2.1. Field procedure............................................................ 37
6.2.2. Post-field procedure..................................................... 37
6.2.3. Theory and calculations................................................ 37
6.2.4. Collecting data to test the method................................... 38
6.3. Canopy subsample method.............................................. 39
6.3.1. Field procedure............................................................ 39
6.3.2. Post-field procedure..................................................... 39
6.3.3. Theory and calculations................................................ 40
6.3.4. Collecting data to develop and/or test a method................... 41

REFERENCES................................................................................. 43

ANNEXES
Annex I
EQUIPMENT REQUIRED............................................................. 44
Annex II
Construction of a foldable metre square.................................... 46
Annex III
Outline of field procedures for method development, Afghanistan........ 47
DATA RECORDING SHEETS......................................................... 50
Annex IV
Questionnaire, Method development, Afghanistan............................. 55
INTRODUCTION

1. There are many ways of assessing the yields of illicit narcotic crops. However, internationally accepted, scientifically sound methods for yield assessment are currently not available for all major opium and cocaine producing countries. 'Yield figures used are frequently standard figures, or yield is assessed based on farmers' and surveyors' estimates, i.e. an assessment based on experience but not a well-defined, scientifically verifiable, and transparent, procedure.

2. These Guidelines describes some of the methods, both direct and indirect, which can be used to assess the potential maximum yield of illicit narcotic crops from brief field visits. The method ultimately used will depend on several, mainly logistic, factors, such as the characteristics of local crop, the stage of crop development, the equipment available, and the accessibility of the sampling area. In an attempt to provide the necessary flexibility to tailor core methods for yield assessment to the specific needs of individual situations / countries, the Guidelines also discuss relevant factors which affect the decision in favour, or against, the application of a particular method under certain circumstances. As a general rule, minimum requirements for scientifically sound yield surveys are stated; a larger number of observations and more sophisticated approaches, whenever possible, will increase the precision of the estimate.

3. The Guidelines start in Part I by discussing general principles of yield assessment and the theoretical background to the methods and procedures described. While the focus is on the use of the methods in yield surveys to estimate, for example, the average national yield, principles and procedures for testing an existing, or developing a new method, are also described. In Part II, outlines of practical procedures at the field level for using, testing and/or developing methods are provided, separately for opium poppy and coca bush. Finally, the details of field procedures applied in selected countries, lists of equipment and other practical details are given in Annexes I to IV.

4. It is anticipated that the Guidelines will be up-dated as more yield surveys are carried out in different countries and as the experience and knowledge base in this area increases. In this context, UNDCP would welcome observations on the content and usefulness of the present Guidelines. Comments and suggestions may be addressed to:

Scientific Section
Division for Operations and Analysis
Policy Development and Analysis Branch
United Nations International Drug Control Programme
Vienna International Centre
P.O. Box 500
A-1400 Vienna
Austria
Fax: +43-1-26060-5967
e-mail: Lab@undcp.org
PART I

A. Principles and methods

1. Principles of yield assessment

5. Yield assessments should be based on objective criteria, clearly stated, and on an appropriate number of samples or observations, selected at random.

6. It is difficult to choose which fields are to be sampled on a random basis for many practical reasons. An acceptable alternative is to choose fields at random within accessible areas. One should always be aware that this approach could bias results. However, if it is known how the accessible area relates to the whole region to be assessed (e.g. through other means such as remote sensing), any bias this might cause can be removed.

7. Plots for sampling within the fields should always be selected at random, to avoid the tendency to select plots with more and healthier than normal plants.

8. The plot size chosen should be large enough to include at least 5 plants normally. Individual plants should be wholly included in the sample or excluded from it.

9. The area sampled should be measured carefully and thoughtfully to ensure that it truly represents the area occupied by all the plants included in the sample.

10. If possible, the part of the crop that is normally harvested should be sampled, i.e., opium gum or coca leaves, using the methods of local farmers. Preferably, harvesting should be done by the farmers themselves under supervision.

11. If it is not possible to sample the part of the crop normally harvested, a relationship between some crop characteristic, e.g. coca leaf area index or poppy capsule volume at harvest, and yield has to be identified, and that crop characteristic has to be measured on the crop.

12. The crop characteristic should be measured as near as possible to the harvest time.

13. If possible, an already established correlation relating crop characteristic to yield should be used. It should be tested that the correlation holds under the new circumstances.

14. If an established correlation cannot be used, a new one has to be established.

15. To establish a new correlation, a crop characteristic that is closely related to the part of the crop normally harvested should be chosen. For example, opium gum is extracted from opium poppy capsules, so the capsule characteristics and opium gum yield should be closely related. Such a crop characteristic will reflect all that has happened to the crop (drought, insect attack, disease) up to the time it formed. Only events happening between its formation and harvest might be expected to break the correlation with yield.

16. If possible, new correlations should be tested or established in farmers’ fields, or in fields tended by local farmers under contract.
17. It should be checked that the correlation holds across varieties, years, soils, and weather patterns, etc. A useful correlation should explain about 80% or more of the yield variation, reflected in a coefficient of determination ($r^2$) of at least 0.8.

18. If plant parts are harvested in the field and removed for later measurement, proper handling and storage of the samples are essential to prevent degradation of the plant material. Measurements on such samples should be made as soon as practical.

2. Yield survey methods

19. Measuring yields of narcotic crops takes much time and labour, because they are harvested by hand. In the course of a yield survey, the labour to harvest the crop is rarely available, and it is often dangerous to stay in the field for as long as it takes to harvest it. Therefore, to assess yield during brief field visits, one must rely on measurements that are reasonable surrogates for yield and can be quickly and easily obtained.

2.1. Opium poppy

20. Studies have shown that opium gum yields can be estimated from the amount of mature capsule material present per unit land area (Safi, A.H., et al., 2000; USDA, 1993; USDA 1992). The amount of mature capsule material can be described either as mature capsule volume per unit land area or as mature capsule dry weight per unit land area. Both methods require measurements to be made when the capsules are ready to be lanced.

21. The capsule volume method requires that the volume of mature poppy capsules is determined via measurements of their height and diameter. Capsule volume is calculated using the geometric formula of an ellipsoid. The total capsule volume per unit land area, typically per square metre (i.e., the ‘plot volume’), is then related to gum yield, using a mathematical formula.

22. The capsule dry weight method relates the oven dry weight of all mature capsules of a plot to the gum yield. This method requires capsules to be removed from the fields.

23. Because harvesting a single poppy field may take 2 to 4 weeks, actually harvesting opium gum, i.e., applying the actual harvest method, also known as the ‘crop-cutting method’ (in India), is an activity best limited to testing quicker methods of estimating yield.

2.2. Coca bush

24. Three methods have been developed to estimate leaf yield: (i) the actual harvest method, (ii) the light interception method and the (iii) canopy subsample method. All the methods require measurements to be made when the leaves are ready to be harvested, and the surveys need to be repeated at intervals throughout a year because coca bushes are harvested several times during the year and yields vary with the season.

25. The actual harvest method removes some of the crop and extrapolates leaf yield from the area sampled to the field as a whole. It may require the farmer’s consent, but does not involve any correlation.

26. The light interception method calculates leaf yield from two parameters, which are measured in the field using specialized equipment: (i) leaf area index, i.e., the leaf area per unit land area, and (ii) specific leaf area, i.e., the leaf area per unit leaf dry weight. Because the equipment is sensitive to the light conditions under which it is used, careful calibration is essential.
27. The canopy subsample method is based on the hypothesis that the number of leaves formed at individual growing points since the last harvest is representative for the amount of growth of the whole canopy over the same period. Since it relies on an equation with an empirically determined parameter, the value of that parameter should be tested on local crop and changed as needed.

3. Choosing a method

28. The choice of a method to estimate yields depends on several factors. In some cases plant factors are critical, for example, the type of poppy grown, or the maturity of the coca or poppy plants to be sampled. However, given the illicit nature of opium poppy and coca bush cultivation in most countries, the choice is also determined by practical and logistical considerations. They include the availability of financial and human resources, the availability of equipment, the accessibility of the areas to be sampled and the time available for each field visit, considering security aspects, etc. In that context, a number of specific aspects have to be taken into account before choosing a method. For both crops, a practical guide is provided in Part II, paras. 116 to 120 for Opium poppy, and paras. 169 to 170 for Coca.

4. Resource requirements

4.1. Opium poppy

4.1.1. Capsule volume method

29. The following resources are required to carry out the capsule volume method:
- Two people minimum to randomly sample a field (using the transect method; see below), 3 people is ideal; if capsules are removed from the field: two people to take samples; as many people as possible for later measurements of capsule dimensions.
- Approximate time required to sample 3 plots per field:
  a) if capsules are counted and measured in the field: about 3 hours (4 people)
  b) if capsules are cut and removed for later measurement: 1.5 hours (if plots have been marked out before, 20 min. will suffice to just cut and collect the capsules).
- Equipment required: GPS, transect tape (100m), metre square, field sample bags, callipers; pruners, portable balance if subsamples are taken; data recording sheets.

4.1.2. Capsule dry weight method

30. The following resources are required to carry out the capsule dry weight method:
- Two people minimum to randomly sample a field (using the transect method, 3 people is ideal; two people to take samples; 2 people for post-field procedure;
- Approximate time required to sample 3 plots per field: 1.5 hours (if plots have been marked out before, 20 min. will suffice to just cut and collect the capsules)
- Equipment required: GPS, transect tape (100m), metre square, field sample bags, pruners, oven, balance, data recording sheets

---

1 Detailed lists of equipment are provided in Annex I.
4.2. Coca

4.2.1. Actual harvest method

31. The following resources are required to carry out the actual harvest method:
   - Two people minimum to randomly sample a field (using the transect method; see below); 3 people is ideal; as many as possible for harvesting;
   - Approximate time required: about 20 person-minutes per square metre of crop harvested, depending on the harvesters’ experience and the age of the crop;
   - Equipment required: GPS, transect tape (100m), field sample bags, balance for taking subsamples, data recording sheets, oven for drying subsamples of leaves harvested; balance to measure oven dry weights of subsamples of leaves harvested (not needed if there is no oven).

4.2.2. Light interception method

32. The following resources are required to carry out the light interception method:
   - Two people minimum to randomly sample a field (using the transect method), 3 people is ideal;
   - Approximate time required: about 20 person-minutes per field;
   - Equipment required: GPS, transect tape (100m), field sample bags, data recording sheets; oven for drying the samples of leaves (highly desirable but not essential); balance to measure oven dry weights of samples of leaves (not needed if there is no oven); light interception equipment for estimating leaf area index, leaf area metre to measure area of samples of leaves (see below).

33. **Light interception equipment**: Several instruments are currently on the market\(^2\) that measure light interception by the crop canopy and calculate leaf area index (Campbell and Norman, 1999). In each of them, optical sensors arranged in concentric rings behind a fish-eye lens detect radiation filtered to exclude wavelengths above 480nm from five unequal segments of the sky. Leaf area is calculated by comparing the radiation above the canopy with radiation that penetrates the canopy from various directions without being intercepted. With the CID image analyzer, the image looking upwards through the canopy is displayed on a small computer screen before capture. The Decagon equipment uses a digital camera to capture the image. All these instruments work best with diffuse radiation from a uniformly overcast sky. They are best used early in the morning, just before sunrise, or on days of cloudy sky. If the sky is too dark, there will be little contrast between radiation above and below the canopy of leaves and the instrument will underestimate leaf area index.

34. **Leaf area metre**: Several types of leaf area metre are available\(^3\); some highly portable that can be used in the field and some that are strictly laboratory equipment because of their size and weight. In all of them a sample of fresh leaves passes between a light source and a sensor, and intercepts the beam of light. The amount of light intercepted is measured, and accumulated leaf area is calculated and displayed.

---

\(^2\) Plant Canopy Analyzer (LI-COR—US$6,000), Image Analyzer (Decagon—US$6,000), or Image Analyzer (CID—US$6,000)

\(^3\) Approximate costs for a leaf area metre are as follows: portable—US$400; laboratory—US$2,000.
4.2.3. Canopy subsample method

35. The following resources are required to carry out the canopy subsample method:
   - Two people minimum to randomly sample a field (using the transect method), 3
     people is ideal; as many as possible for counting;
   - Approximate time required: about 30 person-minutes per field;
   - Equipment required: GPS, transect tape (100m), field sample bags, data recording
     sheets; oven for drying the samples of leaves (highly desirable but not essential);
     balance to measure oven dry weights of samples of leaves (not needed if there is
     no oven).

B. Selection of fields, plots and samples

5. Selection of fields

36. In order to avoid biased results when yield estimates from a number of random
    observations are extrapolated to the national level, the sites within a country where fields are
    to be sampled should be representative of the different agro-ecological regions of that
    country. They should ideally be selected on the basis of, at least, the following critical
    factors, which have an impact on yield: (i) climatic conditions, (ii) soil type, (iii) agronomic
    characteristics, in particular availability and type of irrigation, and (iv) plant characteristics.4
    Fields that are unusual in any regard, for example, if there are only small patches of poppy in
    fields that are predominantly other crops, should not be selected for yield studies.

37. Fields should be chosen on a random basis. The resulting yield estimates from
    random field sampling have to be related to the whole area under illicit crop cultivation, for
    example on a district or provincial basis, by weighting the yield figures with the
    corresponding cultivated areas. In a step-wise process, ultimately, a national average yield
    figure can be estimated; if desired (see also paras. 101 to 103, below).

6. Recording field location

38. Field location should always be recorded. There may be informative differences in the
    way the crop is grown and harvested in various regions, which allow some useful
    generalizations to be made. The most precise instrument for determining location is the
    Global Positioning System (GPS) that gives latitude, and longitude within about 10m, and
    elevation with less accuracy. The instrument should be used discreetly, if at all, since
    farmers throughout the world are increasingly aware of the power of this instrument to
    pinpoint their fields for eradication. Otherwise, the name of the nearest village and possibly
    the name of the owner should be recorded.

7. Deciding on boundaries of field

39. The methods for yield assessment described below allow estimation of potential
    maximum yield. For the purposes of yield surveys, in order to arrive at potential maximum
    yields, it is therefore essential that the area of the field sampled is only that area where the
    illicit crop is actually growing. Large bare areas and areas planted with other crops should
    be excluded; areas in different stages of development should be considered as two fields.

4 For coca in particular, the slope of the field is another important factor to be considered.
40. Deciding on the boundaries of a field may be problematic when yield estimation and measurement of the area under cultivation are done by different groups of people. When that happens, it is essential that both groups agree on the definition of a field, and that some kind of compensation is introduced to take the discrepancy into account and to arrive at figures of potential maximum yield.

41. Another practical problem may arise when the illicit crop is grown continuously over a very large area with no clear indication of borders. In those cases, paths, lines of rock, streams, or other barriers can be used to define smaller areas suitable for sampling. Fields with very irregular outlines should also be broken into more nearly rectangular pieces, in the same way.

8. Random sampling of fields

42. Even though most yield surveys are concerned with estimating a mean yield for a region, one should still try to capture some of the variation within individual fields by random sampling, i.e., by selecting plots within a field on a random basis. There are many possible ways of doing this. They differ in terms of ease and time required, but also in terms of objectivity. Objectivity in the selection of plots in a field is best ensured by randomly marking out one or more straight lines through the centre of the field ('transect'), and randomly selecting the plots along the transect.

8.1. 'Transect method'

43. To lay down a transect across the field and sample randomly along the transect, a measuring tape is run across the field. The tape both marks the transect and gives a means of locating individual plants or plots along the transect. To lay down the transect, two surveyors go to the middle of the field, they spin a stick and let it fall to the ground. The tape is then run across the field by walking from the centre to the borders, in the direction indicated by the stick. If there is an obvious gradient in one direction across the field, the tape should be run across the middle of the field in that direction. If the field is very narrow, like many terraced fields are, the tape should be run along the middle of the long axis of the field.

44. In the case of fields of large plants like coca, and if plants are widely spaced and are not competing for light, measurements can be made on individual plants spaced uniformly along the transect. In such a case, the mean plant yield will have to be multiplied by plant population. However, in the case of small plants like poppy, it is better to mark out plots, measure yield on the plants in those plots, then divide by the area of the plot. The plots should be large enough to contain a representative sample of individuals of the various sizes present in the field. For large plants, five adjacent plants in a row will probably be enough. This method of sampling is described fully in Part II, paras. 171 to 173.

45. To mark out plots along the transect, the length of the transect should be read off the measuring tape. An easy way to select plot positions along the transect is to round the length of the field up or down to the nearest 10 units, and to have a list of random numbers in the range 1-10 prepared in advance. Then a table can be used to look up where each of the 10 plots will occur along a field of that length (see Table 1 below). Typically, three or

---

5 For example, Table 1 was prepared for use with a 300 feet measuring tape. At the top of Table 1 is the length of the transect, and below are the locations along the transect (marked by the tape) of each of 10 possible sample plots. (NB: In some cases, for example, if a 100 metres tape is used, a full metre measurement may be inappropriate, because it introduces restrictions in choice of appropriate plots).
more of those will be chosen at random, using the list of random numbers. If more than 10 samples are needed, the whole process can be repeated, and another transect established.

46. If one of the plots selected contains no plants, this information should be recorded. If all the sample plots were without plants, one would know nothing about the parts of the field that had plants. It is recommended to record the number of plots that contained no plants and randomly select other plots that do contain at least one plant. In data analysis, plots without plants are valid observations that contribute to the sample mean.

47. It should be decided in advance, how the plots will relate to the selected points along the transect. If the plots are 5 metre lengths of row, in which direction will they run from the selected points? If the plots are one-meter squares, will they be centred on the points, or will the points be one corner of each square? Using the points as corners of the one-meter square and running one edge of the square along the tape (as indicated in Figure 1), defines the square’s position precisely and gives less opportunity for the surveyors to introduce bias.

Figure 1: Location of 10 one-square-metre plots along a transect of 20m length

48. To minimize the damage to the plots to be selected, the people running out the tape should hold it at arms’ length, and should walk on the side of the tape away from the plots. For example, if the plots will be laid out on the east side of the tape, the tape handlers should walk on the west side of it. If the field is steeply sloped, it is a good idea to walk on the down-slope side of the tape, and to lay out the plots on the up-slope side.
<table>
<thead>
<tr>
<th>Length of transect</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
<th>120</th>
<th>130</th>
<th>140</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plot interval</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Plot No. 1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Plot No. 2</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>9</td>
<td>11</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>17</td>
<td>18</td>
<td>20</td>
<td>21</td>
<td>23</td>
</tr>
<tr>
<td>Plot No. 3</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>15</td>
<td>18</td>
<td>20</td>
<td>23</td>
<td>26</td>
<td>28</td>
<td>30</td>
<td>33</td>
<td>35</td>
<td>38</td>
</tr>
<tr>
<td>Plot No. 4</td>
<td>4</td>
<td>7</td>
<td>11</td>
<td>14</td>
<td>18</td>
<td>21</td>
<td>25</td>
<td>28</td>
<td>32</td>
<td>35</td>
<td>39</td>
<td>42</td>
<td>46</td>
<td>49</td>
<td>53</td>
</tr>
<tr>
<td>Plot No. 5</td>
<td>5</td>
<td>9</td>
<td>14</td>
<td>18</td>
<td>23</td>
<td>27</td>
<td>32</td>
<td>36</td>
<td>41</td>
<td>45</td>
<td>50</td>
<td>54</td>
<td>59</td>
<td>63</td>
<td>68</td>
</tr>
<tr>
<td>Plot No. 6</td>
<td>6</td>
<td>11</td>
<td>17</td>
<td>22</td>
<td>28</td>
<td>33</td>
<td>39</td>
<td>44</td>
<td>50</td>
<td>55</td>
<td>61</td>
<td>66</td>
<td>72</td>
<td>77</td>
<td>83</td>
</tr>
<tr>
<td>Plot No. 7</td>
<td>7</td>
<td>13</td>
<td>20</td>
<td>26</td>
<td>33</td>
<td>39</td>
<td>46</td>
<td>52</td>
<td>59</td>
<td>65</td>
<td>72</td>
<td>78</td>
<td>85</td>
<td>91</td>
<td>98</td>
</tr>
<tr>
<td>Plot No. 8</td>
<td>8</td>
<td>15</td>
<td>23</td>
<td>30</td>
<td>38</td>
<td>45</td>
<td>53</td>
<td>60</td>
<td>68</td>
<td>75</td>
<td>83</td>
<td>90</td>
<td>96</td>
<td>105</td>
<td>113</td>
</tr>
<tr>
<td>Plot No. 9</td>
<td>9</td>
<td>17</td>
<td>26</td>
<td>34</td>
<td>43</td>
<td>51</td>
<td>60</td>
<td>68</td>
<td>77</td>
<td>85</td>
<td>94</td>
<td>102</td>
<td>111</td>
<td>119</td>
<td>128</td>
</tr>
<tr>
<td>Plot No. 10</td>
<td>10</td>
<td>19</td>
<td>29</td>
<td>38</td>
<td>48</td>
<td>57</td>
<td>67</td>
<td>76</td>
<td>86</td>
<td>95</td>
<td>105</td>
<td>114</td>
<td>124</td>
<td>133</td>
<td>143</td>
</tr>
<tr>
<td>Length of transect</td>
<td>160</td>
<td>170</td>
<td>180</td>
<td>190</td>
<td>200</td>
<td>210</td>
<td>220</td>
<td>230</td>
<td>240</td>
<td>250</td>
<td>260</td>
<td>270</td>
<td>280</td>
<td>290</td>
<td>300</td>
</tr>
<tr>
<td>Plot interval</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>28</td>
<td>29</td>
</tr>
<tr>
<td>Plot No. 1</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>13</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Plot No. 2</td>
<td>24</td>
<td>26</td>
<td>27</td>
<td>29</td>
<td>30</td>
<td>32</td>
<td>33</td>
<td>35</td>
<td>36</td>
<td>38</td>
<td>39</td>
<td>41</td>
<td>42</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>Plot No. 3</td>
<td>40</td>
<td>43</td>
<td>45</td>
<td>48</td>
<td>50</td>
<td>53</td>
<td>55</td>
<td>58</td>
<td>60</td>
<td>63</td>
<td>65</td>
<td>68</td>
<td>70</td>
<td>73</td>
<td>75</td>
</tr>
<tr>
<td>Plot No. 4</td>
<td>56</td>
<td>60</td>
<td>63</td>
<td>67</td>
<td>70</td>
<td>74</td>
<td>77</td>
<td>81</td>
<td>84</td>
<td>88</td>
<td>91</td>
<td>95</td>
<td>98</td>
<td>102</td>
<td>105</td>
</tr>
<tr>
<td>Plot No. 5</td>
<td>72</td>
<td>77</td>
<td>81</td>
<td>86</td>
<td>90</td>
<td>95</td>
<td>99</td>
<td>104</td>
<td>108</td>
<td>113</td>
<td>117</td>
<td>122</td>
<td>126</td>
<td>131</td>
<td>135</td>
</tr>
<tr>
<td>Plot No. 6</td>
<td>88</td>
<td>94</td>
<td>99</td>
<td>105</td>
<td>110</td>
<td>116</td>
<td>121</td>
<td>127</td>
<td>132</td>
<td>138</td>
<td>143</td>
<td>149</td>
<td>154</td>
<td>160</td>
<td>165</td>
</tr>
<tr>
<td>Plot No. 7</td>
<td>104</td>
<td>111</td>
<td>117</td>
<td>124</td>
<td>130</td>
<td>137</td>
<td>143</td>
<td>150</td>
<td>156</td>
<td>163</td>
<td>169</td>
<td>176</td>
<td>182</td>
<td>189</td>
<td>195</td>
</tr>
<tr>
<td>Plot No. 8</td>
<td>120</td>
<td>128</td>
<td>135</td>
<td>143</td>
<td>150</td>
<td>158</td>
<td>165</td>
<td>173</td>
<td>180</td>
<td>188</td>
<td>196</td>
<td>203</td>
<td>210</td>
<td>218</td>
<td>225</td>
</tr>
<tr>
<td>Plot No. 9</td>
<td>136</td>
<td>145</td>
<td>153</td>
<td>162</td>
<td>170</td>
<td>179</td>
<td>187</td>
<td>196</td>
<td>204</td>
<td>213</td>
<td>221</td>
<td>230</td>
<td>238</td>
<td>247</td>
<td>255</td>
</tr>
<tr>
<td>Plot No. 10</td>
<td>152</td>
<td>162</td>
<td>171</td>
<td>181</td>
<td>190</td>
<td>200</td>
<td>209</td>
<td>219</td>
<td>228</td>
<td>238</td>
<td>247</td>
<td>257</td>
<td>266</td>
<td>276</td>
<td>285</td>
</tr>
</tbody>
</table>
49. There are several other options to mark out plots along a transect, however, most of
them will be less objective than the approach described above, because simplifying plot
selection along the transect will adversely affect the randomness of the procedure. For
instance, both modifications described below will always have the centre plot as a fixed plot
position in each field.

8.1.1. ‘Transect method’ – modification A

50. One alternative method, not relying on random numbers, is to lay down the plots at a
fixed fraction of the length of the transect. For example, to select three plots, the length of
the transect is divided by 4. The first plot is laid down at ¼ of the length of the transect, the
second at ½, and the third at ¾ of the length of the transect. This approach is used in Laos
for poppy yield surveys.

8.1.2. ‘Transect method’ – modification B

51. Another modification of the ‘transect method’ as described above, is to lay down two
transects through the centre of the field, which are perpendicular to each other. In this case,
a total of, for example, five plots are marked out: the centre plot, and one plot in each of the
four directions at ¼ of the length of each transect, measured from the centre to the border
(see also Part II, para. 176). This approach is used in Colombia for coca yield surveys, and
in Thailand for poppy yield surveys. In Thailand, where this approach is used on fields which
have previously been classified in low, medium and high density fields, while five plots are
selected, only three observations are considered in data analysis; the two extremes, i.e., the
lowest and highest yielding plot of each field, are excluded.

8.2. ‘Stone method’

52. The ‘stone method’ requires surveyors to throw a stone behind their backs to locate
individual square metre plots (the position of the stone indicates the centre of the plot). This
method is much less objective, since choosing the position from where, and the direction in
which, the stone will be thrown, involuntarily introduces some bias. However, the ‘stone
method’ is attractive because it is very quick and does not involve excessive walking through
the field as required by the ‘transect method’ to lay down the transect and mark out plots
along it. It may be the best possible option under certain circumstances, for example, to
minimize damage to the fields of cooperating farmers.

8.3. Measuring the area sampled

53. With small plants like poppy that are normally broadcast, it is easy to mark out a plot
and sample the plants that fall within the plot. For plants their size, one square metre is an
adequate sampling area (for details of how to construct a foldable metre square, see Annex
II).

54. For larger plants like coca bush, it is often desirable to sample only a few plants and to
know how much of the field area they represent. The procedure described in para. 172,
allows accurate determination of the sampling area. Accuracy is crucial here because the
yield for the area is usually extrapolated to give yield per hectare. Small errors in the
sampling area translate into large errors in the estimate.
9. Subsampling

55. It often happens that the sample selected in the field is too large for all the desired measurements to be made on all of it. In that case, the sample should be subsampled and all the measurements made on the subsample. However, subsampling can easily bias the result, and it is essential that the subsample be representative of the sample, just as the sample must be representative of the whole field. Some methods of subsampling relevant to the assessment of drug crop yields are described below.

9.1. Subsampling in the field

56. Measuring the height and diameter of mature poppy capsules on a sample of plants in the field is time consuming. The task can be made manageable by counting the total number of mature capsules on the plants and measuring mean capsule volume only on a representative subsample of them. To this end, a typical or average plant is selected and the heights and diameters of all the mature capsules on that plant are recorded. The process is repeated with other plants until the sizes of 10 or more mature capsules have been recorded. It is important not to stop measuring after the tenth mature capsule, but to complete measurements on all mature capsules on that plant. The mean capsule volume of the subsample and the number of all capsules and flower buds, which are expected to reach maturity, are used to calculate the total capsule volume of the sample. Thus, in this case, the numbers of capsules are used to relate the sample to the subsample.

9.2. Subsampling after removal of plant parts from the field

57. When a sample of coca leaves or poppy capsules has been removed from the plants, fresh weight can be used to relate the sample to the subsample. This is slightly more accurate than using number since, for opium poppy, fresh weight is highly correlated with both capsule volume and dry weight. However, it is still important to ensure that the subsample contains the same distribution of individual sizes as the original sample. With coca leaves it is easy to mix them thoroughly and take enough in a subsample to ensure a good distribution of sizes, but poppy capsules are more variable in size, and it may be necessary to take fewer (for details, see footnote in para. 130). The ratio of sample fresh weight and subsample fresh weight is used to adjust measured values to represent the whole sample.

10. Deciding how many observations are needed

58. The number of observations needed to assess yield depends on the variability of the crop and the precision needed in the assessment. Variability is commonly expressed as the Coefficient of Variation (CV):

\[ CV = \left( \frac{s}{x} \right) \times 100 \quad \text{(equation 1)} \]

where \( s \) = standard deviation of the sample, and \( x \) = sample mean.

59. For example, a field that has a normally distributed population of plants with a mean yield of 10g and a standard deviation of 1g, has a CV of 10%. CVs observed on opium gum yields in various years and regions are all close to 50%. Well-managed fields often have CVs of 20%.
60. There are statistical tools available to determine the number of observations needed to ensure a desired precision of the results at a given confidence level. In practice, however, as outlined above, there are frequently other factors such as the accessibility of fields, the time available, etc., which limit the number of observations that can be obtained. Therefore, for practical purposes, a yield survey should aim for at least 30 observations (e.g., plots) per sampled area. 'Area', in this context, should be defined as the cultivated area within the boundaries of a village. If 30+ observations cannot be obtained at the village level, the area of the next largest administrative unit (e.g., district) should be used as the next best possible option. For coca yield assessments, para. 176 provides some practical guidance on the minimum number of observations per field.

61. Below are some examples of calculating the statistically relevant number of observations, depending on the CV of the crop and the desired level of confidence and precision of the estimate.

62. **Example 1**: A field with a normally distributed population of plants, a mean yield of 10g and a standard deviation of 2g, has a CV of 20%. When this field is sampled, and one wants to be sure that 19 out of 20 of the samples (i.e., 95%), which might be taken at random, have a mean value within 10% of the true mean, i.e. between 9g and 11g, the number of observations, N needed to do this is given by equation 2:

\[
N = \left( \frac{t \cdot CV}{d} \right)^2
\]  

*(equation 2)*

where \( t = \) Student's t value for \( P \leq 0.05 \) and \( df = N - 1 \), and \( d = \) limit for acceptable variation from the population mean (in this case 10% or 0.1).

In the above example, \( t = 2.110 \), \( CV = 0.2 \) and \( d = 0.1 \), therefore

\[
N = (2.110 \cdot 0.2 / 0.1)^2 \text{ or } 18
\]

The calculation is iterative because the value of t changes with N.

63. **Example 2**: For fields with CVs of 50%, or 0.5, to be confident that 19 out of every 20 means from random samples are within 5% of the true mean, at least 271 samples need to be taken:

\[
N = (1.645 \cdot 0.5 / 0.05)^2 \text{ or } 271
\]

64. **Example 3**: For a well-managed field with a CV of 20%, to be confident that 19 out of 20 means from random samples are within 5% of the true mean, at least 45 samples need to be taken from that field:

\[
N = (1.671 \cdot 0.2 / 0.05)^2 \text{ or } 45
\]

65. It is clear that the number of observations needed is greatly altered by changing confidence limit requirements and the precision for the estimate. Table 2 below summarizes how the number of observations required will change with the confidence level and the desired precision, for crop fields with a CV of 50% and 20%, respectively.

66. For practical purposes, it may also be useful to go the other way round, i.e., to calculate the confidence level of the estimate from the desired precision and the number of observations, which can be obtained in a yield survey limited by certain practical constraints.
Table 2

<table>
<thead>
<tr>
<th>Confidence level</th>
<th>Desired precision</th>
<th>Number of observations required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CV 50%</td>
</tr>
<tr>
<td>P&lt;0.05 (e.g., 19 out of 20 samples)</td>
<td>± 10%</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>± 5%</td>
<td>271</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45</td>
</tr>
</tbody>
</table>

11. Accuracy of measurements required

67. If possible, all measurements should be made to an accuracy of at least three significant figures. Where plant material is weighed in a container, the container must be weighed with sufficient accuracy that the amount of plant material in it can be calculated to three significant figures. For example, if opium gum is being collected on a piece of aluminum foil, and the gum weighs 0.0345g, the foil will have to be weighed to the nearest 0.0001g, regardless of how many significant figures that involves. For larger samples, for example, 400g of material, the nearest one gram should be recorded.

C. Testing an old, or establishing a new correlation

12. General principles

68. Collecting the data needed for developing and/or testing a method demands proper supervision of the complete process. Crop samples have to be measured and related to the survey area, i.e., a field, or part of a field. Observations over a wide range of data are needed to ensure that the models can be widely applied.

69. Differences in plant varieties and, in the case of opium poppy, differences in harvesting techniques, should also be evaluated.

13. Selection of fields, plots and samples

70. To develop a method or test (evaluate) an existing correlation, crops growing in their natural environment should be studied, because it is the yields of such crops which will be assessed. Crops should either be studied directly in farmers’ fields, or they should be grown in the same way as is done by local farmers. The following key helps to decide how and where to grow the crop:

Can safe access to some farmer’s fields be secured for each of the harvests in a year and for the complete duration of those harvests?
Yes - yield correlations can be established in the farmers’ fields.
No - correlations should be established in fields under one’s own control.

Can arrangements be made for the farmers to grow and harvest the crop for the study?
Yes - farmers should be allowed to follow their normal practices in the fields under supervision.
No - prior to the study, as much as possible should be learnt about the methods used by local farmers to grow and harvest the crop, in order to allow replication of those methods in the fields under study.
71. For method development, fields should be selected based on agro-ecological considerations to cover the whole range of conditions encountered in a given country / region; this should also include considerations about the availability or non-availability of irrigation. The number of fields selected should be as large as possible. Plots should be chosen to ensure that the data collected reflects the extremes in terms of crop characteristic and expected yield.

72. For both method development and evaluation, it is also important that the fields be secured before harvest begins, and for the complete duration of the harvest. If more than one harvest is typical for a region, all harvests have to be considered in the same way for method development and evaluation.

73. Ideally, information on factors that have an impact on yield, such as agro-ecological factors, agronomic characteristics, diseases and pests, etc., should also be collected for the experimental fields.

74. Crop samples collected as part of method development or evaluation, have to be handled and stored in a way that allows the measurement of both fresh and oven dry weight as part of moisture content determination (see paras. 91 to 93, below).

14. Collecting data to test or develop a correlation

75. One approach to obtaining the necessary data might be to ask farmers to harvest the gum or leaves from carefully measured sections of their fields and allow the yield assessment team to weigh the gum or leaves collected and take samples for moisture content and alkaloid concentration to be determined. At the same time, crop characteristics from plants growing in these carefully measured sections of the field have to be measured following one of the procedures outlined in detail in Part II (an outline of field procedures for method development for opium poppy used in Afghanistan is attached as Annex III). However, this approach may have a number of problems. Getting the cooperation of farmers might be difficult; ensuring that the opium gum or coca leaves come only from the selected area, without additions and subtractions, may require 24-hour surveillance.

76. Another approach to obtaining the data would be to use facilities at a college or university. The data to develop the correlative models do not need to come from a farmer’s field. However the harvesting practices of local farmers should be used. University personnel are familiar with experimental designs that can maximize the information obtained from the study, testing the relationships under various growing conditions, population densities, management practices, and varieties, and ensuring that the range of conditions observed will enhance model predictions.

15. Identifying an appropriate model for data analysis

77. In order to test old correlations or establish new ones, it is required to record pairs of values for yield and the crop characteristic with which it is correlated. When yield is graphed against the value of the crop characteristic, one hopes to see the data points clustered closely about a line. If the line is straight, data points can be fitted with a linear model. If the data points are scattered, obtaining a reasonable correlation may be difficult. Under those circumstances, first a linear model is tested, then curvilinear models are examined to see if they improve the fit (reflected in an increase in the coefficient of determination ($r^2$), and/or a decrease in the values of the error terms described in the box on p.16). If curvilinear models

14
do not improve the fit significantly, then a linear model may be used, provided that a coefficient of determination ($r^2$) of at least 0.8 can be obtained (see Part I, para. 17, above).

78. The equation for a linear model is:

$$Y = a + b \cdot X$$

(equation 3)

where $Y =$ yield, $X =$ the value of the crop characteristic, and $a$ and $b$ are parameters.

79. Although this model is simple, it has the unfortunate property of predicting that $Y = a$, when $X =$ zero. Since $a$ can be positive or negative, the equation may predict positive or negative yields in the absence of any plant material in the sample, a biological impossibility. This problem can be solved by constraining the graph to go through the origin, i.e. by setting $a = 0$. However, this solution creates a model that fits all the data less well.

80. If the data points fall on a curve, then a curvilinear model is appropriate, and there are many to choose from. If one is certain that the range of values in the data set covers the entire range of values likely to be encountered in the field, then almost any model can be fitted. However, it is difficult to be certain that this is so, and therefore it is more prudent to choose a model that makes botanically plausible predictions beyond the range of the database. Simple polynomial models are said to be "badly-behaved" because they often make implausible predictions outside the range of the database. As a practicality, the most useful models are the rectangular hyperbola and the non-rectangular hyperbola. A rectangular hyperbola describes a curve that goes from one asymptote to another; the asymptotes being at 90° (a right angle) to each other (hence rectangular). In a non-rectangular hyperbola the asymptotes are not at 90°.

81. The equation for a rectangular hyperbola is:

$$Y = \frac{a \cdot X}{(X + b)}$$

(equation 4)

where $a =$ the maximum value of $Y$ when $X$ is large, i.e. the horizontal asymptote, and $b$ defines whether the line curves sharply or gently between the two asymptotes.

82. The equation for a non-rectangular hyperbola is:

$$Y = \frac{(X + b) + ((X + b)^2 - 4 \cdot a \cdot c \cdot X)^{0.5}}{(-2 \cdot c)}$$

(equation 5)

where $a =$ the maximum value of $Y$ when $X$ is large, i.e. the horizontal asymptote, $b$ defines whether the line curves sharply or gently between the two asymptotes, and $c$ defines the slope of the other, i.e. near vertical, asymptote.

83. To determine which model is most suitable, coefficients of determination ($r^2$) should be calculated. It will also be important, whichever model is chosen, to recognize whether the estimated results would be under- or overestimates.

84. To test an existing model (more precisely, to test the formula of an existing model used to estimate yield), the actual crop yield from harvesting a defined area is compared with the calculated yield obtained by using that formula. To this end, the actual yield is plotted against the calculated yield, and a straight line is fitted to these data. The quality of the fit can then be assessed by calculating the coefficient of determination. It should explain at least 80% of the variation ($r^2 = 0.8$) for an acceptable correlation.
The following error terms have also been used to determine the suitability of a model:

**Absolute Mean Error (AME)** is the mean of the absolute difference between observations (O) and predictions (P).

\[
AME = \frac{\sum |O - P|}{n}
\]  
\textit{(equation 6)}

AME describes by how much on average P differs from O.

**Root Mean Square Error (RMSE)** is the square root of the mean difference between O and P squared.

\[
RMSE = \left( \frac{\sum (O - P)^2}{n} \right)^{\frac{1}{2}}
\]  
\textit{(equation 7)}

RMSE reflects the overall accuracy of the shape of the curve. It tends to emphasize large individual errors and is generally considered to be the best criterion of performance.

**Sum of the Residuals (RES)** is the sum of differences between O and P.

\[
RES = \sum (O - P)
\]  
\textit{(equation 8)}

If RES is positive, the model generally underestimates yields, if negative, it overestimates yields. The value of RES indicates how great the over or underestimation is.

**Absolute Sum of the Residuals (|RES|, or ABS)** is the sum of absolute differences between O and P.

\[
|RES| = \sum |O - P|
\]  
\textit{(equation 9)}

Since ABS depends on the number of points in the data set, it can only be used to make comparisons within a data set.

The model that minimizes the error terms should be chosen.

---

**D. Data handling**

**16. Recording data in the field**

85. Providing data recording sheets for all surveyors is a good way of ensuring that all the necessary data are collected. Data that will be collected by different individuals should be recorded on separate data sheets, so that two people are never looking for the same piece of paper and only one person is responsible for each sheet. Data that apply to different levels of organization: the field, individual plants, individual leaves, etc. are also best recorded on separate data sheets for ease of entering the data into a computer (see paras. 89 to 90, below).

86. The data sheets should have a space for each datum to be recorded, with a label to show what should be recorded there. The order in which the data will be collected in the field should determine the order of the data on the data sheet. It is easier to sort data later in a spreadsheet than it is to jump around the data sheet while recording them. If very large numbers of data sheets are involved, printing them on different colours of paper may help during the subsequent analysis. Experience shows that clipboards are not the most convenient way of carrying data sheets in the field. If possible, data sheets should be reduced to a size that fits in a pocket, and they should be bound together to form a small book with a stiff cover.
87. To jog one’s memory, it is also helpful to make a copy of the protocol for the method, which will be used, and a list of the equipment needed in the field to collect the data.

17. Labelling of samples

88. Where samples or subsamples of plant material are collected, for example, for weighing at a later stage, they must all be labelled unambiguously. Labels should also clearly show the origin of the samples and the date they were collected. As soon as possible after the samples are collected, they should be lined up in some order that is meaningful to the individual surveyor, to check that they are all present and correctly labelled.

18. Entering data into computer files

89. Data collected from a field survey or to test or establish a correlation should be entered in an appropriate way into a computer to facilitate calculations and graphing. A database may be one way of doing this. A database is particularly useful if, for instance, all data from a national survey, including data from household surveys and farmers’ interviews are to be entered. Database formats should be designed in a way that can easily be shared.

90. A spreadsheet program may be another way of entering the data into the computer. However, it is a mistake to enter all the data into one large spreadsheet. The data should go into different spreadsheets depending on the level of organization to which they apply. For example, one spreadsheet might contain information about the fields visited: owner, elevation, when fertilized, etc. Another might contain information about plots within the fields: numbers of plants, etc., while a third contains information about individual plants in the plots: height, etc. When the calculations have been made at the lowest level of organization, the results can be summarized and copied to a spreadsheet for a higher level of organization, and so on. This way of handling data makes it possible to enter an equation once and copy it the entire length of the spreadsheet by dragging. If the field data sheets are organized in the same way, it will be easier subsequently to enter the data into the computer.

E. General / other issues

19. Handling of crop samples removed from the field

91. When samples are removed from the field, proper handling and storage are essential. Plant samples lose water by evaporation and by respiration. Loss of water principally decreases the size of the sampled organs and can be reduced by storing the sample in a sealed plastic bag. However, keeping the surface of the sample wet in this way also encourages fungal growth and degradation. Respiration and fungal growth can both be reduced by reducing temperature. Refrigerated samples will keep for weeks.

92. In general, if fresh weight, area or volume is to be measured on the sample, these measurements should be made immediately. If this is not possible, the sample should be stored in a sealed container (e.g., a plastic bag or plastic tube), and measurements should, preferably, be made within one day. Depending on storage conditions, measurements can be made within a maximum of up to 3 days. Even after this time the sample is likely to be

---

*Note that there are no universally agreed 'best practices' for sample handling. The storage conditions and timeframes outlined in this section are intended as a starting point for the establishment of situation-specific procedures.*
partly degraded, although still measurable. Paper bags, which, to a certain extent, also reduce loss of water, may be used to store poppy capsules, for a maximum of 5 days, for example, before volume measurements.

93. Harvested plant parts, which do not need to be measured while fresh, should be stored in cloth or mesh-type bags so that the water evaporated can get out. Measurements should be made within a maximum of 5 days. In all cases, samples should always be stored in the coolest place available.

20. The importance of moisture content in reporting yields

94. Yield figures for coca leaf are often quoted in terms of air dry weight of leaves (Bolivia and Peru) or as fresh weight (Colombia). The water content of fresh coca leaves ranges from about 65 to 75%. The moisture content of bagged, air-dried leaves depends on the relative humidity in the air.

95. A similar problem exists for opium gum. Legally produced opium gum is shipped at 10% moisture content. In India, for example, Grade One opium gum from the field is defined as that having 30% moisture. The conventional wisdom from India is that any gum that is more than 45% moisture has been watered down. However, gum with a water content as high as 55% has been observed.

96. Comparisons of yields are not possible when such a large unknown variable is part of the yield figure. Therefore, to standardize yield estimates, it is recommended that all recorded weights of both coca leaf or opium should be reported as oven dry weights.

97. Some methods for quickly and accurately measuring moisture content would help standardize yield estimates. A TDR (time domain reflectometry) system, currently used to measure soil moisture content and the moisture content of concrete, may prove very useful for measuring the moisture content of opium gum and possibly even the water content of shredded fresh or dry coca leaves. TDR systems generate a microwave signal and analyze the reflected signal to calculate the dielectric constant of the material and then convert that to volumetric water content. The TDR system must be calibrated for the type of material used.

21. Temperatures for oven drying of samples of plant material

98. Different temperatures are used for drying plant material in different laboratories. They range from about 60-80°C. In general, as temperature is increased, more water is removed from the sample, and it is removed faster. However, at very high temperatures some otherwise solid materials may begin to volatilize and further weight may be lost. Also, when very hot samples are removed from the oven to be weighed, they pick up moisture very rapidly from the air. They must be weighed within a few seconds of being removed from the oven. This is especially true of samples that have a large surface area, like leaves. The use of temperatures in the range 60-80°C does not change the amount of water remaining in the sample significantly, i.e. the error is small compared with other errors in the estimation process. 75°C is recommended as the upper limit for drying leaves, so that their weight does not change rapidly while they are being weighed. If coca leaves are to be used for cocaine determination, they should at least be air dried, but not heated above 40°C. Wet coca leaves lose their cocaine by biochemical degradation. Cocaine is also lost from leaves

---

5 Details on how to arrive at 'oven dry weight' are provided in Part II, para. 150 for opium poppy, and para. 179 for coca.
heated above 40°C. Poppy alkaloids are stable in opium gum over a wide range of moisture contents and temperatures.

22. Additional observations useful for interpreting results

99. These Guidelines describe the observations and measurement that must be made to calculate yield using various methods. However, making some additional observations may help to interpret the yield results. One of these additional observations, location of the fields, has already been mentioned (para. 38, above). Other observations to consider include:
   - Sketch map of the field, including streams, roads / paths, etc., and the location of the transect and the plots
   - Slope and aspect of the field
   - Photographs of the field and plants, etc.

100. To the extent possible, it may also be useful, particularly at the beginning of yield-related activities in a country, to gather background information on agronomical practices and on climatic, ecological, geographical and environmental conditions in the area under survey. This helps to identify the different agro-ecological regions within a country, which may differ in terms of yield (see also paras. 36 to 37, above, and Annex IV, which provides an example of information collected during the first opium poppy yield survey in Afghanistan).

23. From yield to production

101. The ultimate goal of most yield studies is to estimate illicit crop production, i.e., the total amount of drug crop harvested from a stated land area, usually a given country, per year (see glossary for definitions). However, in order to arrive at accurate national production figures, several factors have to be considered. They include:
   (i) the net area under cultivation (i.e., total minus eradicated area),
   (ii) a weighted average yield figure (at the national or provincial level),
   (iii) the number of harvests per year, and
   (iv) the yield per harvest (which may not be the same for different harvests).

102. For longer-term strategic drug control decisions, the intention of farmers may also have to be considered. For example, the area which was intended for poppy cultivation may be different from the actual harvestable area, because some poppy seeds may not have germinated on a significant part of the field. For coca, an assessment may be required of how likely it is that farmers will recover apparently abandoned fields.

103. If the ultimate goal is to estimate the illicit drug production, e.g., quantity of heroin and cocaine per country per year, two additional factors need to be considered (i) the drug content, i.e., morphine in opium gum or cocaine in coca leaf, and (ii) the efficiency of clandestine laboratories to convert the raw materials into morphine / heroin and cocaine, respectively.
PART II

A. OPIUM POPPY

1. Growth of the crop

104. The opium poppy is a cool season crop that flowers rapidly in photoperiods of 14 hours or more. Plants are cold hardy but cannot withstand prolonged temperatures of ≤5°C. Poppies are often sown in autumn, overwinter as a rosette, possibly under snow, and flower and are harvested in spring. A typical growing season for the crop would last 120 days. Any or all of the following conditions can influence the actual growing season: daylength, temperature, length of exposure to cold, variety. In mountainous equatorial regions, poppies may be sown year round, and one crop follows another continuously.

105. The plants first go through a vegetative stage and form a rosette of leaves pressed against the soil. Then the stem begins to elongate carrying the leaves up with it. Flower buds become visible among the tuft of leaves at the top of the stem, and branches form in the axis of some upper leaves. At first the flower buds are held upright, then they hang down as the stem carries them clear of the leaves. This is known as the "hook stage". Finally the stem straightens, holding the flower upright again. One day the sepals, enclosing the flower parts, separate, allowing the crinkled petals to expand and reveal the tiny capsule in the centre of the flower. In 1-3 days the petals fall off, but the seed capsule grows rapidly in both volume and weight.

106. About 10-14 days after flower opening (anthesis), capsule volume stops increasing, and the farmers in most parts of the world start lancing the capsules. (Farmers in India wait until about 20 days after flowering). The farmers use a knife to cut about 1 mm deep into the seed capsule wall. White latex, sometimes tinged purple or brown, oozes out of the wound. In South America, latex coozing from a radial cut of a single bladed knife, may be collected immediately. In Southeast and Southwest Asia, the latex oozes from longitudinal cuts of a multi-bladed knife and is allowed to oxidize and solidify overnight into brown opium gum before it is collected the next morning. Results from Pakistan indicate that farmers repeatedly lance the capsules until they stop yielding gum. Harvesting takes place over 7-14 days. The duration of the harvest is proportional to capsule size. During the harvest, the capsules continue to grow in weight as the seeds develop inside. After the gum harvest, the capsules dry on the plants, losing about 50% of their volume but almost none of their dry weight in about 7 days.

2. Recognizing when the crop is ready to be harvested

107. The opium gum is ready to be harvested when the capsules produced by the first flowers are mature. Over the harvesting period, more and more capsules will reach maturity, while the capsules, which had matured first, will stop yielding gum at one point. This means that over a period of 2-4 weeks, a field will contain capsules in different stages of maturity at the same time.

108. In all the methods described below, the mean size or dry weight of mature capsules is determined, and this is multiplied by the total number of mature and immature capsules, and flower buds that are expected to eventually mature and contribute to the gum harvest.

109. Since mean size and dry weight of a poppy capsule are dependent on its maturity, it is important to be able to recognize a mature capsule. Studies have shown that the mean
capsule height and diameter will reach a maximum after approximately 10-14 days after flowering, remain constant for about the following two weeks, before decreasing rapidly afterwards, as a result of shrinkage of the drying capsule. By contrast, capsule dry weight will increase up until the 25th day after flowering and remain almost constant through the drying phase at the end of the capsule's life (Safi, A.H., et al., 2000).

110. For the novice, one of the easiest ways to determine maturity is to examine the capsules in the field to see if they have been lanced. If so, the farmer considers the crop mature and ready for harvest. However, this indicator can be misleading. Farmers will sometimes lance earlier than normal when their immediate need or desire for the gum is more important than the amount or quality of the gum they might harvest. In this case, the size, or dry weight, of the capsules do not represent those of mature capsules, and yield will be underestimated. Using 'lancing' as the only criterion for capsule maturity may also lead to incorrect results with the capsule volume method, if the harvest has been terminated at an unknown time previously to the field visit. In that case, capsules may be beyond the maximum size, and yield will be, again, underestimated.

111. There are a number of other indicators when the capsules are mature and ready for the gum harvest. These indicators may differ among varieties so it is best to learn from those most closely involved with the crop how to recognize a mature capsule.

112. The indicator consistently mentioned by farmers is the firmness of the capsule wall. If the wall is spongy and looks somewhat wrinkled, the capsule probably has not reached its full, mature size. On the other hand, if the capsule is firm to the touch and looks as though it has fully expanded, it is generally ready for harvest.

113. Another indicator that can be used to indicate maturity is the colour of the capsule. When the capsule goes from green to a more yellow-green appearance, it is considered mature. This indicator is variety-dependent and difficult to distinguish for one not familiar with the crop.

114. In most parts of the world, bending and breaking off one point of the stigma surface (i.e., a stigmatic ray, see Figure 2, below) is used as a criterion for maturity. If a bead of latex appears almost immediately on the broken surface, the capsule is mature. However, it is important to know that immature capsules will also yield latex, but much more slowly.

115. Finally, the position of the stigma surface (see Figure 2) can also be used as a quick indicator of capsule maturity. When the capsule is young, the stigma surface is curved around the capsule, lifting and becoming more of a flat plate with maturity. The position of the stigma surface can therefore help to identify maturity but is not always a good indicator because it depends on the variety of poppy. The change in the position of the stigma surface seems to be common in poppy varieties grown in South East Asia.

3. Choosing a method

116. As pointed out in Part I, paras. 20 to 23, opium gum yields can be estimated from the amount of mature capsule material per unit land area using either the mature capsule volume per unit land area ('capsule volume method') or the mature capsule dry weight per unit land area ('capsule dry weight method').

117. Whether to use the capsule dry weight method or the capsule volume method to estimate opium gum yield depends on many factors, but first on the type of poppy grown. If the opium poppy is the dehiscent type, that is, the apertures just below the stigma surface
open at maturity to allow seeds to escape, then it is difficult to use the capsule dry weight method. Seeds account for approximately 50% of the total capsule dry weight at maturity and loss of seed by scattering in the wind can significantly reduce capsule dry weight.

118. The choice of method also depends on the availability of equipment. The capsule dry weight method can only be used where there is a laboratory facility where capsules can be dried.

119. Finally the choice of method also depends on the maturity of the crop to be sampled. Because capsule volume increases rapidly and is stable during the harvesting period, it is the method of choice if sampling occurs during the harvesting period. If the harvest is complete when the field is sampled, then the capsule dry weight method is best with indehiscent poppy. The capsule volume begins to shrink at this point and the volume method could cause an underestimation of yield.

120. The key below can be used to determine which method to use:

<table>
<thead>
<tr>
<th>Is the opium poppy grown a dehiscent type?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes - the capsule volume method has to be used (paras. 124 to 143, below).</td>
</tr>
<tr>
<td>No - both methods are suitable, but there may be other factors that have to be considered, such as the following:</td>
</tr>
<tr>
<td>Can plants (plant parts) be taken from the field?</td>
</tr>
<tr>
<td>Yes - the capsule dry weight method can be used (paras. 146 to 161, below).</td>
</tr>
<tr>
<td>No - the capsule volume method has to be used (paras. 124 to 143, below).</td>
</tr>
<tr>
<td>Are ovens available for drying the capsules, and do the circumstances allow to get samples into the ovens in a few (about 5 maximum) days after sampling?</td>
</tr>
<tr>
<td>Yes - the dry weight method can be used (paras. 146 to 161).</td>
</tr>
<tr>
<td>No - the volume method has to be used (paras. 124 to 143).</td>
</tr>
<tr>
<td>Is the gum harvest still in progress?</td>
</tr>
<tr>
<td>Yes - the volume method should be used (paras. 124 to 143).</td>
</tr>
<tr>
<td>No - the dry weight method should be used (paras. 146 to 161).</td>
</tr>
</tbody>
</table>

4. Measuring the area sampled

121. As pointed out in Part I, para. 53, with small plants like poppy that are normally broadcast, it is easy to mark out a plot and sample the plants that fall within the plot. For plants their size, one square metre is an adequate sampling area. The simplest and lightest device for marking one square metre is a four-metre loop of inelastic string with a knot every metre. Holding the knots, two people can pull the string to form a square. However, it does take two people to just hold the string, and another must make the measurements or collect the sample. Also, the string easily becomes tangled from just being gathered up and pushed into a pocket. Consequently it is much easier to make the metre square from rigid material. Transportation is less of a problem if the sides all consist of two sections each 50 cm long (see Annex II).

5. Handling of crop samples

122. If poppy capsules are removed from the field for later measurement of height and diameter, the capsules can be stored in closed paper bags. These control water loss, but
still allow enough water to evaporate to keep the surfaces of the capsules dry. At room
temperature, capsule dimensions are still measurable after 5 days although an unknown
amount of shrinkage will have occurred. If dry weight is to be measured on the sample, it
should be stored in cloth bags so that the water evaporated can get out. At room
temperature, samples stored in this way will not degrade significantly, but nevertheless, they
should be processed within about 5 days.

123. Opium gum collected for method development or evaluation should be stored in a way
that prevents it from getting mouldy. There is no need to prevent losses of water during
transport, since it is the dry gum weight, which is correlated with capsule volume or capsule
dry weight. However, if the water content of the opium gum sample is to be determined,
which is usually done by measuring the difference between the fresh and the oven dry
weight of the gum sample, the fresh gum should be stored in a properly sealed plastic bag,
and in a cool place, to avoid any leakage and loss of water prior to the determination of its
net weight in an appropriate laboratory facility.

6. Yield survey methods for opium poppy

6.1. Capsule volume method

124. The height and diameter of mature capsules are measured, and mature capsule
volume per square metre is calculated.

6.1.1. Field procedure

125. The field procedure for the capsule volume method involves the following steps:
1. Randomly choose fields where harvest has started (or fields, which are ready to
harvest).
2. Decide boundaries of the field (the general aspects described in Part I, paras. 39 to 41,
apply).
   1. if there are clear boundaries (paths, etc.) -> use them and treat each area as a separate field
   2. if fields are very large, split them up into manageable size, using natural boundaries (paths, etc.), to
      the extent possible
   3. for the purposes of yield assessment, only the area where poppy plants are actually growing should
      be measured (i.e., large parts of a field where seeds did not germinate should be excluded)
3. Record date.
4. Record location of field (GPS + sketch map + photo, if possible).
5. Randomly select 3 (or more) plots per field (the general aspects described in Part I,
paras. 42 to 52, apply).
6. If no poppies occur within the plot at the location, record this and randomly select
another plot (repeat if no poppies occur at other locations)\(^9\).
7. (i) in each plot, count number of mature and immature capsules and flower buds that
   are prominent, i.e., those more than halfway up the plants;\(^9\)
   a) measure height and diameter of all mature capsules, or
   b) measure height and diameter of randomly selected mature capsules\(^10\)
   OR

---

\(^9\) Plots without plants are valid observations and contribute to the sample mean. However, in order to
ensure that crop characteristics of a representative number of mature capsules are measured, the procedure
should be continued until at least 30 mature capsules per field (ideally at least 10 per plot) are sampled.

\(^9\) For practical purposes, a distinction may be made between lanced and non-lanced capsules, rather than
mature and immature. As a general rule, flower buds and immature capsules below ⅓ of the full height of the
plant can be assumed not to mature. Flower buds and immature capsules may also be combined and counted
altogether.

\(^10\) For details of how to subsample in the field, see Part I, para. 56.
(ii) In each plot, remove capsules and flower buds that are prominent, i.e., those more than halfway up the plants. Bag capsules and flower buds and label to identify field and plot. Repeat until three plots with capsules, or a minimum of 30 capsules per field, are sampled. Get samples back to a laboratory facility / secure place and process within a maximum of about 5 days, depending on storage conditions.

6.1.2. Post-field procedure

126. If capsules are measured in the field (i.e., using procedure 7(i) above), no post-field procedure is required; if possible, steps 11 and 12 (para. 132, below) should be carried out in the field, on the intact plants.

127. If capsules are removed from the field (i.e., procedure 7(ii) above), the following post-field procedure should be followed:

128. Recording numbers of capsules and flower buds
1. When the plant samples arrive, group the plant sample bags by teams and fields. Check that the sample bags are all present. Mislabelling can sometimes be caught and corrected at this stage.
2. Prepare a data sheet with column headings such as Team, Field, Plot, Number flower buds, Number immature capsules, Number mature capsules, Total Capsule Fresh Weight, Subsample Capsule Fresh Weight.
3. Lay out the contents of a sample bag on the work surface. Separate the contents of the sample bag into three groups: flower buds, immature capsules, and mature capsules. If there is a flower with petals, place it in the immature capsule group. Record information on field, plot, and numbers in each group in the appropriate columns on the data sheet.
4. Throw away all flower buds and immature capsules in the sample.

![Diagram of capsule with labels for Diameter, Height, Stigma surface, with stigmatic rays, and scar.]

Figure 2

NB. The net height of a capsule should not include the stigma surface. In most cases, the caliper can be placed between the stigmatic rays to measure the net height, as indicated in the photo.

129. If not all of the capsules in the sample returned from the field can be processed, subsampling will be required:

130. Recording fresh weight and selecting a subsample
5. Trim off at the petal scar any stalk attached to the mature capsules (Figure 2).
6. Weigh and record the fresh weight of all mature capsules in the sample for each field and plot.
7. Take a subsample of 10 or more capsules. The subsample should be representative of the whole group, and is best obtained by separating the mature capsules into two, or more,
groups of roughly equal sizes and numbers\textsuperscript{11}. Weigh and record the fresh weight of the subsample under the appropriate column on a data sheet.

8. Throw away the capsules that are not in the subsample.

131. Recording capsule dimensions

9. Prepare a data sheet with appropriate column headings such as Field, Plot, Capsule Height, Capsule Diameter, Number of Gum Cuts, Dry Cuts

10. Taking each mature capsule from the subsample in turn, measure (in mm) capsule height and capsule diameter and record under the appropriate column on a data sheet.

132. Extra data useful for interpreting results, but not needed for correlations:

11. Count the number of knife cuts on the capsule that produced gum (Number of Gum Cuts) and record on data sheet.

12. Finally record the presence (yes) or absence (no) of dry cuts, i.e., cuts that produced no gum (Dry Cuts).

6.1.3. Theory and calculations

6.1.3.1. Formulae for yield calculation

133. Opium gum yield, $Y$ (kg/ha), can be estimated from capsule volume using different formulae. To this end, the total capsule volume per one square metre ($\text{cm}^3/\text{m}^2$) is calculated and correlated with the oven dry gum yield (kg/ha). Below are three formulae, which were developed using data from Pakistan and/or Thailand. They were established for, and applied by, the US Government (Acock, B. and Acock, M.C., 2001; Safi, A.H., et al., 2000; Acock, B. and Acock, M.C., 2000; USDA, 1993; USDA 1992).

134. While it may be convenient to use an existing formula, especially in the beginning of yield-related activities in a country, it should be understood that any correlation used has to be tested to establish whether it is applicable to the locally obtained data (see paras.144 to 145, below); if possible, alternative formulae should be considered as well.

135. a) Non-rectangular hyperbola

As an example, using equation 5 (Part I, para.82) and fitting a non-rectangular hyperbola to the combined data from Thailand and Pakistan, the following formula has been derived:

$$Y = \left[ \left( \frac{VC}{1495} \right) + 1495 \right] ^2 - 395.259 \cdot VC^{0.5} \right] / 1.795$$

where $Y$ = dry gum weight (kg/ha),

$VC$ = projected mature capsule volume per square metre ($\text{cm}^3/\text{m}^2$) (paras. 141 to 143, below explains how to arrive at $VC$).

(NB. The numbers in the above formula result when the following values for parameters $a$, $b$, and $c$ in equation 5 (p.15) are used: $a=110.1$, $b=1495$, $c=0.8975$)

136. This formula is a workable option if no country-specific formula has been developed. In the absence of a model development phase, it can be used to get an overview of potential yield figures for individual plots. The formula is based on the typical number of plantings in Thailand and the maximum number possible on poppy grown in Pakistan. The range of capsule volumes per square metre used to develop this formula was 0 to 1,600 cm\(^3\)/m\(^2\). In

\textsuperscript{11} For instance, if the fresh weight of poppy capsules in a sample is 567g, and oven space to dry is only 100g, subsampling can be done as follows: Capsules are divided into 6 groups by taking the largest 6 capsules and putting one in each group, then the next 6, etc., until all capsules are allocated. Any group can then be taken as subsample and its fresh weight measured immediately. All measurements are made on the subsample.
practice, most capsule volumes at the lower end of the range were from Thailand, while capsule volumes observed in Pakistan ranged at the higher end. For the data collected, the correlation explains 83% of the yield variation.

137. Fitting a non-rectangular hyperbola to data from Pakistan alone, i.e., to data emphasizing the lower end of the range of observed capsule volumes, resulted in the following formula:

\[
Y = \left(\frac{(VC + 1172) - (VC + 1172)^2 - 2160 \cdot VC^{0.5}}{12}\right)
\]

where \(Y\) = dry gum weight (kg/ha), \(VC\) = projected mature capsule volume per square metre \((cm^3/m^2)\) ( paras. 141 to 143, below explains how to arrive at VC).

(NB. The numbers in the above formula result when the following values for parameters a, b, and c in equation 5 (p.15) are used: a=90, b=1172, c=6)

138. The formula is based on the maximum possible number of lancings. The range of capsule volumes per square metre used to develop this formula was 0 to 1,800 \(cm^3/m^2\). For the data collected, the correlation explains 66% of the yield variation.

139. b) Linear correlation
A linear correlation has been developed using data from two subsequent harvesting seasons in Thailand, i.e., data emphasizing the lower end of observed capsule volumes:

\[
Y = 1.89 + 0.0412 \cdot VC
\]

(corrected from originally published value of 0.412 
(Acock, B. and Acock, M.C., 2000))

where \(Y\) = dry gum weight (kg/ha), \(VC\) = projected mature capsule volume per square metre \((cm^3/m^2)\) ( paras. 141 to 143, below explains how to arrive at VC).

(NB. The numbers in the above formula result when the following values for parameters a and b in equation 3 (p.15) are used: a=1.86, b=0.0412)

140. The formula is based on three lancings. The range of capsule volumes per square metre used to develop this formula was 0 to 900 \(cm^3/m^2\). For the data collected, the correlation explains 86% of yield variation \((r^2 = 0.86)\).

6.1.3.2. Projection of final capsule volume per square metre

141. The final volume of capsules at the end of gum harvest can be projected by counting the number of flower buds and immature capsules in the sampled area and assuming that, on average, all will grow to the mean volume of the mature capsules present in the sample. Without any mature capsules in the sample, no estimate can be made.

142. Projected capsule volume for the sample at the end of gum harvest, \(VC\) \((cm^3/m^2)\) is calculated using the following equation 10:

\[
VC = (NFB + NCI + NCM) \cdot VCM / NCM \quad \text{(equation 10)}
\]

where \(NFB\) = number of flower buds per square metre \((\text{number/m}^2)\)  
\(NCI\) = number of immature capsules per square metre \((\text{number/m}^2)\) 
\(NCM\) = number of mature capsules per square metre \((\text{number/m}^2)\)  
\(VCM\) = total volume of mature capsules per square metre \((cm^3/m^2)\)
143. The total volume of all mature capsules per square metre, \( VCM \) (cm\(^3\)/m\(^2\)), is determined by one of the following ways:

1. If capsule measurements have been done in the field, i.e., on the intact plants (see para. 125, field procedure, step 7(i), above), \( VCM \) is obtained either (i) by summing up the volumes of all mature capsules in a plot, following equation 11:

\[
VCM = \Sigma VCM_i
\]  
where \( VCM_i \) = volume of individual mature capsules (cm\(^3\))

or (ii) by determining the mean volume of the mature capsules sampled (\( VCM_s \)), and multiplying this figure with the total number of mature capsules per plot (\( NCM \)), following equation 12:

\[
VCM = VCM_s \cdot NCM
\]  
(equation 12)

The volume of individual capsules (\( VCM_i \)) is calculated using the following equation 13:

\[
VCM_i = \left( \frac{4}{3} \pi \cdot a \cdot b^2 \right)
\]  
(equation 13)

where \( a = \) half the capsule height (cm), \( b = \) half the capsule diameter (cm).

(NB: if capsule height and diameter were measured in mm, equation 13 has to be divided by 1000, to convert those measurements into a volume (cm\(^3\))

2. If capsules have been removed for later measurement, \( VCM \) is either measured directly, or, if subsampling had been necessary, \( VCM \) is given by:

\[
VCM = VCMSS \cdot FWCM / FWCMSS
\]  
(equation 14)

where \( VCMSS = \) total volume of mature capsules in a subsample (cm\(^3\)), \( FWCM = \) fresh weight of mature capsules per square metre (g/m\(^2\)), and \( FWCMSS = \) fresh weight of mature capsules in the subsample (g).

The total volume of all mature capsules in the subsample, \( VCMSS \) (cm\(^3\)), is calculated from the height and diameter of individual capsules (Figure 2) using equation 13, above.

6.1.4. Collecting data to develop and/or test a method

144. The general aspects described in Part I, paras. 68 to 76, apply. In principle, method development and evaluation follow the same field and post-field procedures as outlined above. In addition, the gum from groups of plants growing on a known land area has to be collected. If gum collection is not done on farmers’ fields and by the farmers themselves following traditional harvesting techniques, the typical number of lancings in the region surveyed has to be determined, and that information should be taken into account for gum collection. From the pairs of data collected, the formula that best describes the relationship between total capsule volume per unit land area and gum yield from that same area, should be determined, using coefficients of determination and/or error terms as indicators for the
quality of the fit (Part I, paras. 77 to 84). As an example, the outline for field procedures for
method development, used in Afghanistan, is attached in Annex III.

145. To test an existing formula, the calculated yield using that formula is compared with
the actual gum yield (see para. 84).

6.2. Capsule dry weight method

146. The dry weight of mature capsules is measured, and mature capsule dry weight per
square metre is calculated.

6.2.1. Field procedure
(same as para. 125, applying step 7(ii))

6.2.2. Post-field procedure
(Note: steps 1-8 are the same as those in paras. 126 to 130)

147. Recording numbers of capsules and flower buds
1. When the plant samples arrive, group the plant sample bags by teams and fields.
Check that the sample bags are all present. Mislabelling can sometimes be caught and
corrected at this stage.
2. Prepare a data sheet with column headings such as Team, Field, Plot, Number flower
buds, Number immature capsules, Number mature capsules, Total Capsule Fresh
Weight, Subsample Capsule Fresh Weight.
3. Lay out the contents of a sample bag on the work surface. Separate the contents of
the sample bag into three groups: flower buds, immature capsules, and mature
capsules. If there is a flower with petals, place it in the immature capsule group.
Record information on field, plot, and numbers within groups in the appropriate
columns or a data sheet.
4. Throw away all flower buds and immature capsules in the sample.

148. If not all of the capsules in the sample returned from the field can be processed, for
example, due to limited oven space available, subsampling will be required:

149. Recording fresh weight and selecting a subsample for drying
5. Trim off at the petal scar any stalk attached to the mature capsules (Figure 2).
6. Weigh and record the fresh weight of all mature capsules in the sample for each field
and plot.
7. Take a subsample of 10 or more capsules. The subsample should be representative
of the whole group, and is best obtained by separating the mature capsules into two,
or more, groups of roughly equal sizes and numbers (for details, see para. 130, step 7).
Weigh and record the fresh weight of the subsample under the appropriate column
on a data sheet.
8. Throw away the capsules that are not in the subsample.

150. Drying of subsample to constant weight
9. Place the subsample bag in an oven for 1-2 days at 80°C until its weight is stable, i.e.,
during that period, from time to time, take the bag out of the oven, check its weight,
and continue the drying process until the weight does not change any more. Record
the oven dry weight of each subsample.
151. Extra data useful for interpreting results, but not needed for correlations:
   10. Count the number of knife cuts on the capsule that produced gum (Number of Gum Cuts) and record on data sheet.
   11. Finally record the presence (yes) or absence (no) of dry cuts, i.e., cuts that produced no gum (Dry Cuts).

6.2.3. Theory and calculations

6.2.3.1. Formulae for yield calculation

152. Opium gum yield, $Y$ (kg/ha), can be estimated from capsule dry weight using different formulae. To this end, the total capsule dry weight per square metre ($g/m^2$) is calculated and correlated with the oven dry gum yield (kg/ha). Below are three formulae, which were developed using data from Pakistan and/or Thailand. They were established for, and applied by the US Government (Acoc, B. and Acoc, M.C., 2001; Safi, A.H., et al., 2000; Acoc, B. and Acoc, M.C., 2000; USDA, 1993; USDA 1992).

153. While it may be convenient to use an existing formula, especially in the beginning of yield-related activities in a country, it should be understood that any correlation used has to be tested to establish whether it is applicable to the locally obtained data (see paras. 162 to 163, below); if possible, alternative formulae should be considered as well.

154. a) Non-rectangular hyperbola
   As an example, using equation 5 (Part I, para. 82) and fitting a non-rectangular hyperbola to data from Thailand and Pakistan, the following formula has been derived:

   
   $Y = \frac{[(\text{DWC} + 184) - (\text{DWC} + 184)^2 - 493.92 \times \text{DWC}^{0.85}]}{2.94}$

   where $Y =$ dry gum weight (kg/ha),
   \[
   \text{DWC} = \text{projected mature capsule dry weight per square metre (g/m}^2\text{)} \quad \text{paras. 160 to 161, below explains how to arrive at DWC}.
   \]
   (NB. The numbers in the above formula result when the following values for parameters $a$, $b$, and $c$ in equation 5 (p.15) are used: $a=84$, $b=184$, $c=1.47$)

155. This formula is a workable option if no country-specific formula has been developed. In the absence of a model development phase, it can be used to get an overview of potential yield figures for individual plots. The formula is based on the typical number of lancings in Thailand and the maximum number possible on poppy grown in Pakistan. The range of capsule dry weight per square metre used to develop this formula was 0 to 250 g/m². In practice, most capsule dry weights at the lower end of the range were from Thailand, while capsule dry weights observed in Pakistan ranged at the higher end. For the data collected, the correlation explains 79% of the yield variation.

156. Fitting a non-rectangular hyperbola to data from Pakistan alone, i.e., to data emphasizing the higher end of the range of observed capsule dry weights, resulted in the following formula:

   
   $Y = \frac{[(\text{DWC} + 105) - (\text{DWC} + 105)^2 - 4.368 \times \text{DWC}^{0.85}]}{0.026}$

   where $Y =$ dry gum weight (kg/ha),
   \[
   \text{DWC} = \text{projected mature capsule dry weight per square metre (g/m}^2\text{)} \quad \text{paras. 160 to 161, below explains how to arrive at DWC}.
   \]
(NB. The numbers in the above formula result when the following values for parameters a, b, and c in equation 5 (p.15) are used: a=84, b=105, c=0.013)

157. The formula is based on the maximum possible number of lancings. The range of capsule dry weight per square metre used to develop this formula was 0 to 250 g/m². For the data collected, the correlation explains 64% of the yield variation.

158. b) Linear correlation
A linear correlation has been developed using data from two subsequent harvesting seasons in Thailand, i.e., data emphasizing the lower end of observed capsule dry weights:

\[ Y = 0.997 + 0.279 \times DWC \]

where \( Y \) = dry gum weight (kg/ha),
\( DWC \) = projected mature capsule dry weight per square metre (g/m²) ( paras. 161 to 161, below explains how to arrive at DWC).
(N3. The numbers in the above formula result when the following values for parameters a, b, and c in equation 3 (p.15) are used: a=0.997, b=0.279)

159. The formula is based on three lancings. The range of capsule dry weight per square metre used to develop this formula was 0 to 200 g/m². For the data collected, the correlation explains 91% of yield variation (\( r^2 = 0.91 \)).

6.2.3.2. Projection of final dry weight per square metre

160. The final dry weight of capsules at the end of gum harvest can be projected by counting the number of flower buds and immature capsules in the sampled area and assuming that on average, all will grow to the mean dry weight of the mature capsules present in the sample. Without any mature capsules in the sample, no estimate can be made.

161. Projected capsule dry weight for the sample at the end of gum harvest, \( DWC \) (g/m²) is calculated using equation 15:

\[ DWC = (NFB + NCI + NCM) \times DWCM / NCM \]  
\( \text{equation 15} \)

where \( NFB \) = number of flower buds per square metre (number/m²),
\( NCI \) = number of immature capsules per square metre (number/m²),
\( NCM \) = number of mature capsules per square metre (number/m²),
\( DWCM \) = total dry weight of mature capsules per square metre (g/m²).

The total dry weight of all mature capsules per square metre, \( DWCM \) (g/m²) is either measured directly or, if subsampling had been necessary, is given by:

\[ DWCM = DWCMSS \times FWCM / FWCMSS \]  
\( \text{equation 16} \)

where \( DWCMSS \) = total dry weight of mature capsules in a subsample (g),
\( FWCM \) = fresh weight of mature capsules per square metre (g/m²) and
\( FWCMSS \) = fresh weight of mature capsules in the subsample (g).

6.2.4. Collecting data to develop and/or test a method

162. The general aspects described in Part I, paras. 68 to 76, apply. In principle, method development and evaluation follow the same field and post-field procedures as outlined
above. In addition, the gum from groups of plants growing on a known land area has to be collected. If gum collection is not done on farmers’ fields and by the farmers themselves following traditional harvesting techniques, the typical number of lancings in the region surveyed has to be determined, and that information should be taken into account for gum collection. From the pairs of data collected, the equation that best describes the relationship between total capsule dry weight per unit land area and gum yield from that same area, should be determined, using coefficients of determination and/or error terms as indicators for the quality of the fit (Part I, paras. 77 to 84).

163. To test an existing formula, the calculated yield using that formula is compared with the actual gum yield (see para 84).
B. COCA

164. Coca is an amazingly resilient perennial, tropical tree. Harvesting occurs 3-4 times (Peru and Bolivia) or 4-6 times per year (Colombia) and consists of removing all leaves from the plant. In some countries such as Bolivia and Peru, the leaves are dried in the sun before they are processed in a “laboratory”. In other countries such as Colombia, the fresh leaves are processed immediately after picking. The alkaloid, cocaine, is extracted from the leaves.

1. Growth of the crop

165. Coca plants are grown mostly from seeds, or from cuttings. The plants are usually propagated in nursery beds under light shade, although cuttings are sometimes rooted in the field. When the seedlings are about 20 cm tall, or the cuttings from nursery beds have rooted, they are transplanted into rows in the field. In many parts of South America the rows run at right angles to the contour lines, radiating down the hillsides. Row spacing is frequently irregular. Sometimes several plants are placed in each planting hole, where they grow together like one plant. Most farmers wait 18 months before taking their first harvest, to let the plants get established, but some take their first harvest after only 6 months. A few farmers grow another crop between rows of coca during the first year to provide partial shade for the coca and an income from the land.

166. Coca leaves are harvested by stripping them from the branches. The plants grow a new flush of leaves in about 2 weeks after the harvest. Within 2-3 months, these leaves grow to full size, thicken, and turn dark green, indicating the next harvest. Rain may cause the plants to flush again and this will delay the harvest until the new leaves are mature. Farmers generally avoid picking soft young leaves, because of the risk of damaging the growing points or the branches. This is why most farmers also wait 18 months for their first harvest. With regular picking the coca plant remains relatively small. Yield peaks about 2.5 years after planting and declines steadily with each year thereafter. With some varieties of coca, the farmers rejuvenate the plants about every 7 years by cutting them off completely about 20 cm above soil level and letting new shoots grow out.

2. Recognizing when the leaves are ready for harvesting

167. All the yield survey methods require measurements to be made when the leaves are ready to be harvested. In some cases, the farmers may be prepared to advise when they will be harvesting. However, surveyors must also be able to recognize whether the leaves are ready to be harvested, because in some regions, farmers will follow market circumstances rather than crop maturity in deciding whether or not they will harvest a field.

168. The appearance of the terminal leaf on a shoot can be used as an indicator: when a flush of growth occurs, the young leaves are small, thin and yellow green, and the terminal bud on each shoot is covered by a curled leaf that elongates first, then uncurls, revealing a smaller curled leaf inside it (see Figure 3). As the leaves mature, they become larger, thick, stiff and dark green. When the terminal leaf on most of the shoots is as large, thick and dark green as the others on the same shoot, and the terminal bud is a short brown stub of bud scales, the leaves are ready to be harvested.
3. Choosing a method

169. As pointed out in Part I, paras. 24 to 27, coca leaf yields can be estimated by three different methods, (i) the actual harvest method, (ii) the light interception method, and (iii) the canopy subsample method. Since leaf yields vary with the season, surveys need to be repeated for all harvests during a year.

170. The key below can be used to determine which method to use:

Do the circumstances and resources allow to actually harvest samples of the crop?

Yes - the actual harvest method should be used (paras. 175 to 180, below).

No - other factors have to be considered, such as the following:

Is the equipment available for measuring leaf area index on a standing crop?

Yes - the light interception method can be used (paras. 182 to 187, below)

No - the canopy subsampling method has to be used (paras. 189 to 203, below)

4. Measuring the area sampled

171. As pointed out in Part I, para. 54, for larger plants like coca, it is often desirable to sample only a few plants and to know how much of the field area they represent. Fortunately most large plants are grown in rows and this simplifies the task. The procedure described below allows accurate determination of the sampling area. Accuracy is crucial here because the yield for the area is usually extrapolated to give yield per hectare. Small errors in the sampling area translate into large errors in the estimate.

172. A certain number of plants, for example 5, along a row are chosen. In some cases, where plants are grown in parallel rows, the plot they occupy will be rectangular; in others, where plants are grown in diverging rows, it will be a trapezoid (see example in Figure 4). The area, \( A \), of the plot is determined by measuring distances \( a, b, c, d, e \) and inserting them in equation 17 (NB. For a rectangular plot, distances \( d \) and \( e \) would be the same):

\[
A = (b + ((a + c) / 2)) * ((d + e) / 4) \quad \text{(equation 17)}
\]
173. Another approach\(^\text{12}\) to define the sampling area (plot) is to select a defined segment (e.g., 5 metres, or distance \(b\) in Figure 4) of a row of coca plants. Depending on whether rows are parallel or diverging, the area of the plot is calculated in one of the following ways:

a) If rows are parallel, the formula of a rectangle is used, and the length of the segment along the row (e.g., 5 metres) is multiplied by the distance between the rows (i.e., \(d/2\) or \(e/2\), which would be the same in a rectangle).

b) If rows are diverging, the area of the plot is calculated using equation 17, with a standardized length (e.g., 5 metres) for distance \(b\) in Figure 4, and with distances \(a\) and \(c\) being zero (0). In this case, equation 17 is reduced to the following:

\[
A = 5 \times ((d - e) / 4)
\]

5. Handling of leaf samples

174. If leaf area of coca leaves is to be measured (e.g., as part of the light interception method), leaves should ideally be processed immediately. If this is not possible, they can be stored in clear plastic bags to keep them fresh and prevent water loss and shrinkage. In this case, leaves have to be processed within 1-3 days, depending on storage conditions. Otherwise, harvested leaves should be stored in cloth or mesh-type bags so that the water evaporated can get out. The bags should always be stored in a dark, dry and cool place. Processing within a maximum of 5 days is desirable.

6. Yield survey methods for coca

6.1. Actual harvest method

175. The leaves are harvested from sample plots in the same way that they are harvested from the whole field, preferably by the farmers themselves. The area of each sample plot is determined. The fresh weight of all the leaves from each sample plot is determined. If a drying oven is available, subsamples are taken and their fresh weights recorded. The

\(^{12}\) At the time of the writing of these Guidelines, this approach was used in Colombia. It facilitates field procedures in situations where the terrain is not easily accessible, and where the distance between plants is highly variable.
subsamples are returned to a laboratory facility / secure place for drying and re-weighing (if no drying oven is available, a standard factor for moisture has to be used).

6.1.1. Field procedure

176. The field procedure for the actual harvest method involves the following steps:
1. Randomly choose fields ready to harvest.
2. Decide boundaries of the field (the general aspects described in Part I, paras. 39 to 41, apply).
3. Record date.
4. Record location of field (GPS and/or cartographic record + sketch map + photo, if possible).
5. Randomly select 3 or more plots (the general aspects of how to lay a transect are described in Part I, paras. 42 to 52), depending on the size of the field:
   - Go to the centre of the field;
   - Spin stick to determine the direction of the transect;
   - Lay transect from one edge of the field to the other; for plots of more than 0.5ha, lay down a second transect perpendicular to the first.
   - Locate plots in even distances along the transect(s), according to the following scheme:

   ![Diagram of transects with field size and number of plots]

<table>
<thead>
<tr>
<th>Field size:</th>
<th>Number of plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.5 ha</td>
<td>3</td>
</tr>
<tr>
<td>from 0.5 to 1.0 ha</td>
<td>5</td>
</tr>
<tr>
<td>&gt; 1.0 ha</td>
<td>9</td>
</tr>
</tbody>
</table>

6. At each defined point, select at least 5 plants in the closest row\textsuperscript{13}.
   Alternatively, if the approach described in para. 173 is followed: at each point, mark out 5 metres over the closest row. To this end, a 5m coloured thread may be used. The ends of the thread are attached to the nearest plants.
7. Measure the area of each plot and record on a data sheet.
8. Harvest the leaves from all the plants in each plot in turn, and place them in a container (bag or basket) in a cool, dry place until they can be weighed.
9. When all leaves have been collected from a plot, weigh the container plus leaves on a balance accurate to three significant figures (see Part I, para. 67).
10. Subtract the weight of the container to obtain a fresh weight of all sampled leaves (This is FWLS in paras. 178 and 180, below). On a data sheet, identify field and plot, container weight, and fresh weight of leaves plus container.

\textsuperscript{13} The nearest plant to the transect determines the direction of the plot.
177. If a drying oven is available:
11. Weigh a zip lock bag on a balance to an accuracy of three significant figures (this is best done before going to the field).
12. Take a subsample of leaves by grabbing a handful from the centre of the sample container, put these in the zip lock bag, and weigh bag plus leaves on the same balance. On the zip lock bag, record field plot, weight of zip lock bag and weight of zip lock bag plus leaves.
13. Return the zip lock bag and subsample of leaves to an appropriate laboratory facility for drying. 14

6.1.2. Post-field procedure

178. If no drying oven is available:
1. Assume that \( DWLS = 0.30 \cdot FWLS \)
   where \( DWLS \) is dry weight of a sample of leaves (g), and
   \( FWLS = \) fresh weight of the same sample of leaves (g).
   (NB. The value 0.30 was determined for Hawaii conditions. Leaf dry weight has been calculated from leaf fresh weight for Peru and Bolivia using 0.35.)
2. Calculate leaf yield (kg/ha) using the following modification of equation 18 below:
   \( Y = (DWLS / AS) \cdot 10,000. \)

179. If a drying oven is available:
1. Dry the subsample of leaves for approx. 8 hours in an oven at 75°C until weight is stable, i.e., during that period, from time to time, take the sample out of the oven, check its weight, and continue the drying process until the weight does not change any more. Record the final oven dry weight of each subsample.
2. Calculate leaf yield using equation 18 below.

6.1.3. Theory and calculations

180. Coca leaf yield, \( Y \) (kg/ha), is calculated using the following equation 18:
   \[
   Y = \left( \frac{FWLS}{AS} \right) \cdot \left( \frac{DWLSS}{FWLSS} \right) \cdot 10,000 \quad \text{(equation 18)}
   \]
   where \( FWLS = \) fresh weight of a leaf sample (kg),
   \( AS = \) area from which the sample came (m^2),
   \( DWLSS = \) dry weight of a subsample of leaves (g),
   \( FWLSS = \) fresh weight of the subsample of leaves (g), and
   10,000 is the number of square metres in a hectare.

6.1.4. Collecting data to test the method

181. The method can only be tested by harvesting plots within a defined area, and then harvesting the whole area. To this end, it is necessary to:

(i) harvest the leaves from randomly selected plots and calculate the total yield;
(ii) harvest and weigh leaves from the whole field;

14 NB: In order to prevent degradation of sample material, if it cannot be transported to a laboratory facility within a day, it is advisable to pack and transport the subsamples in a cloth (or mesh-type) bag. The bag should always be kept in a dry, dark and cool place.
(iii) compare the real yield (from step ii) with the estimated yield, and define the accuracy of the method.

6.2. Light interception method

182. Leaf area index (LAI, = leaf area / ground area) is measured at several points throughout the field. Samples of leaves are taken back to an appropriate laboratory facility. The area and dry weight of these leaves are measured and specific leaf area (SLA, = leaf area / leaf dry weight) is determined.

6.2.1. Field procedure

183. The field procedure for the light interception method involves the following steps:
1. Randomly choose fields ready to harvest.
2. Decide boundaries of the field (the general aspects described in Part I, paras.39 to 41, apply).
3. Record date.
4. Record location of field (GPS + sketch map + photo, if possible).
5. Go to centre of field. Spin stick to determine direction of transect. Lay transect from one edge of the field to the other (the general aspects described in Part I, paras.42 to 52, apply).
6. Take the equipment for measuring light interception to one end of the transect.
7. Move into the canopy along the transect a distance of approximately three times the height of the plants. (For example, if the plants are about 1 metre high, move along the transect for 3 metres).
8. Place the equipment on the ground, and remove any nearby weeds.
9. Level the light sensor (some instruments have self-leveling devices that make this task much easier), and take a reading of LAI.
10. Move along the transect a distance of approximately three times the height of the plants, and repeat steps 8 and 9.
11. Continue measuring at the same intervals until you are 3 plant heights away from the end of the transect. The light interception equipment will display a value of LAI for each measurement you take. Record the mean value of LAI for the field.
12. Remove approximately 250 leaves from the plants to obtain leaf area and dry weight measurements. Keep leaves from drying until leaf area measurements are taken.
13. Take this sample to an appropriate laboratory facility.

6.2.2. Post-field procedure

184. The post-field procedure for the light interception method involves the following steps:
1. Measure the area of the sample of fresh leaves = ALS (see para. 186, below).
2. Dry the leaves for approx. 8 hours in an oven at 75°C until their weight is stable, i.e., during that period, from time to time, take the sample out of the oven, check its weight, and continue the drying process until the weight does not change any more.
3. Weigh leaves on a balance that is accurate to ±0.1 gram = DWLS.
4. Use the measurements of LAI, ALS and DWLS in the equations below to calculate Y.

6.2.3. Theory and calculations

185. Coca leaf yield, Y (kg/ha), is calculated using the following equation 19:

\[ Y = \left( \frac{\text{LAI}}{\text{SLA}} \right) \times 10,000 \]  
\[ \text{(equation 19)} \]
where \( \text{LAI} \) = leaf area index = leaf area per unit area (ha/ha),
\( \text{SLA} \) = specific leaf area = leaf area per unit leaf dry weight (m\(^2\)/kg), and
10,000 is the number of square metres in a hectare.

186. How to calculate SLA.
A sample of fresh leaves is spread out on a surface so that the leaves pass between a light source and a sensor, and intercept the beam of light. The amount of light intercepted is measured, and accumulated leaf area (ALS) is calculated and displayed. A sample of leaves that has an area of about 2000 cm\(^2\) is sufficient to determine specific leaf area. This sample is then dried in an oven and weighed (DWLS). Then specific leaf area, SLA (m\(^2\)/kg) is given by:

\[
\text{SLA} = 0.1 \times \frac{\text{ALS}}{\text{DWLS}} \quad \text{(equation 20)}
\]

where
\( \text{ALS} \) = leaf area of sample (cm\(^2\)),
\( \text{DWLS} \) = oven dry weight of leaves in the same sample (g),
0.1 converts measurements in cm\(^2\)/g to m\(^2\)/kg.

187. If it is not possible to measure SLA, the figure of 17.7 m\(^2\)/kg can be used. This is the mean value for many samples of \textit{Erythroxylum coca} var. \textit{coca} measured in Hawaii. In Bolivia, a value of 17.8 m\(^2\)/kg was found for a limited number of samples. For the Hawaii location, specific leaf area (SLA) of \textit{Erythroxylum coca} var. \textit{coca} has been found to be very stable over seasons.

6.2.4. Collecting data to test the method

188. The procedure to test the light interception method involves the following steps:
1. Mark out a square plot in a field of coca plants. The sides of the square should be three times the height of the coca plants. Arrange the plot so that its boundaries pass between plants, not through them.
2. Measure the size of the plot accurately.
3. Restrict the light sensor on the light interception equipment to a 180° field of view.
4. Place the sensor midway along one side of the plot, pointing towards the centre. Level the sensor, and take a reading of LAI.
5. Move to the middle of another edge and measure LAI again.
6. Continue thus until you get three similar readings.
7. Harvest all the leaves from plants in the plot.
8. Weigh all the leaves as soon after harvesting as possible to get a total fresh weight.
9. Take a representative sample of these leaves (about 300 g), and weigh them fresh.
10. Take another sample to calculate SLA (as indicated above).
11. Calculate leaf yield (g/m\(^2\)) from the selected plot using the following equation 21:

\[
\text{YS} = (\text{FWLS} / \text{AS}) \times (\text{DWLSS} / \text{FWLSS}) \quad \text{(equation 21)}
\]

where
\( \text{YS} \) = leaf yield (g/m\(^2\)),
\( \text{FWLS} \) = total fresh weight of leaves harvested from the plot (g),
\( \text{AS} \) = area of the plot (m\(^2\)),
\( \text{DWLSS} \) = oven dry weight of subsample of leaves (g), and
\( \text{FWLSS} \) = fresh weight of subsample of leaves (g).

12. Calculate leaf yield (kg/ha) using equation 19 above.
13. Compare results from Step 11 with results from Step 12 (NB. Results from step 11 are in g/m\(^2\) and have to be multiplied by 10 to convert them into a kg/ha figure).
6.3. Canopy subsample method

189. Leaves are removed from growing points from a subsample of plants located throughout the field. The height, in-row width and between-row width of the sampled plants are also measured. Plant density is recorded. If no oven is available, the fresh weight of the sample of leaves is measured. If an oven is available, the dry weight of the sample of leaves is also measured.

6.3.1. Field procedure

190. The field procedure for the canopy subsample method involves the following steps:
1. Randomly choose fields ready to harvest.
2. Decide boundaries of the field (the general aspects described in Part I, paras. 39 to 41, apply).
3. Record date.
4. Record location of field (GPS + sketch map + photo, if possible).
5. Go to centre of field. Spin stick to determine direction of transect. Lay transect from one edge of the field to the other.
6. At regular intervals along the transect, identify plants (at least 50) to be measured.
7. On each selected plant, record average canopy height, canopy width within the row and canopy width between rows. To do this, try to see the plant as an ellipsoid and ignore the odd long branches that poke out above the mass of foliage.
8. Remove the leaves from one growing point on each selected plant, and place them in a pre-weighed 1-gallon (4 litres, approximately) size zip lock bag. (It is very important that only leaves formed from one growing point are sampled per plant. This requires an understanding of how the leafy crop regenerates itself, or some training of helpers who are not biologists.)
9. Move along the transect and repeat steps 7 and 8, adding to the leaves in the zip lock bag until all 50 plants have been measured. Keep the zip lock bag of leaves in a cool, dry place.

191. If no oven is available:
10. When all the samples have been collected, weigh the zip lock bag on a balance accurate to 0.01 gram.
11. Subtract the weight of the zip lock bag to obtain a fresh weight of all sampled leaves. This is FWLS in para. 193, below.

192. If an oven is available:
12. Return the sample of leaves to an appropriate laboratory facility for drying.

6.3.2. Post-field procedure

193. If no oven is available:
1. Assume that \( \text{DWLS} = 0.30 \times \text{FWLS} \)
   where \( \text{DWLS} \) is dry weight of a sample of leaves (g), and \( \text{FWLS} \) is fresh weight of the same sample of leaves (g).
   (NB: The value 0.30 was determined for Hawaii conditions. Leaf dry weight has been calculated from leaf fresh weight for Peru and Bolivia using 0.35.)

194. If an oven is available:
1. Dry the sample of leaves in an oven at 75°C until their weight is stable, i.e., during that period, from time to time, take the sample out of the oven, check its weight, and
continue the drying process until the weight does not change any more. Record the final oven dry weight. This is DWLS in equation 22, below.

6.3.3. Theory and calculations

195. At each harvest, all leaves formed since the last harvest are removed from the plants. Therefore, the leaves on a single growing point are representative of the amount of growth that has occurred since the last defoliation (see Figure 3, above). A large weight of leaves indicates a high yield and conversely, a small weight of leaves indicates a low yield. Multiplying average leaf weight per growing point by the estimated number of growing points in the crop will give leaf yield. The number of growing points is related to the volume of the plant canopy.

196. Coca leaf yield, \( Y \) (kg/ha), is calculated using the following equation 22:

\[
Y = \left( \frac{\text{DWLS}}{\text{NGP}} \right) \cdot \left( \frac{\text{VPS}}{\text{VGP}} \right) \cdot \frac{\text{POP}}{\text{NPS}} \cdot \frac{1000}{1000} \quad \text{(equation 22)}
\]

where
- DWLS = dry weight of leaf sample (g),
- NGP = number of growing points in leaf sample,
- VPS = accumulated volume of all plants sampled (m\(^3\)),
- VGP = the average volume occupied by one growing point (m\(^3\)),
- NPS = number of plants sampled,
- POP = plant population in the field (number/ha), and
- 1000 converts yield from g to kg.

197. The value of VGP probably depends on the variety of the crop and how it is grown. For a field of *Erythroxylum coca* var. *coca* plants on Hawaii, VGP = 0.003 ± 0.0003 (m\(^3\)).

198. How to calculate VPS

Plant volume, VP, is calculated for each plant in the sampling area by assuming the bush has an ellipsoid shape:

\[
VP = \frac{4}{3} \cdot \pi \cdot (H/2) \cdot \left( \frac{(W1 + WB)}{4} \right)^2 \quad \text{(equation 23)}
\]

where
- \( H \) = plant height (m),
- \( W1 \) = canopy width (m) within the row,
- \( WB \) = canopy width between rows (m).
- Usually \( W1 = WB \).

199. The relationship between plant height (H) and canopy width (W) varies with variety and, if the crop is pruned, also depends on the way the pruning is done. However there is usually a stable relationship that allows calculation of VP based on measurements of H alone. For example, in one field of *Erythroxylum coca* var. *coca*, \( W = H \cdot 0.724 \). In this case, the equation becomes: \( VP = 0.27446 \cdot H^3 \)

200. To calculate VPS, the volumes of the individual plants (VP) that were sampled are summed:

\[
\text{VPS} = \Sigma VP \quad \text{(equation 24)}
\]

201. How to measure POP

The coca crop is usually planted in a regular pattern although plant disease and death can make the pattern seem erratic. To determine how many live plants there are per hectare, three areas in the field are selected randomly.
202. For each area, a tape measure is placed along the row, and the distance \(a\) (metres) between the first and the \(n\)th plant in the row is measured (NB. Where several plants are growing together in each planting hole, each group is counted as one plant). Then the tape measure is turned right angles to the rows, and the distance \(b\) (metres) from the first to the \(m\)th row is measured. The values of \(m\) and \(n\) should both be greater than 20. Then the live plant population, \(\text{POP} \) (number/ha) is:

\[
\text{POP} = \frac{10,000}{[a / (n-1) \cdot b / (m-1)]} \quad \text{(equation 25)}
\]

where 10,000 is the number of square metres per hectare

203. This procedure is repeated in the other two sampling areas. The mean value of \(\text{POP}\) is calculated. If the three values of \(\text{POP}\) are not within 10% of the mean, additional measurements are required until three values within 10% of the overall mean are obtained. This procedure ensures that one takes more samples if population varies greatly over the field. The mean of all calculated values of \(\text{POP}\) is used in equation 22 above to estimate \(Y\) (Paras. 58 to 66 in Part I describe how to calculate the number of observations needed to estimate \(\text{POP}\) more accurately).

6.3.4. Collecting data to develop and/or test a method

204. The procedure to develop and/or test the canopy subsample method involves the following steps:

1. Mark out a plot containing at least 20 plants in a field of coca that is ready for picking.
2. Measure the area of the plot (see para. 172, above).
3. On each plant in the plot, measure and record average canopy height, canopy width within the row and canopy width between the rows.
4. Remove the leaves from 50 growing points (2 or more per plant) and place them into a pre-weighed 1-gallon (4 litres, approximately) zip lock bag.
5. Weigh the zip lock bag containing the leaf sample on a balance accurate to 0.01 gram, and subtract the weight of the zip lock bag to obtain a fresh weight of all sampled leaves. This is FWLS in paras. 205 and 206, below).
6. Harvest all the other leaves from the plants in the selected area.
7. Measure the fresh weight of all these other leaves (also include the weight of the leaves from the 50 growing points).

205. If no oven is available:

8. Assume that \(\text{DWLS} = 0.30 \cdot \text{FWLS}\)

where \(\text{DWLS}\) is dry weight of the sample of leaves (g) taken from the 50 growing points, and \(\text{FWLS}\) is fresh weight of the same sample of leaves (g).

(NB. The value 0.30 was determined for Hawaii conditions. Leaf dry weight has been calculated from leaf fresh weight for Peru and Bolivia using 0.35.)

206. If an oven is available:

9. Dry the sample of leaves taken from the 50 growing points in an oven at 75°C until their weight is stable, and record final weight. This is DWLS in equations 22 and 27.
10. Take a representative sample of the other leaves (from steps 6 and 7 above), record their fresh weight (FWLSS), oven dry them, and record their dry weight (DWLSS).
11. Calculate \(Y\) from the total fresh weight of all the leaves harvested from the plot:

\[
\text{YS} = \frac{\text{FWLSS} \cdot \text{DWLSS}}{\text{FWLSS}} \quad \text{(equation 26)}
\]
12. Calculate the accumulated volume of the 20 plants samples (VPS).
13. Calculate the average volume occupied by each growing point, VGP (m³):

\[ VGP = \frac{\text{DWLS}}{\text{NGP}} \times \frac{\text{VPS}}{\text{YS}} \]  
\text{(equation 27)}

where
- DWLS = dry weight (g) of the sample of leaves taken from the 50 growing points,
- NGP = number of growing points in leaf sample,
- VPS = accumulated volume (m³) of all plants sampled, and
- YS = total dry weight (g) of all the leaves harvested from the plot.

14. Compare value of VGP with one from Hawaii. Substitute the new value of VGP in equation 23 to estimate Y for fields of this type in future

(NB. The canopy subsample method should be tested and validated for each of the coca varieties grown).

207. To test the method, yield is calculated from a certain number of growing points (e.g., 50) from a defined land area, using equation 22. It is compared with the actual gum yield from the same land area (steps 6 and 7, above). (NB. Results have to be adjusted for the area sampled).
REFERENCES


USDA (1992), Thailand opium yield project 1991-1992, ARS, Systems Research Laboratory, Beltsville, MD 20705, USA.

USDA (1993), Southeast Asia opium yield project 1993, ARS, Systems Research Laboratory, Beltsville, MD 20705, USA.

FURTHER READING

Opium poppy


UNDCP/MADERA (1994), Opium poppy yield survey, Dara-I-Noor, Nangahar, Afghanistan

Coca


ANNEXES

Annex I

EQUIPMENT REQUIRED

Opium Poppy: yield surveys

a) Field procedure
- Maps of areas to be visited
- GPS + spare batteries
- Compass / clinometer
- Calculator (+ spare batteries) to calculate area of field
- Camera + films (+ spare batteries) to take photos of fields
- Field instructions (as reminder, for each surveyor)
- Field questionnaire (see Annex IV as an example)
- Measuring tape (100m) to lay transect and locate sampling plots along it
- Foldable plastic metre square (or equivalent) to define area of sampling plot
- Callipers (preferably, electronic digital) to measure capsule dimensions
- Pruners, if poppy capsules are cut and removed from the field
- Field sample bags (paper or cloth), if capsules are removed from field
- Data recording sheets for (i) field data (e.g., size of field), (ii) plot data (e.g., number of capsules and flower buds), (iii) capsule data (e.g., height and diameter)
- Pens, pencils, pencil sharpeners, erasers, permanent markers
- Bags to carry equipment

b) Post-field procedure
- Pruners if capsules are returned from field (required for one modification of capsule volume method, and for capsule dry weight method)
- Data recording sheets for capsule dimensions (if capsules are removed from field) and/or capsule dry weight
- Drying oven (240 or 110 volt, 400 W, for example, 60 x 45 x 45cm), oven thermometer
- Balances (300g ± 0.1g; + transformer or batteries) to determine fresh and dry weight of capsules
- Callipers (preferably, digital electronic; + spare batteries) to measure capsule dimensions
- Calculator
- Pens, pencils, pencil sharpeners, erasers, permanent markers

Opium Poppy: Method development

In addition to the equipment listed above:

a) Field procedure
- 200m string to mark out plots along transect, for the whole duration of the harvest
- 40 one-metre sticks to mark corners of plots
- Plastic knife to collect gum from capsules
- Small plastic bags (e.g., 50 x 90 mm) to collect gum samples for moisture and alkaloid
content determination
- Balances: (i) 20g ± 0.002g (for weighing of fresh gum from 1-m² plots, and gum sample of approx. 1g to be returned for laboratory analysis)
  (ii) 600g ± 0.02g (for weighing of fresh gum from 100-m2 plot)
- Scissors, stapler, plastic and paper tape

b) Post-field procedure
- for moisture content determination, drying oven as above
- for alkaloid content determination, a laboratory equipped with gas chromatograph and relevant supplies is required

Coca: yield surveys

a) Field work
- Maps of areas to be visited
- GPS + spare batteries
- Compass / clinometer to determine the aspect of the field
- Calculator (+ spare batteries) to calculate area of field
- Camera + films (+ spare batteries) to take photos of fields
- Field instructions (as reminder, for each surveyor)
- Field questionnaire
- Measuring tape (100m) or string to lay transect and locate sampling plots along it
- Field sample bags (cloth or mesh-type)
- Data recording sheets
- Pens, pencils, pencil sharpeners, erasers, permanent markers
- Bags to carry equipment
Annex II

Construction of a foldable metre square

One form of metre square that is easy to construct and use is made from plastic pipe and solvent-welded fittings. These are available in most countries, but not all. One square consists of 8 lengths of pipe each about 48cm long. Half of them have a 90° elbow solvent welded on one end and the other half have a straight coupling. They are arranged in a square, and each piece of pipe goes into a joint at one end and accepts another piece of pipe into the joint at its other end. The tapered joints push together for a firm fit. Elastic or string is threaded through the pipes to keep them organized. The best form of elastic is shock cord, sold for mountain climbing. If this is threaded through the plastic pipes, pulled as tight as possible by hand, and the ends tied together, the square practically assembles itself when released and gently shaken with one hand. The diameter and wall thickness of the pipe should be such that the square can be held horizontal by one person holding two adjacent corners. The exact length of each piece of plastic pipe depend on the size of the fittings and should be chosen so that the assembled square is one metre on each side measured between pipe centres.
### Annexe III

(The procedures and data recording sheets below are examples to be adjusted for individual countries and situations)

<table>
<thead>
<tr>
<th>Outline of field procedures for method development, Afghanistan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>50-100m² plot</strong></td>
</tr>
<tr>
<td><strong>Day 1</strong></td>
</tr>
<tr>
<td>1) In each field, define a representative plot, e.g. 50-100m² (use natural boundaries, or tape to mark the plot if it forms part of a larger field); accurately measure selected area (record size in Table 1)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>3) Measure length of transect using measuring tape or paces; use Table A to locate ten 1-m² plots in equal distances, along full length of transect; use 4-m string to mark plots (these marks should stay for the duration of the harvest); draw sketch map of field, location of transect, plots, etc. (Table 1)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>4) Count number of plants in each of the ten 1-m² plots (record in Table 1)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>6) Count all mature capsules, and immature capsules and flower buds, which are likely to contribute to overall gum yield (record in Table 1)</td>
</tr>
<tr>
<td><strong>Day 2</strong></td>
</tr>
<tr>
<td>8) Collect opium gum from all mature capsules in the 50-100m² plot (this should be done according to the normal harvesting procedure, carried out by the farmers themselves)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>10) Record fresh weight of total gum collected in the 50-100m² plot (Table 2)</td>
</tr>
<tr>
<td><strong>Day 3 to end of harvest</strong></td>
</tr>
<tr>
<td>In the middle of harvesting period (day 4 or 5)</td>
</tr>
<tr>
<td>---------------------------------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>On the last day of harvest</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Length of transect</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Plot interval</td>
</tr>
<tr>
<td>Plot No. 1</td>
</tr>
<tr>
<td>Plot No. 2</td>
</tr>
<tr>
<td>Plot No. 3</td>
</tr>
<tr>
<td>Plot No. 4</td>
</tr>
<tr>
<td>Plot No. 5</td>
</tr>
<tr>
<td>Plot No. 6</td>
</tr>
<tr>
<td>Plot No. 7</td>
</tr>
<tr>
<td>Plot No. 8</td>
</tr>
<tr>
<td>Plot No. 9</td>
</tr>
<tr>
<td>Plot No. 10</td>
</tr>
<tr>
<td>Length of transect</td>
</tr>
<tr>
<td>Plot interval</td>
</tr>
</tbody>
</table>
### Table 1: RECORDING OF PLOT CHARACTERISTICS

<table>
<thead>
<tr>
<th>Plot number</th>
<th>Position along transect</th>
<th>Does plot form part of larger 50-100m² plot?</th>
<th>Total number of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>poppy plants</td>
</tr>
<tr>
<td>50-100m²</td>
<td>N/A</td>
<td>N/A</td>
<td>mature capsules</td>
</tr>
<tr>
<td>*plot</td>
<td></td>
<td></td>
<td>immature caps.</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>and flower buds</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* The measured size of the 50-100m² plot is: ___________ by ___________ metres

Please draw sketch map of field, indicating location of 50-100m² plot, transect and plots 1-10 along the transect. Please indicate also any roads, paths, rivers, canals, etc. in the neighbourhood:
**Table 2:** **RECORDING OF WEIGHT** of opium gum in 50-100m² plot  
(n grams; to the second decimal, i.e.: 0.00g)

<table>
<thead>
<tr>
<th>Field</th>
<th>Surveyor</th>
<th>Lancing</th>
<th>Date</th>
<th>Weight of test weight</th>
<th>Weight of opium gum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lancing 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lancing 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lancing 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lancing 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lancing 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lancing 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lancing 7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3:** **RECORDING OF TYPICAL SHAPE** of mature capsules  
(please tick)

☐ [Shape 1] ☐ [Shape 2] ☐ [Shape 3] ☐ [Shape 4]
Table 4: RECORDING OF CAPSULE CHARACTERISTICS (in the TEN 1-m² plots)

<table>
<thead>
<tr>
<th>Field</th>
<th>Plot no.</th>
<th>CapsHt (mm)</th>
<th>CapsDia (mm)</th>
<th>No. of cuts</th>
<th>Field</th>
<th>Plot no.</th>
<th>CapsHt (mm)</th>
<th>CapsDia (mm)</th>
<th>No. of cuts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>total 'dry'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>total 'dry'</td>
</tr>
</tbody>
</table>

.../cont'd
<table>
<thead>
<tr>
<th>Plot number</th>
<th>Number of capsules which have been lanced / harvested (to be recorded on last day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 – 100 m² plt</td>
<td></td>
</tr>
<tr>
<td>Plot 1</td>
<td></td>
</tr>
<tr>
<td>Plot 2</td>
<td></td>
</tr>
<tr>
<td>Plot 3</td>
<td></td>
</tr>
<tr>
<td>Plot 4</td>
<td></td>
</tr>
<tr>
<td>Plot 5</td>
<td></td>
</tr>
<tr>
<td>Plot 6</td>
<td></td>
</tr>
<tr>
<td>Plot 7</td>
<td></td>
</tr>
<tr>
<td>Plot 8</td>
<td></td>
</tr>
<tr>
<td>Plot 9</td>
<td></td>
</tr>
<tr>
<td>Plot 10</td>
<td></td>
</tr>
</tbody>
</table>
### Table 6: RECORDING OF WEIGHT of all opium gum collected on three selected 1-m² plots over the whole harvesting period (in grams; to the third decimal, i.e.: 0.000g)

<table>
<thead>
<tr>
<th>Field</th>
<th>Surveyor</th>
<th>Date</th>
<th>Weight of test weight</th>
<th>Total weight of opium gum collected from selected plots:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Please insert plot numbers</td>
</tr>
<tr>
<td>No. ...</td>
<td>No. ...</td>
<td>No. ...</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 7: RECORDING OF EXACT FRESH WEIGHT of one sample of opium gum (approx. 1-2 grams) from each field (in grams; to the third decimal, i.e.: 0.000g)

<table>
<thead>
<tr>
<th>Field</th>
<th>Surveyor</th>
<th>Date</th>
<th>Weight of test weight</th>
<th>Gross weight of fresh opium+bag</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

54
Annex IV

Questionnaire, Method development, Afghanistan

Surveyor: ........................................................
Province: ........................................ District: .................. Area: ................................................
Village: ........................................ Vector Code: ................. Farmer: .........................................

The questions below relate to THAT field, in which capsule measurements and gum collection are carried out. An overall assessment as to the representativeness of the selected field for the region would be appreciated. Please take photos of field, which would allow to assess its homogeneity in terms of plant density, phenotypes grown, etc. Please also draw a sketch map of the field indicating roads, paths, rivers, canals etc.

1. Description of field
   □ flat □ terraced □ hill
   □ if terraced or hill-side field, please indicate aspect (N, NE, E, SE, etc.): .........................
   □ size: ............ ha
   □ farmer's estimate of YIELD on that field: ........kg/ha (or: ......kg/field)

2. Poppy variety grown
   □ name (if known): ................................................
   □ colour of petal
     □ white □ red □ pink □ purple
     □ bi-coloured:
       □ colour on petal border:.................................
       □ colour at base:...........................................
   □ petal margin
     □ entire □ fringed

3. When was the poppy sown on this field? ............... (please indicate date / season)

4. Origin of seeds: ..............................................................

5. Continuity of growing the same poppy variety, and reasons for change, if any:
   ..............................................................

6. Soil type (if known)
   □ clay □ sandy clay □ sandy loam □ loam □ other: ....................

7. Type and number of irrigation
   □ type of irrigation
     □ none (i.e., rain-fed)
     □ natural springs / streams / canals
     □ kareez
     □ other: .................................................
   □ number of irrigations: .......... times during growing season

8. Management practices
   □ weeding □ hoeing □ thinning
   □ use of fungicides
   □ use of herbicides

9. Fertilizers used?
   □ no
   □ yes: □ animal manure
      □ urea – ...... kg/ha (total)
      □ DAP – ...... kg/ha (total)
   Fertilizer was applied ...... times during growing season.

10. Previous crop on field (before poppy)
    □ none □ wheat □ maize
    □ other: ...................................................

11. Number of blades on lancing tool
    □ 3 □ 4 □ 5 □ 6
    □ other: ..............................................

12. Average number of cuts made on each capsule during one visit to the field
    □ 1 □ more than 1 (pls. specify): ............

13. Average number of lancing
    □ 1 - 3 □ 4 - 6 □ 7 or more

14. Overall weather at harvest
    □ good □ average □ poor