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LIMITED OPIUM YIELD ASSESSMENT SURVEYS

Technical report:
Observations and findings

Guidance for future activities

prepared by

Laboratory and Scientific Section
Division for Policy Analysis and Public Affairs

PURPOSE OF THE REPORT

The purpose of this report is to complement the "Guidelines for yield assessment of opium gum and coca leaf from brief field visits" (UNDCP, 2001a) by providing a summary of relevant experiences, observations and findings from UNODC's experimental work in the area of scientific yield assessment surveys in the years 2000 to 2003.

The report is aimed at providing a practical tool for interested individuals and national authorities for the design and implementation of future yield assessment surveys.

It is organized in three parts. The first two outline observations and findings related to (i) practical work in poppy fields, and (ii) the establishment, evaluation and/or application of mathematical models for yield estimates. The third part provides details on the most relevant substantive findings. An outline of proposed future steps is also included.

Yield calculations and mathematical models discussed in this SCITEC publication relate to estimates at the plot and field level; they do not address the extrapolation to a national yield estimate at the country level.

DEFINITIONS

Method development (MD)
Refers to extensive fieldwork, which requires the presence of surveyors in the **experimental fields** during the entire harvesting period. Plants and capsules are counted, capsules are measured and opium gum is collected in order to establish and/or test a correlation between gum yield and **plot volume** (i.e., the total volume of mature capsules in a one square metre plot).

Limited yield survey (LYS)
Refers to the required fieldwork (capsule counts and measurements) in **randomly selected fields** from all over a country or region within a country. Data are used to estimate potential maximum yield and production for the country / region.

Lancing
Refers to a single visit to a capsule for cutting. During successive field visits not all capsules may be lanced at each visit. Hence, the number of days during which gum is collected from a given field is referred to as number of **field visits**.

Cut
Refers to a single pass with a lancing tool on a poppy capsule; each cut consists of one to several parallel lines, depending on the number of blades on the lancing tool.

Table of contents

SUMMARY OF FINDINGS

Since 2000, UNODC has carried out limited yield-related field activities in Afghanistan, Myanmar and Laos. These activities were aimed at developing and/or evaluating a scientifically sound method to estimate opium gum yield, applicable to existing conditions in the countries concerned. In Afghanistan, it was the first ever scientific yield study in that country. Activities comprised two parts: (i) experiments aimed at developing and/or evaluating a mathematical formula to estimate potential maximum opium yield from crop data collected during brief field visits, and (ii) a limited yield survey, covering a larger number of fields throughout a country, where capsule characteristics are determined during brief field visits. Field activities were complemented by interviews with farmers on prevailing management practices, and an assessment of the range of variability of opium crop characteristics. Activities also included the collection of opium gum samples for the determination of their morphine and moisture content.

Experiences and findings to-date, provide useful guidance for the design and implementation of future yield assessment surveys. In addition, substantive findings, especially on moisture and morphine content, provide new insights in connection with opium-morphine-heroin production estimates.

Findings indicate, *inter alia*, that:

(i) yield can be estimated through a relationship with poppy capsule volume in all regions where opium is harvested as gum (i.e., in Afghanistan as well as in Southeast Asia);[a]

(ii) for high yields, there are discrepancies between estimated yields from scientific yield assessments and farmers' yield estimates; and that

(iii) the morphine content in Afghan opium is higher than in opium from Southeast Asia; and that the 10:1 opium-to-heroin conversion ratio may therefore not be applicable to all regions.

Findings to-date emphasize the importance of further work to better understand the impact of various factors on production estimates. Anecdotal evidence also suggests that a re-evaluation of the availability and quality of opium, morphine and heroin may be required to fully understand poppy cultivation, opium harvest and trade, their regional differences, and the driving forces behind them.

It is important to note that scientific yield surveys will always result in estimates of **potential maximum yield**. Losses in opium gum that are unrelated to the growth cycle of the poppy plant from germination to capsule maturity, such as those due to poor and rainy weather during the harvesting period, cannot be captured. However, if field procedures are applied rigorously, the resulting yield estimates provide a reliable basis for the estimation of potential opium production. This report raises a number of issues that are critical in further improving the reliability of production estimates based on scientific yield surveys.

<u>Findings relevant for the design and implementation of scientific yield assessment surveys</u>

<u>A. Field procedures</u> Page

Correct **recognition of immature capsules, flowers and flower buds that can be expected to contribute to yield**, is probably the most critical element in the field procedures. By the same token, **damaged capsules** that are not likely to be lanced should not be counted. Inaccurate numbers at this stage severely impact on the yield estimate, because it 2/3

[a] In regions where opium is harvested as latex (e.g., Colombia), similar studies are still required.

is this total number of capsules/flowers/flower buds, multiplied with the average mature capsule volume, that is fed into the mathematical formula used to predict gum yield. Page

The main criterion for **selecting capsules for capsule measurements** is maturity (and not size). Mature capsules, regardless of their size, should be measured systematically. After having selected a typical plant in a one square metre plot, all *mature* capsules on that plant should be measured, before moving on to another typical plant, repeating until the required number (usually at least ten) of mature capsules has been measured. 3/4

In order to minimize errors due to the selection for measurements of capsules that are not yet mature or that are already dried up, it is **recommended to carry out yield surveys only in fields where harvest is still under way**. Within a field, only those capsules that have already been lanced should be measured. Ideally, a mature capsule should be measured between about ten to 25 days after flowering, as during this period capsule volume has been shown to be stable. 3

B. Yield calculations

The existence of a **measurable relationship between capsule volume** (more precisely: plot volume) **and opium gum yield**, which was known to exist for Southeast Asia, has been confirmed to be also valid for poppy in Afghanistan. The applicability of this approach in regions where opium is harvested in the form of latex (i.e., Central and South America) still needs to be evaluated. 6

A **linear model** best predicts yields for plot volumes of up to a maximum of 1,000cm^3/m^2. Beyond that, **non-linear models** appear to better reflect botanical realities. Plot volumes larger than approximately 1,800-2,000 cm^3/m^2 should be excluded from calculations (as a general rule, any formula for any model should not be used beyond the range of data for which it was established). 9

In geographic terms, linear models should continue to be used in regions characterized by small capsule volumes, e.g., Southeast Asia. Non-linear models are more appropriate to predict yields for Afghanistan, where capsules are much bigger. 9

Predicted potential yields from scientific yield assessment surveys are in good agreement with farmers' estimates (and with actual yields collected from individual plots) **for plot volumes at the low end, up to about 500cm^3/m^2**. Beyond that figure, farmers' estimates are considerably lower than the predicted yields from any of the models. 11

In the absence of additional data from experimental fields in both Afghanistan and Myanmar to determine more precisely the range of applicability of any of the mathematical models, the formulae described in the Guidelines (UNDCP, 2001a) should be used, namely a linear model for regions characterized by plot volumes of less than 1,000cm^3 per square metre, i.e., for South East Asia. Non-linear models result in acceptable yield estimates for regions where plot volumes are predominantly around and beyond 1,000cm^3 per square metre, e.g., in Afghanistan. 12

Substantive findings

A. Opium-morphine-heroin production estimates

The average weighted **opium gum yield** in Afghanistan's Northeastern Province of Badakhshan, as estimated by farmers themselves, was 24kg/ha. The corresponding figure from the scientific approach for yield assessment was about 40kg/ha (similar comparisons are not available for Southeast Asia). 11

Opium from Afghanistan and Myanmar differs in its **morphine content**: While the morphine content of opium from the majority of fields in Myanmar is between 10% and 14%, it can be significantly higher in Afghanistan. In that country, more than 40% of the fields surveyed showed a morphine content higher than 15%, frequently as high as 20%. 25

Page

Relatively more opium samples from Northern Afghanistan have a higher morphine content than samples from the East and South. The morphine content of opium harvested in different years also shows significant differences that may be related to significantly different weather conditions in the years studied. 26

In Myanmar, the morphine content of opium from the WADP survey area in Mongyang township (in the South of the Wa Special Region) is slightly lower than that of opium from other townships further north in Shan State.

While it is well known that the morphine content of opium decreases with the number of lancings, this decrease, together with differences in harvesting practices, may also explain - at least partly - the observed regional differences in morphine content: Afghan opium is typically harvested during fewer field visits than in Southeast Asia. As a result, the relative weight of gum of higher morphine content in the total amount of gum harvested is likely to be higher. By contrast, a larger number of visits, as typically seen in Southeast Asia, decreases the weight of gum of high morphine content, thus decreasing overall morphine content as well. 29

Fewer but stronger plants produce opium with a higher morphine content. This appears to be the result of a **positive correlation of morphine content with plot volume**, and a **negative correlation with plant density**. In terms of morphine output (amount of morphine per unit land area), the limited data available do not show a clear trend, other than regional differences, between Afghanistan (higher output) and Myanmar (lower output). 29/30

On the basis of morphine content, findings confirm reports from farmers and traders, which indicate that the **"best" quality opium** is obtained from the first field visit (UNDCP, 1998). It remains, however, uncertain how, if at all, farmers and traders can assess quality based on morphine content with the simple means they have at hand. 29

Considering also clandestine laboratory efficiencies, the simple 10:1 rule-of-thumb **conversion rate** for opium to morphine/heroin may not be appropriate in both regions: It is too low to adequately reflect potential heroin production from opium from Myanmar, and it may only result in conservative estimates for the amount of heroin base produced from Afghan opium. In addition, conversion rate should not be equaled to morphine content. 31

The **moisture content** of fresh opium is dependent on the weather conditions at harvest. It does not reflect the moisture content of the opium as traded. 22

The moisture content of fresh opium ranges between 30% and 50%. Opium after storage typically has a moisture content of 10% to 15%. Although usually referred to as 'dry' opium, **opium after the natural drying process still contains residual water**. 24

B. Other substantive findings and observations

B.1. Crop characteristics, management practices, and their relation with gum yield

Capsule volumes differ on a regional basis. They are bigger in Afghanistan, with the majority of capsule volumes ranging between 10 and 30cm^3, and smaller in Myanmar and Laos, where most capsule volumes are less than 10cm^3, frequently even less than 5cm^3. 17

On a provincial basis, in Afghanistan, capsule volumes are larger in the East (Nangahar) than in the North (Badakhshan and Balkh) and the South (Helmand). Interestingly, capsule volumes in Helmand, the province which, historically, accounted for the highest opium production, are more similar to those in Badakhshan than to those in Nangahar, historically the second largest production area in Afghanistan. 22

In terms of **capsule shape**, the more spheroid capsule shapes encountered in Afghanistan tend to produce higher gum yields than the more oval capsules in Myanmar. 17

No single factor could be identified to be directly correlated with gum yield. Fertilizer use however does seem to play a central role. From available background information, in addition to amount and number of fertilizer applications, the ratio of the two most commonly used chemical fertilizers, urea and diammonium phosphate (DAP), also appears to be 11, 29 important. Excessive fertilizer use may increase gum yield beyond an amount predictable from capsule (plot) volume. Page

B.2. Harvesting practices

The extent of gum harvest varies depending on the geographical region: In all fields studied in Afghanistan, two-thirds to 100% of opium gum is harvested within the first three visits. In Eastern and Southern Afghanistan, harvest was usually terminated when the yield obtained from a field visit fell below 5% of the total yield. In Northern Afghanistan, the end-of-harvest figure was much more variable, ranging from close to 30% to less than 1%. In Myanmar harvest was terminated when the yield obtained from a field visit fell below 1% of the total yield. 13/14

The **timing of opium gum harvest** (its beginning and end, based on the maturity stage of the poppy field) varies strongly across regions and even from one year to another within a country. 13-16, 21

An inverse relationship appears to exist between the **number of blades on the lancing tool and the number of cuts per lancing**, i.e., the fewer blades, the more cuts are made per lancing. 21

Significant regional differences in the **relationship between capsule volume and number of cuts** were observed. In general, the small capsules which are characteristic for poppies in Southeast Asia tend to be cut more often than the bigger capsules in Afghanistan (this may be a reflection of the inverse relationship between the number of blades on the lancing tool and the number of cuts made). Within Afghanistan, the number of cuts appears to be independent of capsule size, although the largest capsules tend to be cut the most often. 22

INTRODUCTION

In 2000, the United Nations Office on Drugs and Crime (UNODC) carried out a limited yield survey in Afghanistan, aimed at providing the basis for developing a scientifically sound method to estimate the yield of opium gum, applicable to existing conditions in Afghanistan. This study, carried out in the framework of the Global Illicit Crops Monitoring Programme (ICMP) and as an adjunct to the Annual Opium Poppy Survey, was the first ever scientific yield study in Afghanistan. It comprised two parts, (i) activities for method development (considering that plant characteristics in Afghanistan are different from those in Southeast Asia), including also the collection of opium gum samples for the determination of moisture and morphine content, and (ii) a limited yield survey, covering a larger number of fields throughout Afghanistan, where capsule characteristics were determined without collecting gum.

Worldwide, there is a need to estimate the extent of illicit opium production as a basis for estimates on potential morphine and heroin production, and availability for illicit demand. Currently, estimates of opium gum yield are frequently derived from non-scientific approaches such as interviews with farmers. This applies particularly to Afghanistan, the major opium producing country worldwide

The yield of illicit crops, together with area under cultivation, is one of the key factors for determining illicit production. For Southeast Asia, capsule volume has been shown to correlate with opium gum yield (USDA, 1992). Using this relationship, brief field visits to determine the required plant characteristics allow the estimation of potential production of opium gum in a given country. This approach has been used in the past by the US government in opium producing countries in Southeast Asia (USDA, 1992 and 1993).

Findings, experiences and difficulties encountered during the 2000 Afghanistan were discussed at an international expert meeting on methodologies for yield assessment of illicit narcotic crops (covering both opium poppy and coca bush), convened in Vienna in autumn 2000. The outcomes of this meeting were published in a manual providing “Guidelines for yield assessment of opium gum and coca leaf from brief field visits” (UNDCP, 2001a).

In 2001, applying the guidelines set out in the manual, yield studies were repeated in Afghanistan. Due to the Taliban’s ban on poppy cultivation, activities in 2001 were limited to Northeastern Afghanistan (Badakhshan Province), the only province, where the ban was not enforced effectively. Limited activities were also carried out in the Wa Special Area in Myanmar’s Shan State. In 2002, yield-related activities for method development were carried out in Myanmar and, for the first time, in Laos. The security situation in Afghanistan did not permit field activities in that year. In 2003, work for method development was again carried out in Afghanistan [b], and Myanmar.

Part I of this report outlines observations and findings relevant to the design and implementation of *activities in the fields*, while Part II focuses on findings and observations relevant for the *calculation of yields*. Part III summarizes substantive findings.

A summary of UNODC’s yield-related activities is given in Annex I.

[b] The analysis of data from the 2003 activities in Afghanistan showed some inconsistencies with data from previous years. Discrepancies may be a consequence of significantly different weather conditions during the 2003 growing season compared to 2000-01, or they may be the result of limitations in the field work carried out. To avoid incorrect overall conclusions, where necessary, 2003 data are presented separately in relevant graphs in this report. The security situation permitting, another yield method development exercise will be carried out in Afghanistan in 2004 to confirm findings and finalize conclusions.

Part I

OBSERVATIONS AND FINDINGS RELEVANT FOR YIELD ACTIVITIES IN THE FIELD

Field procedures generally followed guidelines laid out in the manual "Guidelines for yield assessment of opium gum and coca leaf from brief field visits" (UNDCP, 2001a). Study design and a summary of field procedures are given in Annex II.

> The parameter used for yield estimates and comparisons between fields is the total volume of all gum-yielding capsules, at maturity, in individual one square metre plots. This is the so-called **plot volume** (expressed in cubic centimetres [cm^3] per square metre [m^2]). It is calculated by multiplying, on a one square metre plot basis, the average mature **capsule volume** with the **number** of capsules, flowers and flower buds in that plot that can be expected to contribute to yield.

As a consequence of this approach, there are a number of critical factors in the field procedures that impact on the yield estimate (at the one-square-metre-plot-level). In order to minimize the error, several checks and balances were built into field procedures, which addressed in particular:

A. The recognition of capsules, flowers and flower buds that will contribute to yield;
B. The recognition of *mature* capsules that are used for capsule measurements; and
C. (For method development only) the collection and weighing of opium gum from one square metre plots.

Practical details are summarized below.

A. Recognizing capsules, flowers and flower buds that will contribute to yield

Gum yield is calculated from the *total number* of capsules that contribute to yield. This includes capsules that are mature (and lanced) at the time of the field visit. However, it also includes capsules that are immature at the time of the field visit, and flowers and flower buds, as long as they can be expected to contribute eventually to yield. Proper recognition of immature capsules, flowers and flower buds that meet those criteria is critical. Counting capsules, flowers and flower buds that will not mature during the harvesting period results in an overestimate of yield.

As part of the field procedure, surveyors were asked to count, at the beginning of the harvest, mature and immature capsules, flowers and flower buds, which they expected to reach maturity during the harvesting period, and which would thus contribute to overall opium yield. The accuracy of the surveyors' assessments (initial count) was checked by the requirement to re-count all lanced capsules after harvest was completed.

Results from Afghanistan in 2000 showed that estimates based on the initial count would lead to an overestimate of the number of gum-yielding capsules of, on average, less than 5% for all experimental fields. However, initial capsule counts in subsequent years were less accurate, leading to an overestimate of the projected number of gum-yielding capsules (Figure 1).

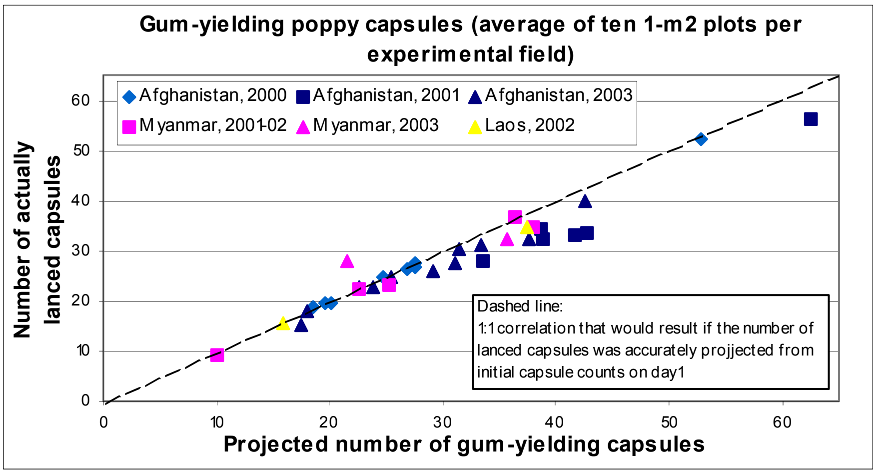

Figure 1

It is clear that the lower the capsule/plant density in a plot, the larger the impact of minor errors in capsule counts, because the incorrect assessment of a single (or a few) capsule(s) may lead to large errors in the final yield estimate. On a regional basis, this applies mainly to poppy fields in Southeast Asia, which are characterized by lower plant densities than fields in Southwest Asia (i.e., Afghanistan).

Another source of error that was encountered is damaged crop. Especially in Myanmar, discrepancies (overestimates) between the initial estimate and the number of actually lanced capsules appear to be the result of damaged capsules being counted at the beginning of the harvest, but not lanced because of their damage. Such capsules clearly should not be included in the initial capsule count on day one (the impact of crop damage on gum yield is addressed in part III-C, below).

B. Recognizing mature capsules

Because gum yield is calculated from *mature* capsule volume per square metre, proper assessment of the maturity stage of poppy capsules is critical. Measuring immature capsules may result in an underestimate of gum yield, since the capsule size of an immature capsule can be significantly smaller than that of a mature capsule.

However, as a practicality, yield surveys are usually carried out in the context of opium poppy surveys that are aimed primarily at estimating cultivated area. Since area can be estimated almost over the entire growing cycle with sufficient accuracy, the time window for opium surveys is much larger and extends considerably beyond that conducive for yield surveys, which require the presence of mature capsules in the poppy fields.

As a consequence, yield surveys may not be carried out at comparable maturity stages in all regions, even within a country. If surveys are carried out early in the growing cycle, when a large share of capsules has not reached maturity, the accuracy of yield estimates will to a large part depend on surveyors' ability to recognize *mature* capsules, and to distinguish between those immature capsules, flowers and flower buds that can be expected to reach maturity and contribute to yield, and those that will not. (see also section A below)

In order to minimize errors in capsule volumes resulting from measuring capsules that are not yet mature or that are already dried up, only those fields should be selected for capsule measurements where harvest is still under way. Within a field, only those capsules that have already been lanced should be measured. Ideally, a mature capsule should be measured between about ten to 25 days after flowering, as during this period, capsule volume has been shown to be stable (Acock and Acock, 2000).

During training of the surveyors, emphasis should also be laid on the requirement to measure mature capsules systematically. It is important to select a typical plant in a one square metre plot and measure all mature capsules on that plant, before moving on to another typical plant, repeating until at least ten mature capsules have been measured per plot. If such a procedure is not followed, surveyors may bias their selection of mature capsules and measure mainly the larger capsules. This will result in a yield overestimate.

C. Measuring capsule height and diameter

Capsule volume is calculated from capsule height and diameter, using the formula of a sphere (see UNDCP, 2001a).

While diameter is easily recognizable at half the height of the poppy capsule, a practical problem can arise when measuring capsule height, i.e., the distance from below the stigma surface ('crown') to the bottom of the capsule (see Figure 2). In order to measure capsule height accurately, the callipers should be placed properly under the stigma (or between the stigmatic rays).

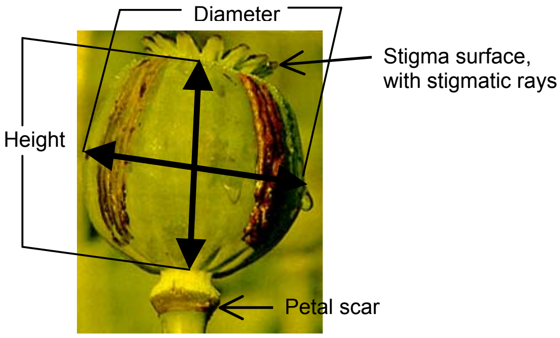

Figure 2

To quantify possible errors, capsule height was measured twice, excluding and including the stigma surface, on a small number of capsules. Measurements showed that errors were in the order of about 15% (Afghanistan), and up to 10% (Myanmar) of capsule height. In absolute numbers, the difference, on average, is about 4mm and 2mm for Afghanistan and Myanmar, respectively. Surprisingly, the error appears to be smaller for smaller capsules.

These errors in height translate to differences of about 10-15%, on average, for the calculated capsule volumes in fields in Afghanistan (range: 5-36%), and around 6%, on average, in Myanmar (the smaller impact on capsule volumes may be a result of capsule indices being higher in Myanmar, i.e., capsules are more oval than spheroid; see Part III-B1 and B2, below).

It has been shown that adequate training of surveyors can reduce the error. In addition, since the parameter used for yield estimates and comparisons between fields is not individual capsule volumes, but the total projected volume in individual plots of all gum-yielding capsules at harvest, minor differences in height measurements on some individual capsules do not appear to affect overall calculations.

D. Weighing opium samples collected from experimental fields

In order to ensure accuracy in weighing the opium gum collected from individual one square metre plots, a test weight was used. Surveyors have been requested to weigh the test weight, selected to be in the range of the typical weight of opium gum that is collected from a one square metre plot over the harvesting period (Table 1), each time before weighing the actual gum collected. The test weight was submitted to UNODC's Laboratory and Scientific Section, where it was re-weighed, in order to assess the accuracy of the weighings made.

Table 1: Typical amounts of fresh gum collected from one square metre plots over entire harvesting period	
Country	Amount of gum collected (gram)
Afghanistan	5g to 11g (range: 0.7g to 27.1g; only in four out of 75 plots less than 1g were collected)
Myanmar	0.8g to 2.5g (range: 0.2g to 4.2g; amounts collected from a one square metre plot on a single field visit ranged from 0.003 to 2.4g)
Laos	1g to 2g (range: 0.8g to 2.7g)

Weighing errors in Afghanistan were usually less than 2%; in Myanmar, they were between 4% and 6%. Despite the relative small average weighing errors observed in UNODC's yield studies so far, it is recommended that this practice should be continued so as to provide a means to monitor, assess and, if necessary, correct weighings made by surveyors in the field.

E. Handling empty and sparsely cultivated plots

Typically, the opium gum yield of a poppy field is calculated as the simple mean of the individual yields (in kg/ha) from a random selection of one square metre plots (usually three to five) per field. In order to arrive at representative yield estimates, all selected one square metre plots within a field have to be considered. That is, also plots without plants are valid observations, which contribute to the sample mean. The corresponding procedure is outlined in the Guidelines (UNDCP, 2001a), and provides reasonable results in the majority of cases.

However, there may be situations, where plant densities are too low to provide meaningful yield estimates. The 2002 joint Myanmar-US opium yield survey, for example, describes a situation, where an unusually large number of poppy fields with extremely low plant densities was encountered, which led to the rejection of about 30% of fields by the Myanmar-US field team (Acock, 2002). It has been suggested that this, in turn, may have led to yield estimates that are biased towards higher figures, and that a mechanism will have to be established in the future to account for a possible bias resulting from very low plant densities.

Although similarly detailed findings are not available from the UNODC Opium Poppy Surveys in Myanmar, which started only in 2001, observations in that country, and in Southeast Asia in general, confirm that poppy plant densities in the region are often smaller and, above all, far more variable than in Afghanistan.

F. Evaluating yield assessment methodologies

In general, when carrying out practical field experiments for method development, an attempt should be made to gather as many independent yield data as possible on the experimental fields. To this end, it is recommended to include the experimental fields in the otherwise random sample of fields where a yield survey is carried out (i.e., only capsule measurements without collecting opium gum). Potential yields from the experimental fields can then be calculated in the same way as for other fields for which only the calculation method is applied. Calculated yields can then be compared with actual yields (from collected opium gum). It is also recommended to cross check calculated and actual yield data with farmers' estimates of the yields for the experimental fields (relevant observations from UNODC's activities are summarized in Part II-C below).

Part II

OBSERVATIONS AND FINDINGS RELEVANT FOR YIELD CALCULATIONS

A. Relationship between measurable plant characteristics and gum yield

As pointed out above, scientific opium yield assessment methodologies are based on the assumption that potential gum yield can be estimated reasonably accurately from capsule size (expressed as capsule volume or capsule dry weight).

It is important to note that the principle of this approach (i.e., the existence of a measurable relationship between capsule volume and gum yield) should be applicable to poppy grown in any part of the world. However, while practical field procedures to determine capsule height and diameter should also be the same or very similar, the exact correlation, i.e., the mathematical formula relating capsule volume to yield, may not be the same in different poppy growing regions. The applicability of any existing formula therefore needs to be tested before using it in another cultivation area. In addition, the applicability of the approach, for the time being, is limited to opium harvested as gum. [c]

For Southeast Asia, the volume of mature capsules in a field has been shown to correlate with the opium gum yield (USDA, 1992 and 1993). Similar studies had not been carried out for Afghanistan. It was therefore one of the main objectives of this study to use physical measurements of plant characteristics and gum yield from experimental fields to establish a relationship between the two variables, which is applicable to conditions in that country. As of 2001, with limited data from Myanmar and Laos being available, the applicability of a common formula for both Southwest and Southeast Asia could also be tested.

Figure 3 shows the correlation between the total volume of all mature capsule in a one square metre plot (plot volume) and the dry gum yield from that plot [d], using data from Afghanistan, from 2000. Figures 4 to 7 are graphical presentations of other easily accessible plant or plot characteristics and gum yield.

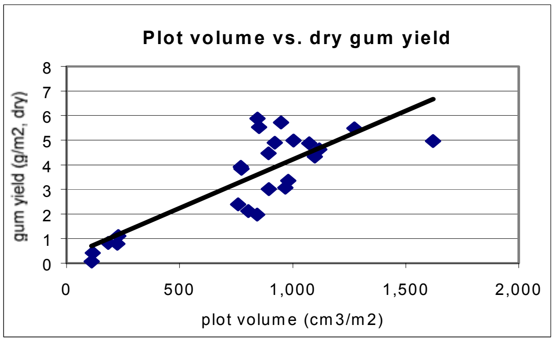

Figure 3

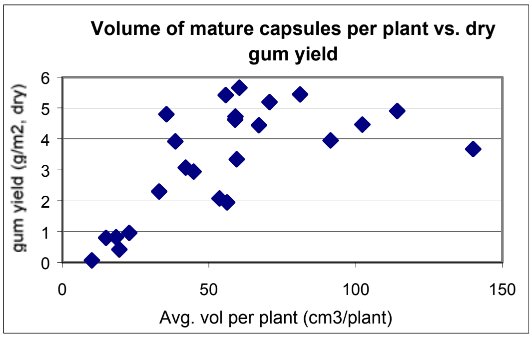

Figure 4

[c] This limitation relates specifically to Latin America where opium is typically harvested as latex, i.e., in a much more liquid form than gum harvested in Southeast and Southwest Asia.

[d] Yield figures in grams per square metre (g/m^2) convert into kilogram per hectare (kg/ha) figures when multiplied by 10.

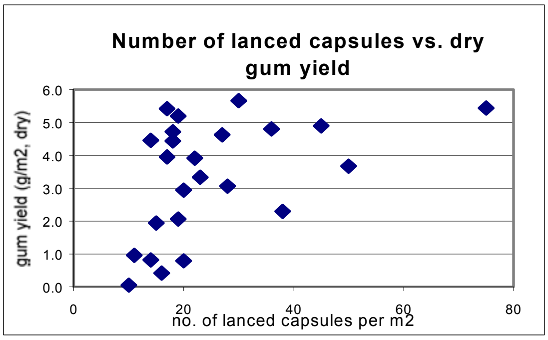

Figure 5

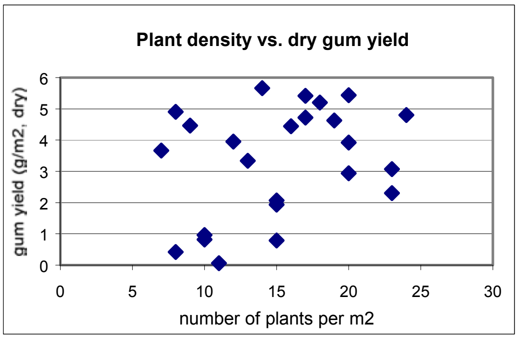

Figure 6

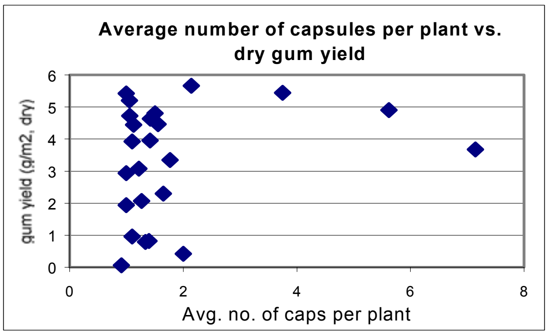

Figure 7

Despite the limited data, and although the effects of other, as yet undetermined, variables cannot be excluded, Figures 3 and 4 **confirm that a relationship between capsule (or plot) volume and gum yield is likely to exist also for Afghanistan**. Linear regression of the data in Figure 3 was considered the 'best possible fit' under the circumstances of the limited data collected in 2000 (note, however, the cluster of data at plot volumes between 800 cm^3/m^2 and 1,100cm^3/m^2, where no clear correlation between plot volume and gum yield is apparent).

As of 2001, as a result of yield-related activities being extended to Myanmar, data at the lower end of the plot volume-gum yield relationship became available (capsule volume and gum yield are traditionally smaller in Southeast Asia than in Southwest Asia). At the same time, a special effort was made in the selection of fields for the 2001 and 2003 activities in Afghanistan to include extreme fields in terms of plant density and capsule characteristics. The combined data are shown in Figure 8.

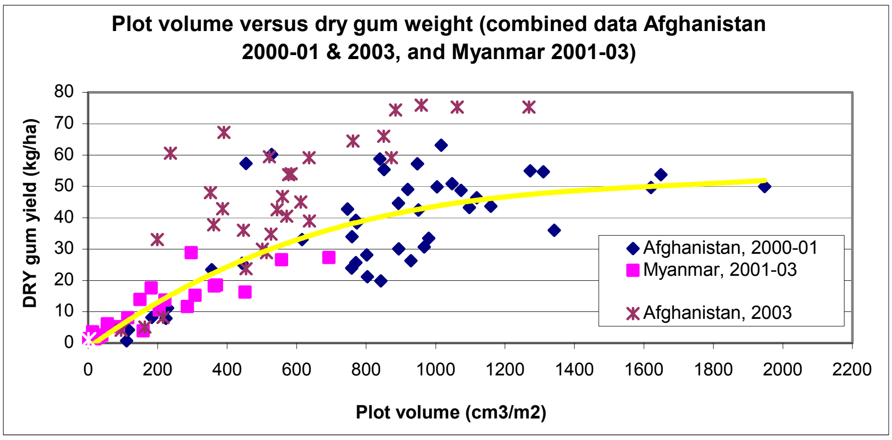

Figure 8
Actual yields of gum in Afghanistan in 2003 were considered very high, even by experienced surveyors. They may be truly high, or incorrect measurements resulting in too low plot volumes may explain these results. As the 2003 Afghan data would have resulted in significantly higher yields, they were not included in establishing the correlation (yellow line). The dry weight for Afghan and Myanmar opium collected in 2003, was calculated assuming a moisture content of 40% and 35%, respectively.

With the extended data at both ends of the curve, it is easier to justify a non-linear regression as shown in Figure 8, although the same limitations already shown in Figure 3, regarding the cluster of data at plot volumes between 800 cm^3/m^2 and 1,100cm^3/m^2, also apply. The leveling off of the superimposed non-linear trendline also reflects the botanical realities, i.e., that there is a maximum in plot volume beyond which there is only minimal increase in yield. However, available data, especially those from Afghanistan, at higher plot volumes, are still insufficient to determine the exact shape of such a curve.

B. Comparison of different statistical models

As part of the method development procedure, the formula [e] emerging from the regression in Figure 8 was compared with other existing formulae, i.e., the formula for the linear model and the model of a non-rectangular hyperbola as described in the Guidelines for yield assessment (UNDCP, 2001a). Figure 9a shows this comparison over a wide, and largely theoretical, range of plot volumes to illustrate major differences. Figure 9b and Figure 9c show the same data for smaller, and more realistic, ranges of plot volumes.

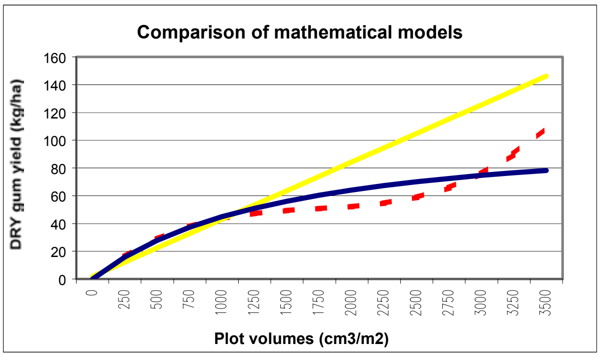

Figure 9a

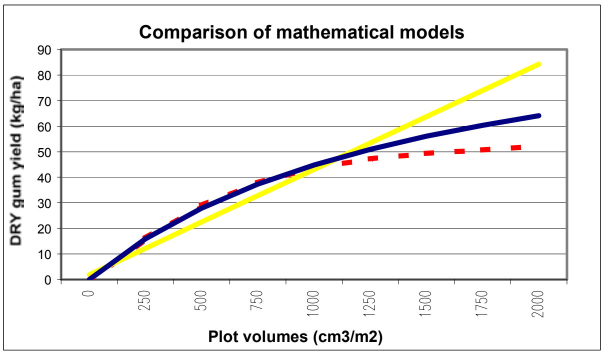

Figure 9b

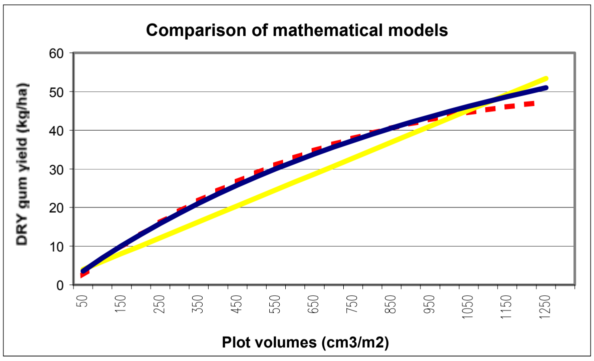

Figure 9c

Legend

- 3rd order polynom (16-digits)
- Linear (UNDCP, 2001a)
- Non-rectangular hyperbola (UNDCP, 2001a)

Typical plot volumes in comparison:
Afghanistan: 700 to 1,500cm^3 per square metre
Myanmar: <1,000cm^3 per square metre (usually <500 cm^3 per square metre)
(Note that 1,000cm^3 per square metre happens to be the plot volume where all three models return the same yield figure)

It is apparent that there are significant differences in the three models, which have an impact on yield estimates, at both the low and the high end of the plot volume-yield correlation. Non-linear models (in a realistic range) may reflect botanical realities and are thus more adequate for higher plot volumes, such as those typically seen in Southwest Asia (Afghanistan). Figure 9c shows, however, that applying a non-linear model also to plot data from Southeast Asia bears the risk of overestimation in the relevant range for that growing region (plot volumes of less than 1,000 cm^3 per square metre, frequently even less than

[e] Note: As a practicality, using Excel, the superimposed trendline was constructed using the formula of a 3rd order polynom (coefficient of determination: r^2=0.71). A problem that arises when Excel is used to obtain the formula of the polynom is that a sufficiently accurate data format has to be chosen. Otherwise, the formula may not represent the true shape of the curve. In this case, a 16-digit formula appeared to reflect the true shape with reasonable accuracy ($y=0.0000000086007612*x^3-0.0000441040770906*x^2+0.0806500640352459*x-1.4866649200078000$).

500cm^3 per square metre). The overall yield estimates for countries such as Myanmar would thus be relatively more affected by a decision in favour of a combined (non-linear) model for both poppy growing regions than estimates for Afghanistan.

As a general rule, therefore, any formula for any model should not be used beyond the range of data for which it was established (see UNDCP 2001a, for details: plot volumes of up to 1,600 cm^3 per square metre were used to develop the formula of the non-rectangular hyperbola, while for the linear model, only plot volumes of up to 900 cm^3 per square metre were used).

With regard to the actual plot data obtained from the field experiments, Figures 10 and 11 show data separately for the two poppy growing regions. In each case, the best fitting trendline is shown, together with other superimposed models.

For experimental fields in Myanmar, the best fitting model is a linear model (Figure 10), with a formula that is very similar to the formula described in the Guidelines (UNDCP, 2001a). **A linear model may therefore be the best possible fit for all data from Southeast Asia**.

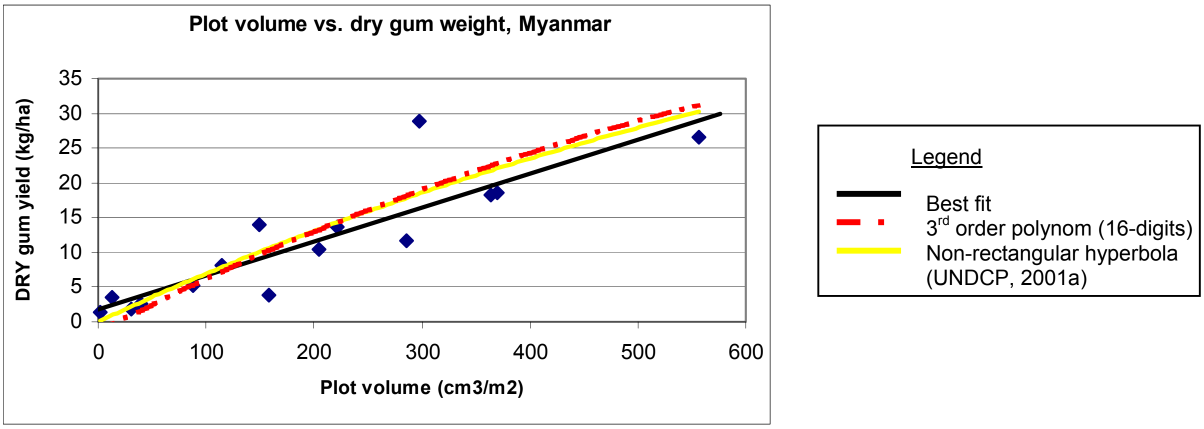

Figure 10

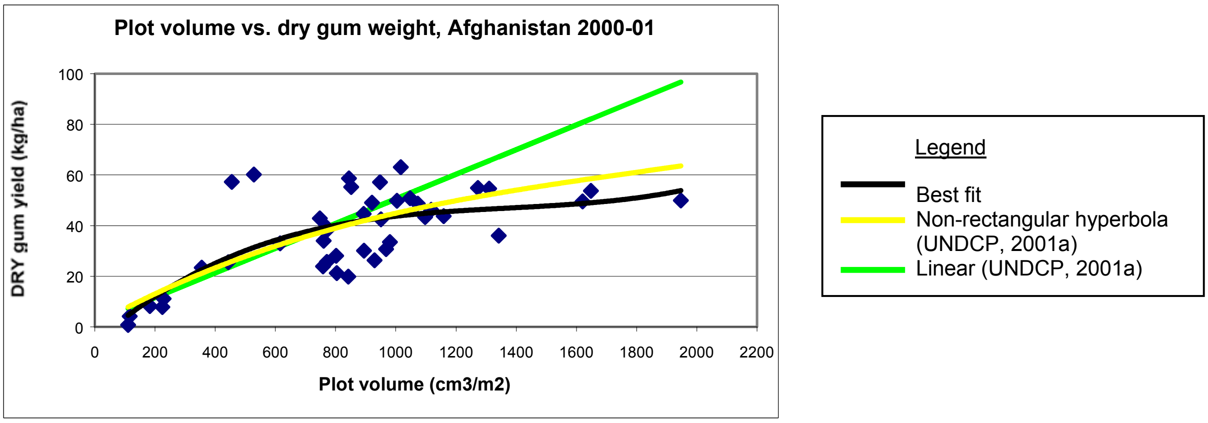

Figure 11

For Afghanistan, with most data being clustered at a plot volume of approx. 800-1,100cm^3 per square metre, neither a linear nor a non-linear model appears to describe the data sufficiently well. It is interesting to note, however, that all **trendlines meet close to the centre of the data cluster, corresponding to a dry yield of about 40-42kg/ha**.

Within the limits of available data, a comparison of errors terms for the different models, again separate for the two major cultivation regions (Table 2), further suggests that the linear model best reflects realities in Myanmar (possibly Southeast Asia in general). A non-linear model, preferably the 3rd order polynom for the range of plot volumes from which it was developed, best explains data from Afghanistan.

Table 2: Comparison of error terms for different models					
		Standard error (RMSE)	ABS	RES	AME
Myanmar	Linear (UNDCP, 2001a)	1.15	**40.2**	-21.0	**2.7**
	Linear (Fig. 10)	**1.05**	40.4	**0.0**	**2.7**
	Non-rectangular hyperbola (UNDCP, 2001a)	1.08	47.1	10.3	3.1
	3rd order polynom (Fig. 10)	1.14	53.1	5.4	3.5
Afghanistan	Linear (UNDCP, 2001a)	2.12	431.5	-9.4	10.3
	Linear (Fig. 11)	2.54	517.9	259.5	12.3
	Non-rectangular hyperbola (UNDCP, 2001a)	1.82	375.2	49.2	8.9
	3rd order polynom (Fig. 11)	**1.75**	**353.4**	**-5.5**	**8.4**

Note: The smaller the error terms the better the model explains the data.
RMSE: Root means square error; ABS: Absolute sum of residuals; RES: Sum of residuals;
AME: Absolute mean error

C. Comparison of predicted yield (models) versus 'observed' yield (actual gum collected and farmers' estimates)

Figure 12 compares the actual (dry) gum collected from individual one square metre plots (converted into a kilogram-per-hectare figure) with the predicted yield for those plots using the different mathematical models. It shows that for small plot volumes, usually the linear model best predicts yield, while at higher plot volumes differences between the models are small, compared to variations in actual gum collected. Beyond plot volumes of approximately 1,300cm^3 per square metre, differences between the models become significant.

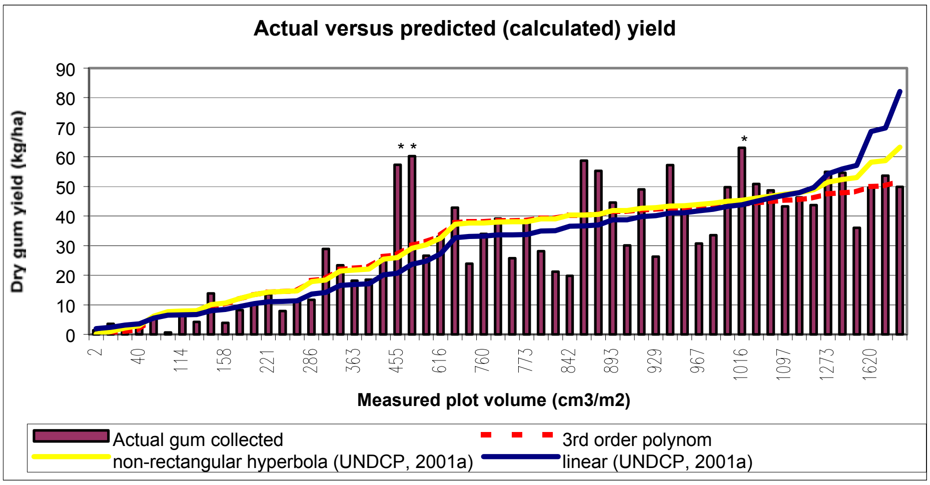

Figure 12

From available information, no single factor is identified as being responsible for the observed strong variations in actual gum yield for individual plots. However, the extent of fertilizer use does seem to play a central role. In addition to the amount and number of fertilizer applications, the ratio of the two most commonly used chemical fertilizers, urea and diammonium phosphate (DAP), also appears to be important (data on the timing of fertilizer application was not available for all fields).

The impact of extensive fertilizer use has been analyzed in more detail for the field with the most apparent discrepancy between actual and predicted yield. Plots of that field (marked with * in Figure 12) are characterized by very high gum yields, far beyond the predicted yield from any of the mathematical models. The corresponding plot volumes, however, are within the typical range for Afghanistan. Analysis of available background information shows that this field is characterized by a very high fertilizer input (both in terms of amount and number of fertilizer applications). Also, the ratio of urea to diammonium phosphate (DAP) is the highest observed (almost 2.5:1). **The observed effects of extensive fertilizer use result in smaller than average capsule volumes** (see Part III-B1, below), **and relatively higher plant densities**. However, as a consequence of the inverse impact of fertilizer on capsule volume and plant density, plot volumes (the relevant parameter for yield estimates) are still within the typical range. **Overall, these results appear to indicate that excessive fertilizer use may increase gum yield beyond an amount predictable from the related capsule (plot) volume** [f] (by contrast, the morphine content of the opium collected from this field was extremely low; for details see Part III-F, below).

As outlined in Part I-E, for cross-checking purposes, it is recommended to obtain as many independent yield data from different sources as possible. For Afghanistan, modification of the yield questionnaires allowed for the recording of farmers' (from 2001 onwards) and surveyors' estimates (from 2003) of opium gum yield from the surveyed fields. Results are shown in Figure 13.

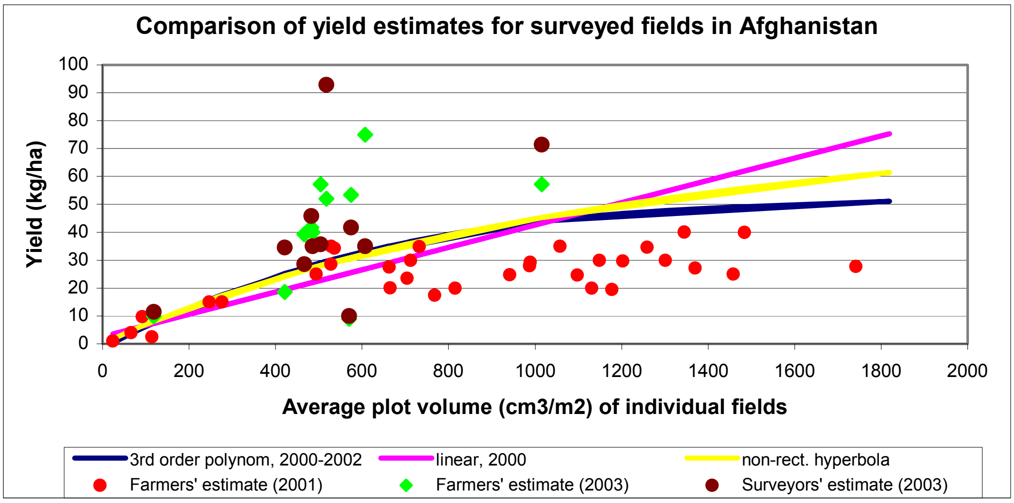

Figure 13

As can be seen, **farmers' estimates**, surveyors' estimates **and predicted potential yields from scientific yield assessments are comparable at the low end, up to plot volumes of about 500cm^3/m^2** (about 25% of all fields surveyed). Beyond that figure, i.e., for the majority of fields in Badakhshan (2001), farmers' estimates were considerably lower than the predicted yields from any of the models. [g] In 2003, farmers' estimates varied significantly for fields of comparable plot volumes. Surveyors' estimates also varied, but less. The reasons for these discrepancies need to be addressed in future surveys.

In absolute figures, in 2001, when systematic data were collected in Badakhshan, the average weighted farmers' estimate was 24kg/ha (compared to a weighted average yield of just less than 40kg/ha calculated applying any of the mathematical formulae). Taking into account that the figures provided by farmers are most likely to refer to FRESH gum (i.e., at least 30% higher than the calculated yields, which are based on DRY gum (= 0% moisture), **farmers' estimates may have to be considered as considerable underestimates (i.e., the actual output of opium gum per hectare could be significantly higher than**

[f] More detailed information on fertilizer use, the amounts applied and the timing of application during the growing cycle, are required to assess its impact on plant development, gum yield and morphine content.

[g] With plot volumes of typically less than 500 cm^3 per square metre in Myanmar, farmers' estimates in that country can be expected to be much closer to scientifically predicted yields. However, for the two fields surveyed in that country in 2003 (plot volumes 285 cm^3/m^2 and 325cm^3/m^2), farmers' estimate were about 30% and 150%, respectively, of predicted potential yield from the linear model. This suggests that also in Myanmar, there is a need to better understand the context of farmers' ways of reporting yield.

assumed previously). The significance of this finding is further heightened by results concerning the morphine content of the gum (see Part III-F below).

One possible explanation for the large discrepancy between the yield figures could be that farmers only provide figures of what they themselves obtain from the gum harvested (i.e., minus any “tax”, “payment” in kind of the harvesters, or local consumption). In this particular study, however, it could not be verified whether farmers’ estimates reflect the total botanical yield or the practical yield. Information from UNODC fieldwork suggests that one fifth to one sixth of yield may be paid to itinerant harvesters (UNDCP, 1999a). Further clarification is therefore required of what farmers actually refer to when reporting ‘yield’. In addition, the comparability/objectivity of other sources of yield data, e.g., assessments from experienced surveyors or coordinators, should also be explored more systematically in future studies.

D. Conclusions

Predicted potential yields from scientific yield assessment surveys are in good agreement with farmers’ estimates (and with actual yields collected from individual plots) for small plot volumes, up to about 500cm^3/m^2. Beyond that figure, farmers’ estimates are considerably lower than the predicted yields from any of the models.

Overall, it is concluded that, **in the absence of additional data from experimental fields in both Afghanistan and Myanmar to determine more precisely the range of applicability of any of the models, the formulae described in the Guidelines for yield assessment (UNDCP, 2001a) should be used**, namely a linear model for regions characterized by plot volumes of less than 1,000cm^3 per square metre, i.e., for South East Asia. Non-linear models such as a non-rectangular hyperbola [h] result in acceptable yield estimates for regions where plot volumes are predominantly around and beyond 1,000cm^3 per square metre, e.g., in Afghanistan. [i]

<u>Linear model</u>:

Yield (kg/ha, dry gum weight) **= 1.89 + 0.0412 * VC**
With **VC** = plot volume (cm^3/m^2)

<u>Non-rectangular hyperbola</u>:

Yield (kg/ha, dry gum weight) **= [(VC + 1495) – ((VC + 1495)^2 – 395.259 * VC)$^{0.5}$] / 1.795**
With **VC** = plot volume (cm^3/m^2)

Source: UNDCP, 2001a

[h] Note that a 3rd order polynom leads to similar, acceptable results. However, as outlined above, a formula that requires more than 3 digits in its factors for sufficient accuracy may not be practical.

[i] Note that the formula of the non-rectangular hyperbola was developed using plot volumes of up to 1,600cm^3/m^2 (UNDCP, 2001a).

Part III

SUBSTANTIVE FINDINGS

A. Gum yield from different field visits and different maturation stages of poppy fields

In all experimental fields, the timing of the harvest of the experimental fields was made by the farmers, and harvesting itself followed common harvesting practices, being carried out by professional lancers and the farmers themselves.

1. Afghanistan

A comparison of the amounts of gum obtained from individual field visits during the harvesting period usually showed an increase in gum yield from the first to successive days. Figures 14a and 14b show the relative amounts (in %) of gum yield from experimental fields in Afghanistan in 2000 and 2001, ranging for the first visit from less than 10% to more than 50% of the total gum collected.

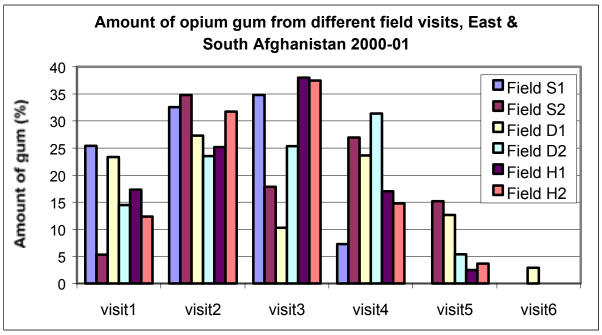

Figure 14a

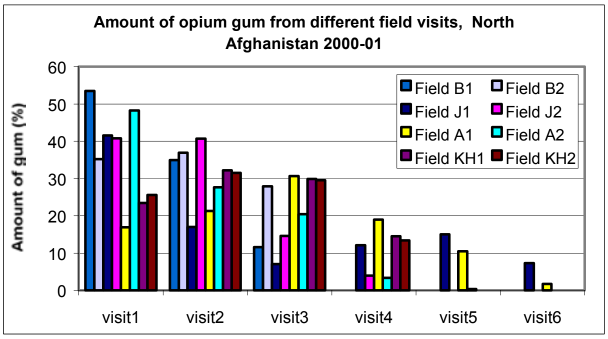

Figure 14b

In all fields studied, two-thirds to 100% of opium gum is harvested within the first three visits. In Eastern and Southern Afghanistan, harvest was usually terminated when the yield obtained from a field visit fell below 5% of the total yield. In Northern Afghanistan, the end-of-harvest figure was much more variable, ranging from less than 1% to close to 30%. A similar pattern was also seen in the 2003 harvest.

Figure 15 shows the maturation stage of poppy fields in Afghanistan at the beginning of the gum harvest by comparing the number of mature capsules with that of immature capsules, flower buds and flowers, on the first day of the harvest. In less than 50% of fields was the number of mature capsules larger than that of immature capsules, flowers and flower buds, i.e., the majority of capsules was not ready for lancing on the first day of the harvest.

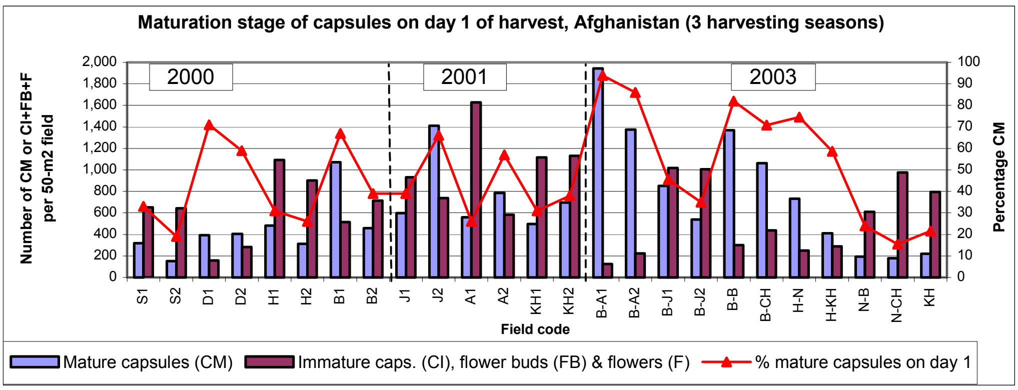

Figure 15

On average for the three harvesting seasons surveyed in Afghanistan, lancing started when about 40-50% of capsules were mature (range: 15-94% for 2000, 2001 and 2003 combined). While the average percentage of mature capsules at the start of harvesting was comparable in 2000 and 2001, it was higher, and the range larger, for the 11 fields surveyed in 2003. (for possible implications for yield assessment studies, see section A.3, below).

2. Southeast Asia

In contrast to Afghanistan, where harvest usually lasts for about 2 to 3 weeks, in Myanmar and Laos, lancing traditionally takes places every second or third day, for a period of up to six weeks (see also section D, below). [j] In Myanmar, the weather during the 2001-02 harvesting periods was considered bad (rainy and cold), which may explain the strong variation in amount of gum harvested on individual days (Figure 16 and 17), and the early termination of harvest, after 15 field visits, in 2001. Weather conditions during the 2003 harvesting period were considered 'average', resulting in 15 and 17 visits to the two fields.

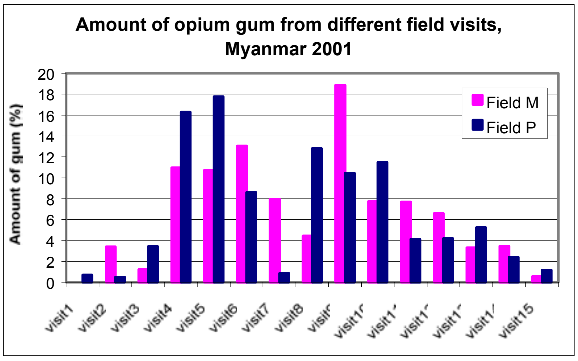

Figure 16

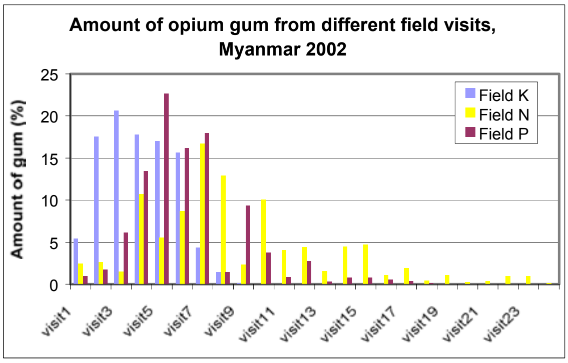

Figure 17

Figure 18 compares the amounts of opium collected from different field visits from the same field in three successive harvesting periods.

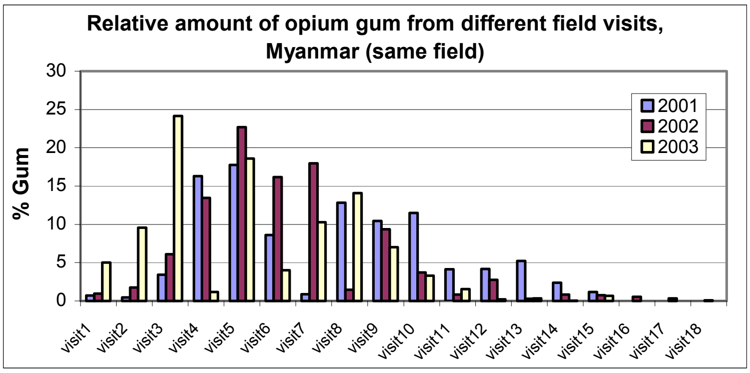

Figure 18

Overall, however, and disregarding losses in gum due to bad weather, the amount of gum collected during different field visits is much closer to normal distribution in Myanmar than in Afghanistan, particularly Badakhshan Province. Unlike in Afghanistan, farmers in Myanmar only terminated harvest when the yield obtained from a field visit fell below 1% of the total yield.

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[j] This is probably also a reflection of the lower homogeneity of fields in Southeast Asia compared to Southwest Asia. While in Afghanistan the number of field visits equals frequently the number of lancings (i.e., visits to the same capsule), this is not the case in Southeast Asia, where subsequent visits to the same field result in more capsules being lanced, but not necessarily the same ones.

In terms of maturation stage, in Myanmar, the number of immature capsules was usually larger than that of mature capsules at the start of harvesting. On average, mature capsules constituted 11% to 63% of all capsules, flowers and flower buds at the beginning of harvest, with a range, for individual plots, from 1 to 100%.

In this connection, it is interesting to note that in Myanmar, in the same field, harvest started in 2001 when about 60% of capsules were considered ‘mature’ by the surveyor, while in 2002 and 2003, it started already at a ratio of less than 15% and 11% mature capsules, respectively.

In Laos, UNODC has conducted limited yield surveys on a regular basis since 1998, initially using an existing formula developed by the USDA (LCDC, 2000). In 2002, for the first time in that country, also the related field experiments for method development have been carried out, with the aim of evaluating the procedure and the mathematical formula for yield calculations for that country. However, resource constraints did not permit full monitoring of the activities carried out, and data therefore have to be used with some caution. Nevertheless, for comparative purposes, Figure 19 provides information on the amount of opium collected during different field visits in Laos in 2002. In both fields, harvest was terminated when the yield obtained from a field visit fell below 5% of the total yield.

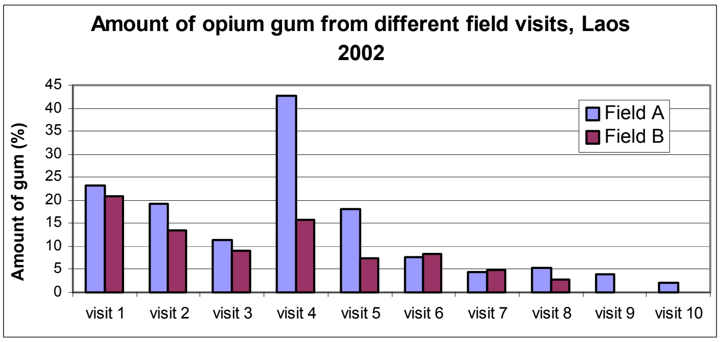

Figure 19
Note that a period of heavy rains has affected gum yield between visit 4 and 5.

3. Afghanistan and Southeast Asia combined

Figure 20 illustrates the maturation stage of poppy fields expressed as the relationship between the number of mature capsules (CM) on the one hand, and of immature capsules (CI), flowers (F) and flower buds (FB) on the other, at the beginning of harvest. It shows that, typically, in both poppy growing regions, harvest starts before the majority of capsules has reached maturity. The number of mature capsules at the beginning of the harvest was particularly low in Southeast Asia, which may also explain the comparatively longer duration of the harvesting period in that region, compared to Afghanistan.

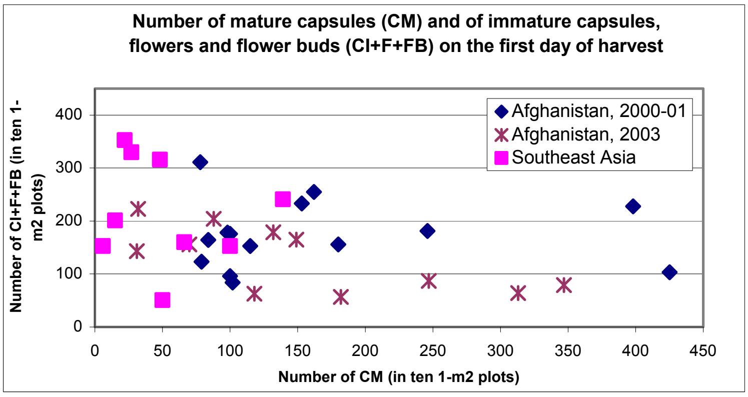

Figure 20

The observation that the timing of opium gum harvest (its beginning and end) varies strongly across regions and even within a country, from one year to another, has implications for yield assessment studies estimating yield from characteristics of *mature* poppy capsules. Part I-A and I-B, above, summarize observations from UNODC field activities related to the maturation stage of poppy fields at the beginning of harvest (particularly the recognition of capsules, flowers and flower buds that will contribute eventually to yield), and possible consequences for practical field procedures.

It should also be noted that the timing of harvest and the number of lancings also has an impact on the morphine content of the opium gum (see section F, below).

B. Gum yield and plant characteristics

Yield estimates, using the scientific approach proposed in the UNODC yield manual (UNDCP, 2001a), are based on capsule volume, which itself is calculated from capsule height and diameter using the formula of a sphere.

Typical capsule shapes and the capsule indices in the surveyed fields were determined in order to test the applicability of this approach. Relevant observations and findings are presented below. They do confirm the approach, although the range of capsule shapes observed in the experimental fields in the three countries varies relatively widely.

1. Capsule shape

Visual classification by the surveyors of poppy capsules into one of three groups that were considered to represent the extremes possibly encountered (Figure 21) confirmed that in most experimental fields in all three countries, the majority of capsules was, indeed, spheroid. Co-existence of different capsule shapes, including conical shape, was more common in fields in Myanmar and in the North of Afghanistan. [k]

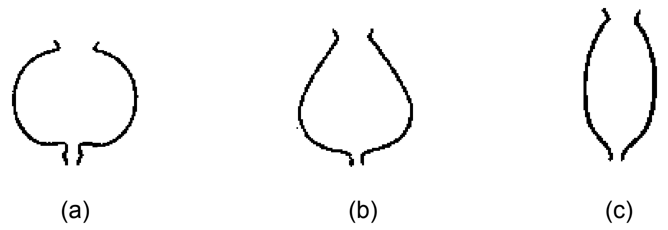

Figure 21 Different capsule shapes: (a) spheroid, (b) conical, and (c) oval.

The predominant capsule shape in Thailand is conical followed by spheroid, and oval (Chamnivikaipong, 2000). Available information from that country also suggests that there is a correlation between capsule shape and the number of stigmatic rays (see Figure 2, above). According to that information, spheroid capsules are characterized by twelve or more stigmatic rays, conical capsules by ten to twelve, and oval capsules by no more than five.

[k] It is a well known fact that different shapes can be found in the same field, or even on the same plant; and that transitions are gradual (Veselovskaya, 1933/1976).

2. Capsule index

The system of capsule indices (capsule height divided by diameter), as established by Veselovskaya (Veselovskaya, 1933/1976), provides another means for classifying poppy capsules. The classification system can be summarized as follows:

Capsule index	Shape
1.76-2.70	oval
1.26-1.75	wide oval
0.76-1.25	spheroid (orbicular), conical, or cylindrical
0.45-0.75	flat

Using that system, the majority of capsules of the experimental fields in Afghanistan fell in the 0.76-1.25-index range. Of those, about 70% fell between capsule index 1.00 and 1.25, i.e., with capsule height larger than diameter. In one field, capsule height and diameter were equal (index 0.99-1.01). In Myanmar and Laos, capsule indices of experimental fields were typically higher than in Afghanistan. A wide oval shape was the predominant shape in the two experimental fields in Laos. These results confirm the reported visual classifications.

Figure 22 compares data from Afghanistan and Myanmar. It shows that the more spheroid capsule shapes encountered in Afghanistan tend to produce higher gum yields.

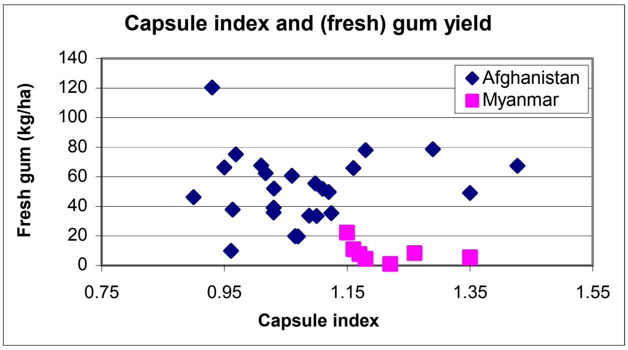

Figure 22

3. Capsule volume (cm^3) and plot volume (cm^3/m^2)

Graphical presentation of the frequency distribution of individual capsule volumes from experimental fields showed significant differences between Afghanistan on the one hand, and Southeast Asia on the other (Figure 23): While for Afghanistan, the distribution is characterized by a wide plateau representing capsule volumes from 10 to 35cm^3, heavily skewed to higher capsule volumes, the distributions for Laos and Myanmar peak at capsule volumes of less than 5 cm^3 and 15cm^3, respectively.

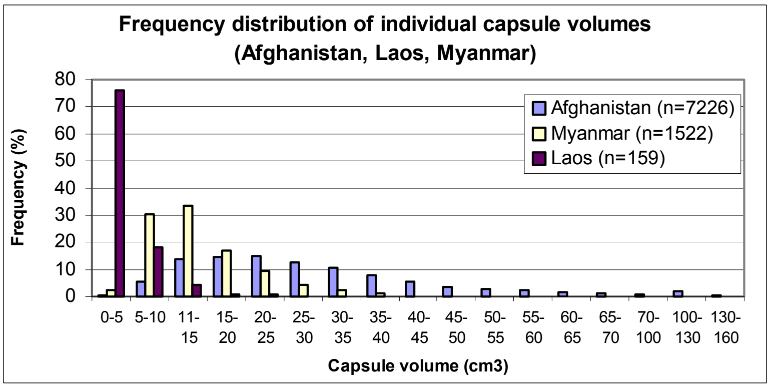

Figure 23

On a provincial basis, for Afghanistan, and acknowledging that some small capsules are present in each field, capsule volumes were lower in the North (Badakhshan and Balkh Provinces) and South (Helmand) than in Nangahar (see also Figure 28, below).

In 2001, when activities were limited to Badakhshan, there were two fields within that province with a significantly lower capsule volume than the others. As pointed out above (Part II-C), the most apparent difference [1] between these two and all other fields was the excessive fertilizer application. Actual (collected) yields on those fields were high, as were farmers' expectations regarding yield.

Again, as already pointed out above, it should be noted that those two fields were not outstanding from others in the region with regard to plot volume, i.e., the relevant parameter for yield estimates; higher plant densities therefore appear to have made up for the smaller capsules). Overall, however, as shown in Figure 24, capsule volumes and plot volumes appear to be linearly correlated.

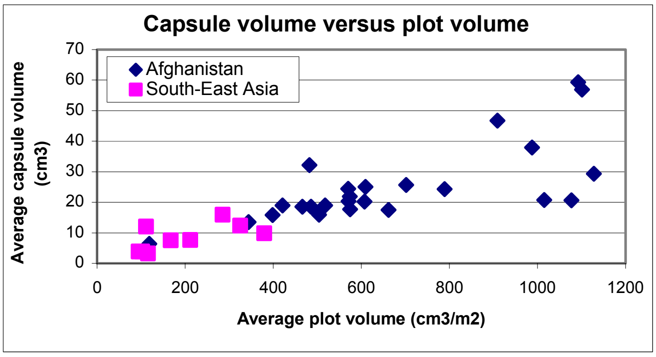

Figure 24

The same distinct regional frequency distribution illustrated for capsule volumes in Figure 23 is also observed for plot volumes. Figure 25 compares the plot volumes observed in Afghanistan in 2001 with those from other countries in the same year. It shows that the majority of plots in Southeast Asia have volumes of less than 500cm^3 per square metre, while plot volumes in Afghanistan typically fall within the range of about 700 to 1,500cm^3.

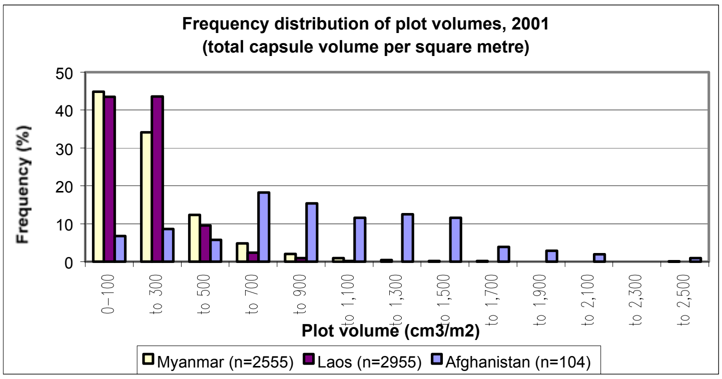

Figure 25

Table 3 compares the resulting national yield figures for Afghanistan for the 2000 harvesting season (when 91 fields from all over Afghanistan were surveyed), when non-linear models such as the 3rd order polynom and the non-rectangular hyperbola are applied. National average yields were calculated as simple and weighted figures (weighted against field size),

[1] Note that the available background information for the experimental fields has not yet been analyzed systematically to identify more complex relationships.

using either all available data or, separately, excluding plots with volumes larger than 2000cm^3 (i.e., assuming that a procedural error may have been responsible for such large plot volumes).

Table 3: Afghanistan, 2000: Comparison of national yield figures (kg/ha of DRY opium gum), using different formulaes and data sets		
	3rd order polynom	Non-rectangular hyperbola
ALL plots included		
Simple average	45	46
Weighted average	44	46
Excluding fields with average plot volumes > 2000 cm^3 per square metre		
Simple average	41	43
Weighted average	41	45

The fact that the two figures for the simple and the weighted average are so close is the result of a relatively even distribution of field sizes in Afghanistan (the most common size of a field in Afghanistan is around one jerib, or 2000m^2, or 1/5 of a hectare). For the range of field sizes covered by the 2000 study, it also indicates that opium gum yields in Afghanistan are largely independent of field size.

For comparison, based on the opium gum actually collected in three plots of each of the experimental fields studied in Afghanistan in 2000, the simple average dry gum yield is 34.4kg/ha. The **standard error of the mean** for the actual yield for three one square metre plots of the experimental fields in Afghanistan (n=24) is 3.7kg/ha.

4. Opium poppy variety

The information collected on poppy varieties is descriptive in nature, and was obtained through interviews with farmers, or from assessment by surveyors themselves; no botanical classification has been carried out. In the three growing seasons surveyed in Afghanistan, eight different poppy varieties were identified, by local name [m], on the experimental fields. Three of them, among others, are described in Annex E of the UNODC Annual Opium Poppy Survey, 1999, which provides a discussion of the advantages and disadvantages of different poppy varieties from a socio-economic point of view (UNDCP, 1999b; a summary of the information on poppy varieties is provided in Annex III to this report). Information on the poppy varieties grown on the experimental fields in Myanmar and Laos is incomplete.

In Afghanistan as a whole, more than 25 poppy varieties, by local name, were grown; in some fields cultivation of more than one variety was reported.

Considering this variability, and also considering other factors which may have an impact on gum yield, such as soil type, use of fertilizer, type and extent of irrigation, etc., **no significant impact of the poppy variety on gum yield could be observed**. The preference for the cultivation of individual poppy varieties appears therefore to be guided by other factors, such as resistance to drought and diseases, possibility to stagger maturity and thus timing of harvesting of different varieties, extent of farmer's care required, and other, socio-economic aspects. Beliefs in the 'quality' of opium gum from different poppy varieties

[m] Since local names are usually descriptive in nature, featuring, for example, the petal colour, the origin of the seeds, or the farmer who first cultivated a variety in a region, there may actually be considerable overlap in the varieties described. This is confirmed by individuals knowledgeable of the situation in Afghanistan, who have suggested that there may be in fact only four to five different varieties grown in the country, namely, (i) Watani Soorgulai, or W.Surguly, (ii) Watani Spingulai, or W.Spinguly, (iii) Bahrami Baragai, and (iv) Bahrami Soorgulai. In the absence of a full botanical classification, the systematic analysis of the information collected during the yield studies might provide a first assessment of the variability of poppy varieties encountered.

may also play a role; they would, however, require scientific substantiation in view of the observations made during this study.

Information from Myanmar and Laos suggests that poppy is usually grown from seeds from the previous harvest. Available data are, however, too limited to draw conclusions on the impact of poppy variety on gum yield and/or morphine content. Anecdotal information from Myanmar suggests that there is a belief that a more spheroid capsule shape, which appears to be characteristic for red coloured varieties, produces higher gum yields (Naing, 2002).

C. Gum yield and crop damage

Data and information collected during the limited yield survey activities in Afghanistan (Badakhshan Province) in 2001 confirm the existence of an inverse relationship between crop damage [n] and yield. Figure 26 illustrates this relationship, using plot volume, i.e., the projected total volume of mature capsules in a one square metre plot, as an indicator for yield. However, further data are required to substantiate this finding, especially at lower levels of damage.

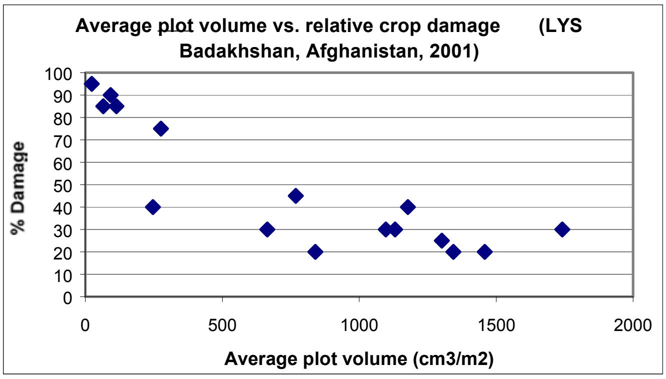

Figure 26

In terms of the direct causality, it appears that both plant density and average capsule volume are negatively correlated with crop damage as shown in Figures 27a and 27b.

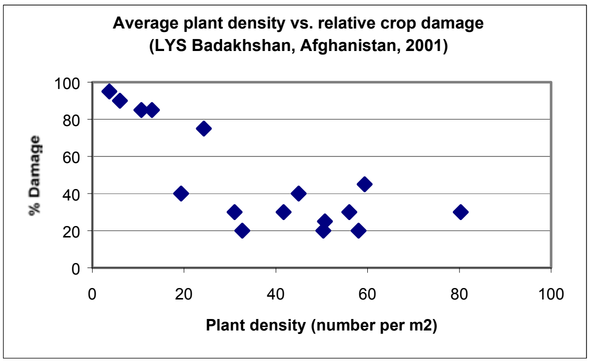

Figure 27a

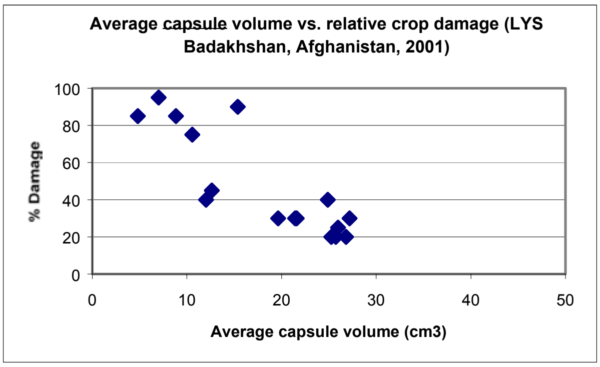

Figure 27b

The specific impact of crop damage caused by downy mildew infection on yield has been investigated in more depths at Rajasthan Agricultural University, Udaipur, India. The study found that such damage results in a loss in opium gum yield of up to almost 40% (Table 4) (CBN, 1999):

[n] 'Crop damage' refers to the extent of damaged crop (expressed as a percent figure), irrespective of the type of damage, as assessed by the surveyors.

Table 4: Effect of downey mildew on opium gum yield		
Infection index	Gum yield (kg/ha)	Yield (%)
<10%	56	100
~20%	49	87.5
~60%	35	62.5

D. Gum yield and harvesting practices

Observations from experimental fields indicate that the **timing of the gum harvest** (i.e., its beginning and end) **varies strongly across regions and even within a country from one year to another** (see section A, above). It appears, therefore, that the timing is not only determined by the maturity of a given poppy field, but is also influenced by other considerations, such as availability of harvesters and overall timing for harvest in a region.

Gum harvest in Afghanistan usually lasts for about 2 to 3 weeks. In Southeast Asia, by contrast, lancing traditionally takes places every second or third day, for a period of up to six weeks.

Data from the questionnaires related to the experimental fields in Afghanistan, Myanmar and Laos show that the number of blades on the lancing tool, the number of cuts made during one visit to a capsule (lancing), and the number of lancings (i.e., visits to the same capsule in a field) differ within and between countries and regions.

Typically, harvesters in Afghanistan make one cut per visit, using a lancing tool with 4 to 5 blades in Badakhshan, 6 to 8 blades in the East and South, and 10 blades in Balkh Province in the North (2003 data). In 2000-2001, the typical number of lancings, i.e, the number of visits to the same capsule, ranged from 1-3 times in the North to 4-6 times in the South and East of Afghanistan. However, bearing in mind that the weather conditions during the 2000 and 2001 growing and harvesting seasons were unusual, the reported numbers of lancings may not be representative for a "normal" year. In 2003, the weather during the growing season was considered much more favourable, but poor weather with rain during the harvesting season may have contributed to fewer lancings, especially in the South.

In Southeast Asia, harvesters appear to make typically one to two, and up to three, cuts on a single lancing, using a tool with fewer blades (usually 3 blades) [o]. However, since fields in Southeast Asia are far less homogeneous in terms of maturation stage than in Afghanistan, a single capsule is usually lanced only 4-6 times.

Taking the observations from the different growing regions together, it appears that there is a relationship between the number of blades on the lancing tool and the number of cuts made per visit. **Generally, the fewer blades, the more cuts are made per lancing.** This appears to be a reasonable / expected result, taking the 'physics' of opium latex exudation into account: fewer incisions tend to increase the size of the drop of latex with a danger of losses due to dripping off.

The implications of the observed regional differences for gum yield and morphine content are not known. Further systematic work is required to better understand this issue (for the relationship between number of lancing and morphine content, see section F, below).

[o] Available information suggests that in other parts of the Shan State of Myanmar, namely the South (Pinlaung Township), lancing tools with up to 13 blades are used.

Figure 28 shows the relationship between capsule volume and number of cuts in experimental fields. While there is no overall relationship, significant differences between regions are apparent. In general, and this may be a reflection of the inverse relationship between the number of blades on the lancing tool and the number of cuts made, the small capsules which are characteristic for poppies in Southeast Asia tend to be cut more often than the bigger capsules in Afghanistan.

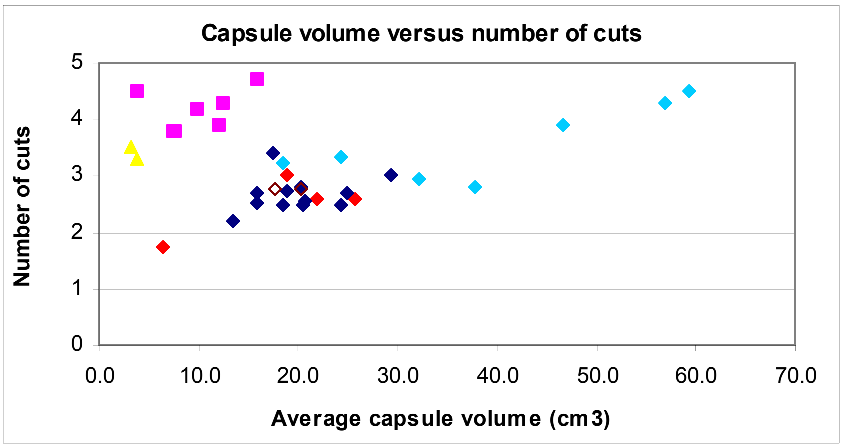

Figure 28

Legend

- Myanmar
- Laos
- Afghanistan, Helmand Province
- Afghanistan, Nangahar Province
- Afghanistan, Badakhshan Province
- Afghanistan, Balkh Province

Within Afghanistan, the number of cuts appears to be almost independent of capsule size, although the largest capsules tend to be cut more often. On a provincial basis, Figure 28 confirms that capsule volumes are typically larger in the East (Nangahar) than in the North (Badakhshan and Balkh) and the South (Helmand) of Afghanistan. Interestingly, capsule volumes and number of cuts in Helmand, the province, which, historically, accounted for the highest opium production, are more similar to those in Badakhshan than to those in Nangahar, historically the second largest production area in Afghanistan (in 2003, Nangahar, Helmand and Badakhshan accounted for 23%, 19% and 16% of the total poppy cultivating area in Afghanistan (UNODC, 2003a).

E. Moisture determination

Fresh opium contains between 20% and up to 60% water, depending on the weather conditions at harvest, i.e., when exactly the opium was collected (e.g., before or after sunrise), on the extent of morning dew, etc. During storage and transport, opium loses water to varying extents, again, depending on the storage conditions (type of wrapping, temperature, size of the opium material/block, etc.). When not dried in an oven, in a laboratory, raw opium will always contain residual water (moisture).

In order to be able to estimate opium production from the yield figures obtained at harvest time, information about the water content is critical.

It was one of the objectives of the yield-related activities in Afghanistan and Southeast Asia to investigate the issue of moisture content. However, for practical reasons it was not possible to determine, on the spot, the dry weight of the opium collected on individual plots. Therefore, the weight of the fresh opium gum, at harvest, was determined, and the difference between fresh and oven dry weight of representative samples returned to UNODC's Laboratory and Scientific Section was calculated as moisture content. This figure was then used in connection with the fresh gum weights determined for individual plots. Figures thus represent the moisture content as an average of the combined gum from all field visits of a given poppy field.

Results from experimental fields in both Afghanistan and Myanmar are summarized in Table 5. It shows that in 2000 and 2003, the moisture content, at harvest, of gum from Afghanistan ranged between 32% and 53%. In 2000, it was slightly lower in the North than in the South and the East; in 2003, available results for samples from the different regions are far more varied. The typical moisture content of opium samples harvested in 2001 in Afghanistan's Northeastern province of Badakhshan was around 40%. The moisture content of opium from Myanmar was calculated at 35%, as an average of three samples from one field. [p]

Table 5: Moisture content of fresh opium gum at harvest (average of all lancings)

Code	Province (district)	Moisture content
Afghanistan, 2000		
North (B1)	Badakhshan (Jurm, Qada)	**32%**
North (B2)	Badakhshan (Jurm, Aslijurm)	**35%**
East (D1)	Nangahar (Dara-e Nur)	**42%**
East (D2)	Nangahar (Dara-e Nur)	**44%**
South (H2)	Helmand (Nad-e Ali)	**45%**
East (S1)	Nangahar (Shinwar)	**45%**
East (S2)	Nangahar (Shinwar)	**53%**
South (H1)	Helmand (Nad-e Ali)	**(62%)***
Afghanistan, 2001		
North (J2)	Badakhshan (Jurm, Sasht-e-Shahr)	**32%**
North (KH2)	Badakhshan (Jurm, Dar-Khan-Khash)	**38%**
North (A1)	Badakhshan (Faizabad, Argo)	**40%**
North (A2)	Badakhshan (Faizabad, Argo)	**41%**
North (KH1)	Badakhshan (Jurm, Dar-Khan-Khash)	**41%**
North (J1)	Badakhshan (Jurm, Dashtak)	**42%**
Afghanistan, 2003		
South (H-KH)	Helmand (Naway i Barakzayi)	**37%**
Northeast (B-J1)	Badakhshan (Jurm)	**39%**
Northwest (BLK)	Balkh	**48%**
South (QDR)	Qandahar	**53%**
Myanmar (Shan State, Wa Special Area), 2001		
M	Mong Pawk Distr., Mong Pawk Village Tract	**35%**
P	Mong Pawk Distr., Wan Kong Village Tract	**n/a**

Note: Moisture contents may, in fact, be slightly lower since minor inaccuracies cannot be excluded due to procedural difficulties (weighing fresh gum on the spot, losses during transfer of sample from plastic bag to container in the lab, etc.).
As outlined above, method procedures were designed to ensure the accuracy of field weighings. In general, readings in the field were within 95% accuracy.
All fields in Afghanistan were irrigated; field M in Myanmar was rainfed.

* The figure may not represent the 'moisture' content of the fresh opium sample, since losses due to procedural difficulties may partly account for this high figure.

Results were cross-checked and confirmed by (i) determining the moisture content in gum collected separately from individual one square metre plots (average of all lancings from these plots), and (ii) calculating weighted moisture figures from a field, where gum was also collected separately for individual lancings.

As pointed out above, the moisture content of fresh opium is dependent on the weather conditions *at harvest*, and does not, therefore, reflect the moisture content of the opium as

[p] Due to delays in shipment or weighing errors in the field, the moisture content of opium samples from subsequent years could not be determined.

traded. UNODC has traditionally calculated production figures for Afghan opium by deducting 30% from the gum's fresh weight at harvest. The 30% figure is based on information from fieldwork in the context of UNODC's Annual Opium Poppy Surveys (AOPS), which suggests that freshly harvested opium loses about 30% of its original weight during transport and storage, within the first 2-3 months. Information from fieldwork in Myanmar consistently suggests smaller evaporation losses during the drying process, although with a reported variability ranging from evaporation losses of 4-10% within a year, to 15% already within the first month (Lwin, 2002; Naing, 2002).

To obtain data on the residual moisture content of opium after storage, two samples from fields in the East, from the previous year's harvest, were also analyzed. Both samples had been stored following the traditional preferences in that region, that is, in a way, which allows moisture to evaporate. The residual moisture content found in these samples was 10% and 12%, respectively.

The range of moisture content of fresh opium at harvest, as summarized in Table 5, is in line with observations from previous field work in Afghanistan (UNDCP, 1995). In addition, two studies on Indian opium also found similar figures. The first study, conducted by Rajasthan Agricultural University, Udaipur, in 1999, found the moisture content in fresh opium to range from 26.3% to 55.3%, with an average of 39.4% (CBN, 1999). For opium dried at 70°C, the same study found an average residual moisture content of 12.7% (range: 1.8% to 36.2%). Another survey of opium production practices in connection with India's legitimate opium industry found that opium contained 25-60% water when delivered by farmers, 30-40% water when put into trays for sun drying, and about 12% after 10-12 days of sun (Mallinckrodt, 1994).

It can be concluded, therefore, that the moisture content of fresh opium typically ranges from 30-50%, and that after storage it is between 10-15%. Although usually referred to as 'dry' opium, opium after the natural drying process still contains residual water.

Although technically incorrect, if the term 'dry opium' is understood to refer to opium after the natural drying process, and is used consistently, this can still serve as a basis for comparing opium production from one year to another. Nevertheless, the issue has implications for estimating the amount of morphine, and heroin, that can typically be obtained from a given quantity of opium. Further and more detailed background information is required in this area in order to improve production estimates, for opium, and, ultimately, for morphine and heroin (see also section F, below, and Annex IV which raises related questions).

F. Morphine content

The **morphine content** of opium is determined by subjecting opium to laboratory analysis. It is calculated on the basis of oven-dry opium.[q] Morphine content is thus the maximum extractable amount of morphine in opium. It is not necessarily the same as the **conversion ratio**, which refers to the amount of morphine that can be produced from opium. However, due to the simplicity of the process, opium-to-morphine conversion ratios, even under crude clandestine laboratory conditions, are high.

In order to investigate the morphine content of opium from Afghanistan, Myanmar and Laos, usually two gum samples were returned to UNODC's Laboratory and Scientific Section from each of the experimental fields. These gum samples were collected after harvest was terminated, i.e., they are representative, in terms of moisture (see above) and morphine content, of the combined gum from all lancings.

[q] Note that throughout this section, as is common practice for the reporting of laboratory data, use of the term 'dry opium' has been standardized to refer to oven-dry opium.

Figure 29 shows the morphine content of samples from fields from Afghanistan and Myanmar. **It shows that there is a significant difference between opium from Myanmar and Afghanistan: While the morphine content of opium from the majority of fields in Myanmar is between 10% and 14%, it can be significantly higher in Afghanistan. In that country, the opium from more than 40% of the fields surveyed showed a morphine content higher than 15%, frequently as high as 20%.**

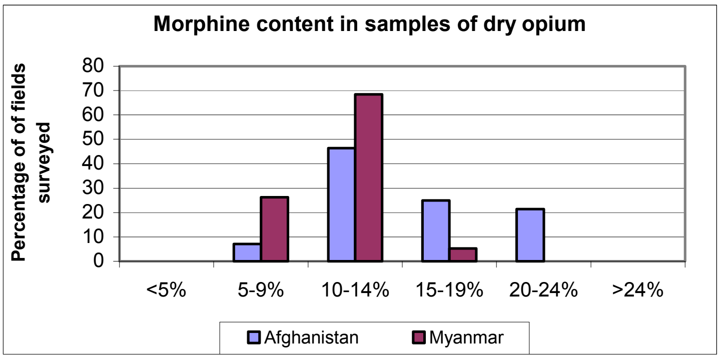

Figure 29

The high morphine content of opium from Afghanistan was also confirmed by the analysis of an old opium sample from that country from the late 1950s, which resulted in a morphine content of almost 17%. It was also indirectly confirmed by reports from the Kyrgyz Republic, stating that the morphine content of opium trafficked in that country ranged from 14% to 22%, with a typical morphine content of 18% (ARQ, 2001).

Tables 6a and 6b provide details on the morphine content of opium from Afghanistan and from Southeast Asia, on a sample-by-sample basis.

Table 6a: Morphine content in dry opium gum (all lancings combined)

Sample description		Morphine content
Code	Province (district), year	(%, in dry gum)
Afghanistan		
East (D1)	Nangahar (Dar-e Nur), 2000	23.5
North (J1)	Badakhshan (Jurm), 2001 (sample 1)	22.3
	Badakhshan (Jurm), 2001 (sample 2)	19.3
North (B5)	Badakhshan (Jurm), 2000	21.0
North (KH2)	Badakhshan (Jurm), 2001 (sample 1)	20.4
	Badakhshan (Jurm), 2001 (sample 2)	20.0
North (J2)	Badakhshan (Jurm), 2001 (sample 1)	19.4
	Badakhshan (Jurm), 2001 (sample 2)	17.2
North (KH1)	Badakhshan (Jurm), 2001 (sample 1)	19.6
	Badakhshan (Jurm), 2001 (sample 2)	18.6
North (B1)	Badakhshan (Jurm), 2000	19.7
North (B3)	Badakhshan (Jurm), 2000	19.6
North (KH)	Badakhshan (Jurm), 2001 (rainfed field)	18.4
East (S2)	Nangahar (Shinwar), 2000	18.1
Northwest (B-CH)	Balkh (Chimtal), 2003 (sample 1)	16.4
	Balkh (Chimtal), 2003 (sample 2)	11.4
East (S1)	Nangahar (Shinwar), 2000	16.3
North (B2)	Badakhshan (Jurm), 2000	16.1
East (D2)	Nangahar (Dar-e Nur), 2000	15.9
North (A2)	Badakhshan (Jurm), 2001 (sample 1)	15.4
	Badakhshan (Jurm), 2001 (sample 2)	13.8
South (H1)	Helmand (Nad-e Ali), 2000	14.5
South (H2)	Helmand (Nad-e Ali), 2000	13.9
North (B4)	Badakhshan (Jurm), 2000	13.7
East (KH)	Nangahar (Khogyani) , 2003	13.3

Sample description		Morphine content (%, in dry gum)
Code	Province (district), year	
Northeast (B-A1)	Badakhshan (Faizabad), 2003 (sample 1) Badakhshan (Faizabad), 2003 (sample 2)	11.6 11.2
Northeast (B-J1)	Badakhshan (Jurm), 2003 (sample 1) Badakhshan (Jurm), 2003 (sample 2)	11.6 11.1
South (H-N)	Helmand (Nad-e Ali), 2003	11.5
South (H-KH)	Helmand (Naway i Barakzayi), 2003 (sample 1) Helmand (Naway i Barakzayi), 2003 (sample 2)	11.0 10.9
North (A1)	Badakhshan (Faizabad), 2001 (sample 1) Badakhshan (Faizabad), 2001 (sample 2)	10.9 10.6
East (Q)	Nangahar, 2000 (karez irrigated)	10.8
Northeast (B-A2)	Badakhshan (Faizabad), 2003	10.7
East (N-CH)	Nangahar (Chaparhar), 2003	9.1
South (Q-Ar)	Qandahar, 2003 (sample 1) Qandahar, 2003 (sample 2)	8.6 8.4

For those fields, where more than one sample was available for analysis, the variation in results reflects reasonable margins of error due to sampling and analytical variation. In the few cases where results varied by more than an average 1-%-point, harvesting practices, in particular, keeping gum from individual lancings separately, may account for the difference. Further background information on such practices will help to clarify this issue (related questions / areas are included in Annex IV).

Table 6a shows that relatively more opium samples from Northern Afghanistan have a higher morphine content than from the East and South (Figure 30). The morphine content of opium harvested in different years also shows significant differences. It tends to be higher in 2000 and 2001 than in 2003 (Figure 31). This finding is in line and provides further support to anecdotal information from the literature (Bernáth, 1998) that the overall climatic conditions during the growing season can have a considerable impact on the morphine content, namely, that hot and dry conditions may result in higher alkaloid content. Concerning the three years when opium samples were collected for analysis, the year 2003 was characterized by significantly more moderate temperatures than 2001 and, particularly, the year 2000.

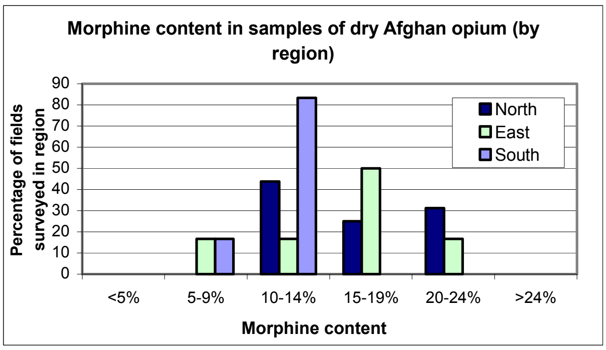

Figure 30

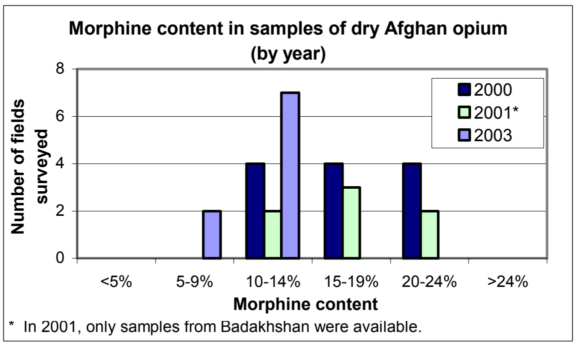

Figure 31

For Myanmar, Table 6b shows that the morphine content of opium from the WADP survey area in Mongyang township (in the South of the Wa Special Region) may be slightly lower than that of opium from other townships further north in Shan State (Muse, Kulong and Hopang townships).

Table 6b: Morphine content in dry opium gum (all lancings combined)		
Sample description		Morphine content
Code	Township (district), year	(%, in dry gum)
Myanmar		
M36	Muse (Ponkan), 2001	15.2
M28-30	Hopang (Panlong), 2001 (sample 1) Hopang (Panlong), 2001 (sample 2) Hopang (Panlong), 2001 (sample 3)	14.7 13.6 13.5
M38	Muse (Ponkan), 2001	13.6
M31	Hopang (Lokke), 2001	13.3
M15	Mongyang (Tong Pha), 2001	13.1
M37	Muse (Ponkan), 2001	13.1
M14	Mongyang (Mong Pawk), 2001	12.3
M32/33	Hopang (Lokke), 2001 (sample 1) Hopang (Lokke), 2001 (sample 2)	12.5 11.9
M26/27	Kunlong (Patou), 2001 (sample 1) Kunlong (Patou), 2001 (sample 2)	11.6 10.0
M35	Muse (Khon Han), 2001	11.6
M	Mongyang (Mong Pawk), 2001 (sample 1) Mongyang (Mong Pawk), 2001 (sample 2)	11.6 11.0
K	Mongyang (Mong Kar), 2002	11.3
P	Mongyang (Mong Pawk), 2002 (sample 1) Mongyang (Mong Pawk), 2002 (sample 2)	10.9 7.4
M17	Mongyang (Mong Kar), 2001	10.5
M34	Muse (Khon Han), 2001	10.0
M13	Mongyang (Mong Pawk), 2001	9.6
P	Mongyang (Mong Pawk), 2001 (sample 1) Mongyang (Mong Pawk), 2001 (sample 2) Mongyang (Mong Pawk), 2001 (sample 3)	9.1 8.9 8.6
M16	Mongyang (Mong Phen), 2001	9.1
N	Mongyang (Mong Phen), 2002	8.7
Laos		
L1	Seized sample, 2001	15.1
India		
I2029b	Extracted from cloth, 2000	13.9
I2029c	Seized sample, 2000	7.2

From two farmers in Eastern Afghanistan, samples from two successive harvesting seasons were available for analysis of morphine and moisture content (see also section E, above). Samples differed in morphine content, with the 1999 samples containing less drug than the 2000 samples (Table 7). The observed differences in morphine content could either reflect year-by-year variations or losses during storage. Although neither option can be excluded at this stage, the latter appears to be less likely.

Table 7: Morphine content in opium gum harvested from fields from the same farmers in two successive years in Eastern Afghanistan		
Sample description		Morphine content (%, in dry gum)
Code	Year	
Farmer D1	2000	23.5
	1999	18.9
Farmer S1	2000	16.3
	1999	11.9

Similarly, the opium yield survey in Myanmar included the same field in three consecutive harvesting seasons. The average morphine content of opium samples harvested from that field in 2001 and 2002 was 8.9% and 9.2%, respectively. [r]

For one field in Afghanistan, in addition to a sample of the combined gum from all field visits, gum samples from the individual visits were also available. Gum yield and morphine content of those samples are shown in Figure 32, with both gum yield and morphine content decreasing with each field visit.

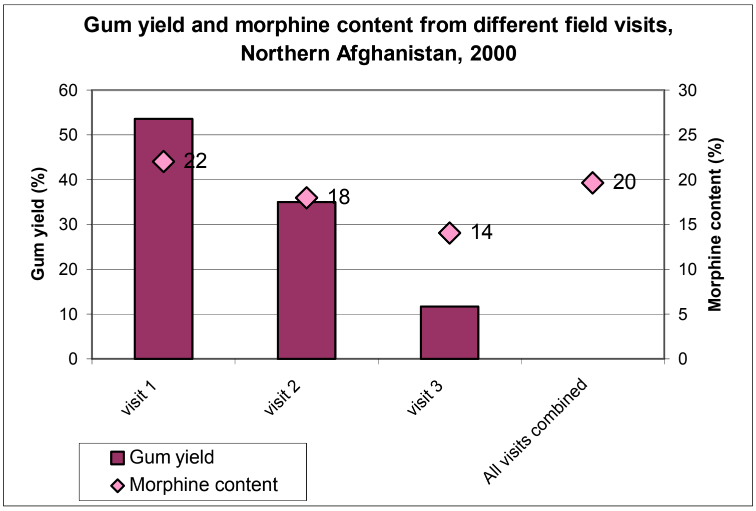

Figure 32

The weighted [s] average morphine content of the three samples collected during the three field visits was used to cross check and confirm the corresponding figure of the combined opium gum from all visits to that field (field B1 in Table 6a, above).

The observed differences in morphine content of gum from different field visits also confirm what is known in the literature for other countries (USDA, 1992; UNDCP, 1994; UNDCP, 1999b; CBN, 1999). Figures 33 and 34 reflect this, using data from different literature sources. [t]

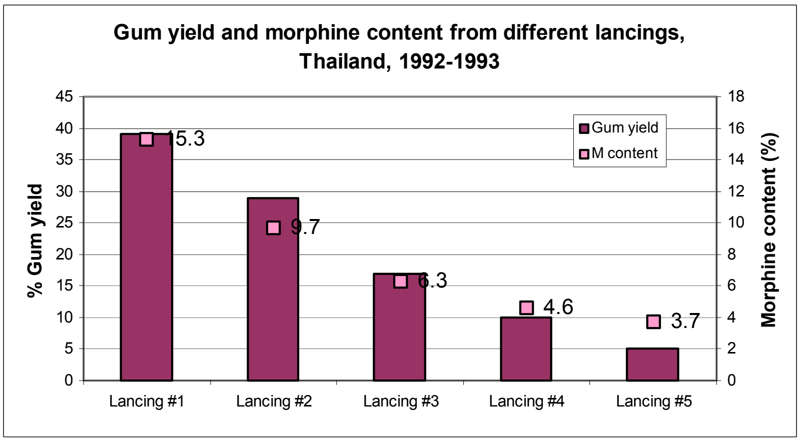

Figure 33

[r] Samples from the 2003 harvest were not available for analysis.

[s] Morphine content of gum from the three field visits was weighted for the amount of gum collected during each of the visits.

[t] Available information also suggests that the morphine content of opium depends the position of the capsule on the plant: It is higher in opium from terminal capsules than from lateral capsules from the same plant.

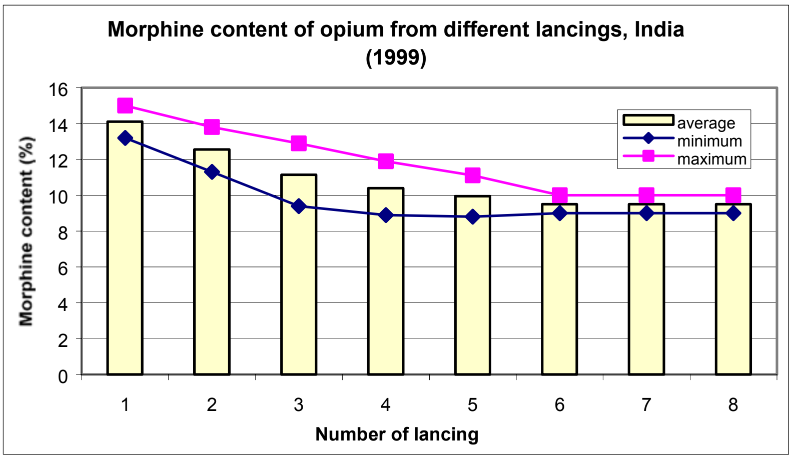

Figure 34

Findings thus appear to confirm reports from farmers and traders, which indicate that the 'best quality' opium is obtained from the first field visit (UNDCP, 1998). In general, 'quality' of opium, as harvested, is determined by morphine and moisture content. Scientific findings confirm the higher quality of gum from the first field visit compared to subsequent visits on the basis of higher morphine content. It is, however, uncertain how farmers and traders might be able to assess quality based on morphine content with the simple physical means they have at hand.

The decrease in morphine content of opium from subsequent lancings together with differences in harvesting practices (see section D, above) may also explain - at least partly - the observed regional difference in morphine content: The higher morphine content of Afghan opium (i.e., the combined gum from all field visits) may be the result of a significantly smaller number of visits (and lancings) than in Southeast Asia. This increases the relative weight of gum of higher morphine content in the total amount of gum harvested, while a larger number of visits, as typically seen in Southeast Asia, decreases the weight of gum of high morphine content, and thus decreases overall morphine content.

Overall, poppy cultivation and harvesting in Southeast Asia appears to be much less intensive than in Afghanistan.

Using the background data collected for the experimental fields, the relationship between measurable plant (plot) characteristics and morphine content was also investigated. Results indicate that morphine content is negatively correlated with plant density (Figure 35), but positively correlated with capsule and plot volume (Figures 36a and 36b). Taken together, it appears that fewer but stronger plants, i.e., with more or larger capsules, result in higher morphine content (Figure 35 shows that data from Afghanistan from 2003 do not always seem to be in line with previous years' findings. As pointed out before, it is not clear at this stage whether this is the result of the significantly different climatic conditions during the 2003 growing season and/or inconsistencies in data collection. Future studies will help to clarify this).

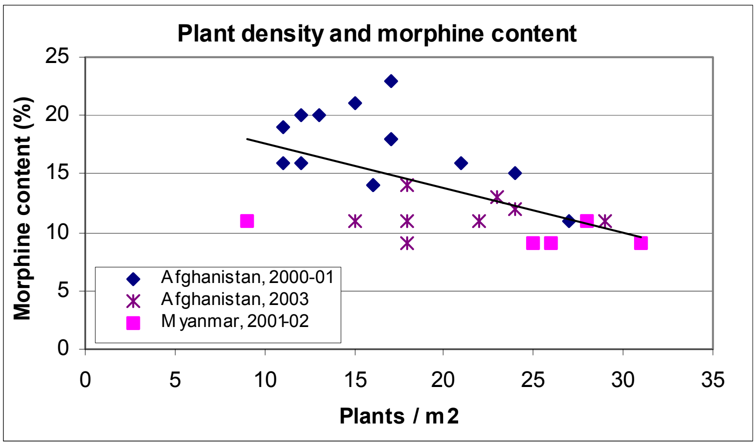

Figure 35

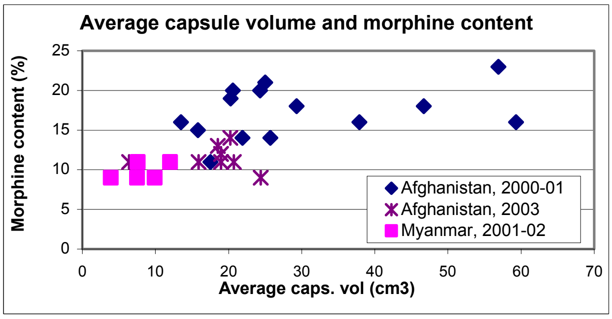

Figure 36a

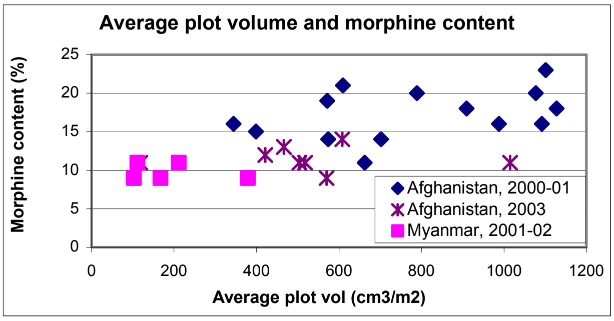

Figure 36b

Figure 37 illustrates the morphine output per unit land area. The limited data available, from Afghanistan and Myanmar, do not show a clear trend, apart from regional differences: The morphine output (reflected in both higher gum yield and higher morphine content) tends to be higher in Afghanistan than in Myanmar. However, more data are required to explore this correlation in more detail, as well as the significance of differences in harvesting practices and field homogeneity.

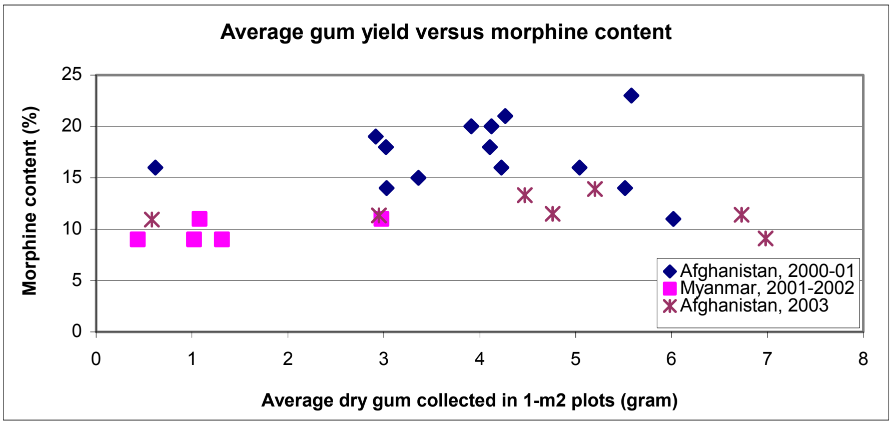

Figure 37

For Afghanistan and Myanmar, a moisture content of 40% and 35%, respectively, was used to convert fresh into dry gum weight.

G. Implications for morphine and heroin production estimates

In order to estimate the morphine or heroin yield per unit land area, or per weight unit of opium, the morphine and moisture content of opium as well as the clandestine laboratory efficiency are critical. Laboratory efficiency is a measure of the ability of clandestine operators to extract the morphine contained in the opium and to convert it into heroin. Overall laboratory efficiency is thus the combined efficiency of: (i) the extraction step (opium to morphine), and (ii) the conversion step (morphine to heroin). [u] Information on clandestine laboratory efficiencies is, however, very limited. Data from the US (DEA, 2002) indicate that overall laboratory efficiencies for opium latex-to-morphine-to-heroin in South America are close to 70% on a weight-by-weight basis.

Using a conservative figure of 15% morphine in Afghan opium, and assuming an overall laboratory efficiency of 70%, 10kg of dry opium [v] could be converted into about 1kg of heroin base, i.e., a ratio that corresponds to the traditionally used rule-of-thumb conversion rate. By contrast, assuming the same laboratory efficiency of 70%, 14kg of Southeast Asian dry opium with a morphine content of 10% would be required to produce 1kg of heroin base. [w]

Higher morphine content and/or higher laboratory efficiencies would further decrease the ratios, for example, for Afghan opium to about 7:1 or even 6:1. [x]

The simple 10:1 rule-of-thumb conversion rate therefore may not be appropriate in both regions. It is too low to adequately reflect potential heroin production from opium from Myanmar, and it may only result in conservative estimates for the amount of heroin base produced from Afghan opium. In addition, conversion rate should not be equaled to morphine content.

H. Limitations

Findings presented in this report should be seen against the background of the limited nature of the yield-related activities carried out by UNODC so far. Relevant facts of those activities are summarized in Table 8.

In view of the limited number of observations, findings on yield and morphine content also have to be seen against prevailing climatic conditions in the surveyed years and countries. During 2000 and 2001, climatic conditions in Afghanistan were unusual in two regards: First, many parts of Afghanistan suffered from severe drought during the growing period. Secondly, in particular in 2000, there was an extreme heat wave during the harvest. While for method development experiments, "normal" fields were selected, i.e., fields not affected by the drought, which can thus be considered representative in terms of plant (capsule) characteristics, the heat wave can be assumed to have affected gum yield [y]: capsules hardened after a few days and harvest was in fact speeded up by the farmers, thus lasting only one week instead of two. [z] In 2003, weather was much more favourable for poppy cultivation, but rain during the harvesting period may have reduced actual yields, especially

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[u] A clandestine laboratory efficiency of 100% means that morphine is converted quantitatively, without losses, into an equal amount of heroin (kilogram-by-kilogram basis).

[v] Throughout this section, 'dry opium' refers to oven-dry opium.

[w] If chemical standards are applied to this calculation, and conversions are calculated on the basis of the molecular weights of morphine and heroin (and not simply on a kilogram-by-kilogram basis), the 10:1 conversion rate for Afghan opium would be immediately be reduced to a 7.5:1 rate, while the corresponding figure for opium from Myanmar would be about 11:1.

[x] Note that there is anecdotal information suggesting a conversion ratio between 8:1 and 6:1 also for Myanmar (Johnny, 2002).

[y] It may have also affected the alkaloid composition (Bernáth, 1998).

[z] The more experienced surveyors expected the opium yield in 2000 to drop to about half of the 1999 figure, an assessment that was confirmed, by and large, by findings from UNODC's Annual Opium Poppy Survey.

in the East. Damage to poppy fields from disease and the resulting reduction of gum yield, as anecdotally reported by farmers (UNODC, 2003a), did not play a role in the yield experiments as only healthy fields were selected for the estimation of potential yield.

Table 8: Yield-related activities in Afghanistan, Myanmar and Laos				
	Year	Afghanistan	Myanmar	Laos
Activities for method development				
Number & location of fields ("experimental fields")	2000	2 fields in Badakhshan; 2 fields in Helmand; 4 fields in Nangahar	-	-
	2001	6 fields in Badakhshan	2 fields in Wa Special Area	
	2002	-	3 fields in Wa Special Area	2 fields in Ban Ja Mai
	2003	4 fields in Badakhshan 2 fields in Helmand 3 fields in Nangahar 2 fields in Balkh	2 fields in Wa Special Area	-
Limited yield surveys (LYS), using capsule measurements to estimate potential gum yield				
Number & location of fields	2000	91 fields in 16 provinces	-	516*
	2001	35 fields in Badakhshan	511*	591*
	2002	-	1,278*	691*
	2003	*		
Opium samples analyzed				
Number of opium samples analyzed	2000 2001 2002 2003	17 13 - 14	- 27 5 -	- 1 (seized sample) 2 -

* In Myanmar and Laos, and in Afghanistan as of 2003, limited yield surveys are integral parts of the respective Annual Opium Poppy Surveys. Detailed results are reported elsewhere (UNDCP, 2001b; UNDCP, 2001c; UNODCCP, 2002a; UNODCCP, 2002b, UNODC, 2003a and b), and this paper only covers relevant aspects for comparative purposes.
Note: All experimental fields in Afghanistan were irrigated, while all experimental fields in Myanmar and Laos were rainfed.

In Myanmar in 2001, according to farmers' assessments, climatic conditions were not optimal for opium poppy cultivation, with too low temperatures during the second half of the growing cycle. In 2002, heavy rainfall during early germination and during the harvesting period reduced overall yields. 2003 was again more favourable for poppy germination and growth (UNODC, 2003b).

In Laos, farmers described the 2001/02 growing season as moderate to poor, with lack of rain after sowing, and too much rainfall late in plant development, as well as during the harvesting period. Both were considered to have an impact on the quantity and the quality of the opium.

I. Conclusions

The findings from the limited yield-related work carried out by UNODC suggest that yields of opium gum in Afghanistan may be high, morphine content may be higher than previously thought, and moisture content may also be higher.

However, the variability of results is also high, within fields, and between provinces. For Afghanistan, some of the discrepancies between previous reports and the figures emerging from these studies may be explained by the unusual climatic conditions during the 2000 and 2001 growing and harvesting seasons. The results from the 2003 yield exercise have further highlighted this. The set of data obtained during these limited yield activities is not sufficient to draw final conclusions.

Findings should therefore not be interpreted in absolute terms but rather to indicate directions and trends.

In connection with the central question on how much morphine and/or heroin can be obtained from opium produced in a given harvesting season, the report highlights the need for improved understanding of the different contributing factors, and their individual contributions, namely morphine and moisture content of the opium raw material, and clandestine laboratory efficiency.

In the greater context of illicit poppy cultivation and opium, morphine and heroin production and trade, a number of questions have emerged during UNODC's yield-related work so far. These questions, which are summarized in Annex IV, address areas where further and more systematic information is required [aa] in order to draw meaningful conclusions from opium yield and morphine and heroin production figures. This would eventually also serve overall trend analyses, using data from traditional sources, such as UNODC's Annual Reports Questionnaire.

Questions like those in Annex IV should therefore also be seen as a starting point to improve the knowledge base of clandestine opium-morphine-heroin production and trafficking in general, and in the context of data triangulation.

NEXT STEPS

Improved understanding of poppy cultivation practices, opium harvest and trade, their regional differences, and the driving forces behind them remain a critical issue. It may not only contribute to improved data and trend analyses, but also to improved operational responses and strategies.

Concrete future steps should therefore include the continuation and systematization of yield-related activities, including an extension of work towards a better understanding of clandestine production processes. **Anecdotal evidence to-date suggests that a re-evaluation of the availability and quality of opium, morphine and heroin may be required.**

Evaluation of the yield assessment methodology under different ecological and agricultural conditions, and collection of data on illicit crop cultivation and trade, and their regional differences, are central elements of such an approach. Specifically, activities in subsequent havesting seasons in the different poppy growing regions should aim at:

- further refining practical field procedures,
- evaluating the mathematical models for yield estimate calculations, and
- gathering necessary background information on factors that may have an impact on yield.

From an agronomical point of view, activities in any one country should cover at least three to five growing seasons to eliminate annual variation due to climatic differences.

Continuing future studies are thus required to strengthen the scientific basis for more objective results on opium yields and morphine/heroin output. In addition, **systematizing efforts to answer questions such as those raised in Annex IV, will contribute to improving the knowledge base and understanding the mechanisms and driving forces**

[aa] Responses received from surveyors in Myanmar indicate that some information is available on an anecdotal basis, which requires further systematization in order to provide a more comprehensive picture on poppy cultivation, harvesting practices and their impact on production estimates.

of poppy cultivation and opium harvest and trade in Afghanistan, and the differences with other poppy cultivating regions, such as Southeast Asia.

ANNEX I

Summary of UNODC yield-related activities (Scientific approach to yield assessment)

Since 2000, UNODC has been involved in activities to improve opium yield estimates based on scientific procedures using poppy capsule characteristics to estimate gum yield. Activities include:

- An expert meeting (Oct./Nov. 2000) to discuss methodologies (for both opium poppy and coca bush);
- A manual on methodologies for yield assessment from brief field visits (ST/NAR/33);
- Field activities in Afghanistan (2000, 2001, 2003), Myanmar (2001, 2002, 2003), and Laos (2002);
- Statistical analysis of data and information collected in the field; and
- Analysis of opium samples for their moisture and morphine content.

Field activities are twofold:

A) **Method development (MD)** to establish and/or test a correlation (i.e., a mathematical formula) between poppy capsule volume per square metre and dry gum yield:
   - Field procedures for determining capsule height and diameter, and fresh gum yield;
   - Determination of the moisture content of fresh gum; and
   - Establishment of a mathematical formula describing the correlation between capsule volume per square metre (plot volume) and dry gum yield (or the testing of an existing formula)

B) **Limited Yield Survey (LYS)** to collect capsule data from a statistically relevant number of randomly selected fields for estimates of *potential maximum yield* at district, provincial and national levels:
   - Field procedures for determining capsule height and diameter of ten mature (lanced) capsules per square metre; three (five) one square metre plots per field.

ANNEX II
Study design and summary of field procedures

1. Field procedures for method development

Within the overall limitation of security and farmers' readiness to cooperate, fields were selected to represent "typical" fields for certain countries and regions. On a practical basis, the main selection criterion was plant density.

In Afghanistan, most fields, especially in the South and East, were rectangular in shape and just about the minimum size considered necessary for meaningful field experiments ($100m^2$). The transect (i.e., the 'backbone' for the selection of the one-square-metre experimental plots) was therefore laid along the full length of the field. This procedure was considered to give representative results, since fields were usually homogeneous, and at a given time in a poppy field, most plants were in the same stage of development.

In Myanmar and Laos, fields were far more irregularly shaped, and far less homogeneous in terms of plant density. The experimental plots used for more extensive capsule measurements and recording of fresh gum were therefore selected based on plant density, covering plots of low, high and intermediate plant density.

While plant and capsule counts were carried out in ten one square metre plots and one 'larger' plot (ranging from $50m^2$ to $1000m^2$ in the different countries) per field, capsule measurements and opium gum collection were only done in three out of the ten one square metre plots, i.e., pairs of data (plot volume and gum weight) are only available for these three plots per field. In addition, the total fresh gum weight for the larger plot was also recorded.

All activities related to harvesting of opium gum, i.e., the timing of the beginning and end of the harvest, lancing, and gum collection were carried out by local harvesters following common practices. The gum was then stored airtight for the period of the harvest to obtain the total fresh weight of opium from all field visits combined. Opium samples for return to UNODC's Laboratory and Scientific Section were taken at the end of the harvest after thoroughly mixing the gum from different field visits. Their fresh weight was determined; they were packed in plastic bags; and upon arrival in Vienna, their oven dry weight was determined at UNODC's Laboratory and Scientific Section.

For each field, additional background information on poppy variety, cultivation and harvesting practices, etc. was collected.

2. Field procedures for limited national yield survey (LYS)

In Afghanistan in 2000, fields were selected at random from some distance, so that the condition of the field (drought, diseases) was not immediately visible to the surveyors, i.e., they were unable to determine whether the crop was healthy or not. Future plans foresee the random sampling of about five villages per district (as part of the coordinators' monitoring visits). In each of those villages, two to three fields will be randomly but systematically selected, and capsule measurement carried out in mature fields.

In Myanmar and Laos, the limited yield survey is an integral part of the Annual Opium Poppy Survey. The procedure involves the selection of a random sample of poppy growing villages. In each village, a random sample of poppy growing households is surveyed; all fields of those households are visited, and in fields were harvest is under way at the time of the visit, capsule measurements are carried out.

For each field, additional background information on poppy variety, cultivation and harvesting practices, etc. was collected.

ANNEX III

Varieties of opium poppy cultivated in selected districts (provinces) in Afghanistan (UNDCP Annual Opium Poppy Survey, 1999)

District	Name	Flower	Capsules / plant	Yield / quality	Maturity	Spread	Cultivated in comb. with:	Soil type / irrigation	Resistance	Input
Shinwar (50 respondents)	1) *Spinguly* @	White	More elongated than other varieties	High yield, low quality (= high H_2O content; i.e., opium not stored but sold immediately)	Early (up to 20 d before other varieties in the region)	70% of respondents: cultivate some (1); cultiv. in Shinwar for up to 18y	Usually in combination with other varieties	Sandy-loam; clay-loam	Relatively resistant to diseases + poor weather	Low (less fertilizer, irrigation, labour); only 3 lancings
	2) *Surguly Watani*; also known as *Surguly*	Pink or red or red & white	Small	Low yield, good quality (low H_2O content)	Later than (1)	(2) cultivated by 50% of respondents; only one: only (2); cultiv. for > 50y	Spinguly	Can be grown in both canal or karez irrigated	Vulnerable to worms and withering leaves	Harvest = labour intensive: small caps., up to 6 lancings
	3) *Surguly Khogiani** (=hybrid variety of (2)); also known as *Surguly Ghanikhely***	Dark red or purple		Quantity + quality of opium higher than (2)		(3) cultivated by 20% of respondents; cultiv. only for shot period	a) Alone (majority of farmers) *b) Spinguly*			5-7 lancings
	4) *Charchary*	Pink and white; fringed	Small (probably even smaller than (2))	Low yield; particularly good quality		(4) cultivated by 25% of respondents; only one: only (4); cultiv. for almost 20y	*a) Spinguly* *b) Surguly* c) Both	Sandy loam	Particularly vulnerable to diseases, incl. withering of leaves	Harvest = very labour intensive: small capsules, 5-6 lancings
	5) *Choraguly****	Red and white		High quality		Introduced in Shinwar area in last 3-4 years		Generally found to be cultivated in karez area; some: canal	Vulnerable to diseases, particularly: worms; resistant to wind (preventing damage during flowering stage)	Labour intensive requiring as many as 7 lancings
Khakrez **** Maiwand (100 respondents)	6) *Sabai*	White or pink	*Mananai* < (6) < *Kataguli*; spherical (*sab* = Persian for apple) Plant ht: 110-120cm; 5-7 caps.	Good quality (low moisture; if affected by spring rains: high moisture)	Early (10-20 d before other varieties)	(6) cultivated by 20% (50%) of resp. in Khakrez (Maiwand); only (6): 1 in K.; 40% (of 50%) in Maiw	a) mostly *Mananai* (in Maiwand)	Extensive irrigation required *(BR, p.41: karez does not seem to be enough)*	Resistant to cold temp.; but the least resistant to disease + drought, since early maturing: vulnerable to damage from spring rains during harvest period (up to 50% loss of yield) + increase in H_2O content	5-6 lancings
	7a) *Mananai* and 7b) *Mananai Ashaguli (M.Kataguli??, p.42)*	Red/ white or pink/white; (7b) = fringed	(7a) < *Sabai*; conical plant ht: 100-120cm (shorter than other var.); more caps. (up to 10 per plant)	Lower quality than (6) due to higher water content	Later maturing; therefore less vulnerable to spring rains	(7) = 75% of total poppy in Khakrez		Sandy and clay loam; karez areas (as it is thought to be more drought resistant)	Resistant to fungal disease; vulnerable to worms and frost	5-6 lancings
	8) *Kataguli*, also known as *Sadal* or *Macrani*	Red or pink	Larger caps. than other var.; smooth texture; Plant ht: 160-180 3-4 caps.	Poor quality (high water content): *sur* (red) or *jar* (yellow)		(8) not grown in Maiwand; grown by 8% in Khakrez		Requires more fertile soil => grown in clay loam soils of canal areas		Labour intensive: 6-7 lancings
Badakhshan & (60 respondents)	9) *Watani* ***** @	White	Conical	Reasonable quality, low moisture content	Early	(9) cultivated by all but one resp.		Drought resistant => grown on rain-fed land	Drought resistant	4-5 lancings
	10) *Khashi #*	Pinkish white	Brown in colour			(10) cultivated by only one respondent (Argo district)	Together with *Kabuli* and *Hindi*		More resistant to cold => grown in higher + colder valleys	
	11) *Hindi*	Purple	Larger than other var. grown in Badakhshan; 7-9 caps.	Higher yield than other varieties in Badakhshan, relatively poor quality		(11) cultivated by 70% of respondents; introduced to Badakhshan ~5y ago	Usually in comb. with *Watani*	Requires more water than other var. => rarely cultiv. in rain-fed areas	Relatively resistant to disease	Only 3-4 (!) lancings
	12) *Wardoojee*	Purple	3-4 caps.	Higher yields than other local varieties, quality high		(12) only cultivated by one household		Requires regular irrigation => no good results on rain-fed land	Because of low spread; possibly vulnerable to other natural deficiencies	5-6 lancings
	13) *Kabuli $*	Pink/white or red/white	Smaller than other varieties grown in the area			(13) cultivated by 20% of respondents (all in Argo + Darayem)	Always in combination with other varieties	Requires more irrigation than *Watani*; no good results on rain-fed land		Particularly labour intensive: small caps., 5-6 lancings

Notes to Annex III:

1) Origin of names of poppy varieties:
Watani means 'local'
* Khogiani district is assumed to be the district where seeds originally came from
** *Ghanikhely* = Ghani Khel bazaar
*** *Choraguly* = farmer's name who had produced this variety from his own land
$ *Kabuli* is known in Argo and Darayem as *Americaee*
in Badakhshan: perceived origin of seeds = determinant of name: *Wardoojee* (*Wardoojee* named after Wardooj valley (crosses districts of Baharak, Zebak and Eshkashem)), *Americaee*, *Khashi* (a valley in Afgh.), *Jalalabad*, and more recently *Italiaee*; as a consequence, name = relative, reflecting local knowledge and circumstance rather than the attributes of the variety as in the east (i.e., *Surguly*, red flower, *Spinguly*, white flower)
Hindi: (speculative) colour purple = close association with Hindu population in Afghanistan

2) Origin of seeds
Maiwand: respondents typically obtained poppy seeds from their previous year's crop or from neighbours; Khakrez: almost 40% had obtained seeds from Helmand, in particular Sangin
Shinwar: seeds typically purchased from within village or district, particularly from Ghani Khel bazaar, or from other districts within Nangahar province, including Khogiani, Deh Bala, Durbaba and Achin; very few respondents indicated that seeds were obtained from their poppy crop in the previous year
Badakhshan: >50% of respondents obtained seeds from previous year's crop; from neighbouring villages or adjacent districts; 3 respondents obtained seeds (all: *Americaee*) from outside Badakhshan

3) Crop cycles
Shinwar respondents: summer crop influences variety of poppy cultivated: any variety can be cultivated after maize, but due to late summer harvest, *Spinguly* typically cultivated after cotton

4) Abandoned varieties
Khakrez and Maiwand: *Shin Kalai*, *Tor Kalai* have been popular, but due to high incidence of worms and disease: farmers shifted to other varieties in last three years; initially: *Shin Kalai* and *Tor Kalai* were replaced with *Sabai*, but yield was found to be disappointing; therefore, more recently, shift towards *Mananai*
Badakhshan: *Bairaqee*, *Jalalabadee*

5) Other notes
**** Khakrez district = dependent on karez irrigation
***** seeds of Watani produce more oil than other varieties (higher seed yield plus higher oil yield)
# Khashi was reported to be almost identical to Watani in appearance, except colour of capsules and flowers;
@ *Spinguly* variety in Shinwar seems to have very similar characteristics to *Watani* in Badakhshan, including its flower colour, its early maturation and its resistance to drought
& Badakhshan: respondents in all five districts (Jurm, Khash, Faizabad, Argo, Darayem) cultivated a combination of *Watani* and *Hindi*, except in Faizabad where Watani tended to be the only variety cultivated. In Khash district, *Wardoojee* was cultivated along with *Hindi* and *Watani*, whilst in Argo and Darayem, *Americaee* (=*Kabuli*) was widely cultivated in combination with *Watani* and *Hindi*
Hindi: less oil content
There is a suggestion that there may be a link between higher water content and fewer lancings as the opium may flow more easily after lancing ….

6) Advantages / disadvantages of selected characteristics of poppy varieties
Early crop: allows harvest prior to fall in opium prices associated with harvest of later maturing varieties; staggered harvesting
High water content: less important if gum is used to repay advances that are provided primarily on the basis of an agreed quantity
Low water content: popular for storing and selling when prices increase post harvest

ANNEX IV
Scientific yield surveys: Areas for consideration / discussion

During UNODC's yield-related activities several questions have emerged, which cannot be solved by scientific analysis alone. They require a comprehensive picture of opium poppy cultivation practices, driving forces behind them, including an understanding of other aspects, such as socio-economic aspects, of opium harvest and trade, as well as a better knowledge about geographic and climatic conditions in different poppy growing regions. The areas, which require clarification and systematization (although data/information are available on some issues), are summarized below. For ease of reference, the most critical questions are in **bold**.

Moisture content / quality of opium gum

1. How is opium stored before it is sold (why exactly is it stored anyway?)? How does storage differ within and between countries? What is the share of opium being sold on the field, and at the farm gate, immediately, after some time, or even the next year?

2. What is known about storage practices? Is opium for local consumption treated / stored differently from opium destined for international trafficking? What is the share of opium for local consumption versus international trafficking?

3. **What is the range of moisture of the opium when farmers report their estimated yield in interviews? Does this figure change from one year to another?**

4. **When reference is made to the opium production in a given year, which opium is being referred to? As harvested? I.e., fresh opium, with a high moisture content, or opium after storage, i.e., after having lost some of its weight due to drying up (evaporation of water/moisture)? While for comparative purposes, it is desirable to define the moisture content of opium, which level is the most reasonable? 0% moisture (i.e., oven dried opium – the scientifically most desirable approach)? Or assuming a residual moisture content of 10-15%, which is probably more realistic when opium is, at best, dried in the sun (a 10-15% figure is used, for example, by the US, and also by INCB in its reporting system).**

5. Is there any information that early morning dew on the surface of the exuded opium is collected together with the gum, thus increasing the "moisture" content of fresh opium gum? Or is it just that opium collected later during the morning is itself drier because of exposure to the sun? Do different areas within a country, or different poppy growing regions, differ in terms of possibility and extent of early morning dew (and/or of timing of gum collection)?

6. **What do farmers refer to when they report "yield" as part of an interview? Is it the total gum harvested? Or is it the share they have at their disposal, after deducting any "taxes" and payment of harvesters in kind? Are there different practices in different countries / regions?**

7. What do farmers mean when they talk about "quality" of opium? For Afghanistan, why is opium from fields with "karez" irrigation sold for a 20-25% higher price?

8. How do local traders assess moisture content, quality (adulteration), and at what point do they do it?

9. What is the reason for the differences in morphine content found in opium samples collected from the same field? Inhomogeneity of the sample material (i.e., opium from different lancings?), or a real variation? What is known about losses in

morphine content during storage? Is there really a loss, or is the observed difference between two subsequent years (10-20% difference) typical of the variation year to year?

Cultivation and harvesting practices

10. What is the impact of poppy variety on opium yield, quality (morphine / water content) and capsule size / shape? What additional work (questioning farmers or scientific study) would be required to obtain accurate data? What can realistically be done to advance knowledge in this area?

11. What is the impact of autumn versus spring sowing? What is the share of either?

12. What is known about the effect of using (different) fertilizer(s)? It increases yield, but why (bigger capsule volume? more capsules? more opium per capsule, healthier plant less susceptible to disease? etc.)? Is the usual way of applying fertilizer on a field by farmers likely to be inhomogeneous, so that plot volumes are, for example, higher at field borders and lower at the middle of the field?

13. **How do farmers determine the maturity of their fields? Is the decision to harvest a field only guided by the aspect of maturity, or is it possible that, because of shortage of harvesters, harvest in some fields does not start at the optimal time (i.e., is it possible that harvest starts too early/too late)? In terms of weeks, what is the range that the beginning of harvest may be too early/too late (i.e., ± weeks)? How is this reflected in yield (range?)?**

14. What is the guiding principle for selecting a poppy variety for cultivation (yield / quality, resistance to diseases, or else)? What is the level of continuity, i.e., how often, and for which reasons, do farmers switch to other varieties? Is there a difference between different farmers / districts etc.?

15. What is the impact of diseases on gum yield and morphine content? Are fields (visibly) affected by disease nevertheless lanced?

16. How is the opium collected? Are different lancings kept separate and “graded” into different qualities, or are all lancings from one field mixed together? Are there differences within and between countries?

17. What is required to rationalize different numbers of blades / cuts (i.e., “physics” of exudation / oozing of latex)?

Questions in the context of operational intelligence gathering

18. What is known about practices related to adulterating and packaging opium? Are bags of opium graded and sealed at source, never to be reopened again until processing?

19. What is known about the extent of practices such as mixing poorer quality opium with that of higher quality? When does this take place in the distribution chain?

20. If two products exist (e.g., adulterated (for local consumption), and pure), this has to be taken into account when considering seizure data/prices, unless adulteration is carried out at the field. What is known about such practices? What is known about the prices of “different” products, from farm-gate to illicit laboratory, not withstanding the costs of smuggling, etc.?

21. In estimating available morphine for heroin production, is there any data (for anywhere) which gives a split of use of the overall opium yield as pure product, adulterated product, morphine or heroin?

22. Is there any anecdotal description of illicit opium poppy cultivation, opium collection and, particularly, opium / morphine processing? What is known about the efficiency of clandestine laboratories extracting morphine from opium and/or converting morphine into heroin?

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