


CENTRO INTERNACIONAL DE LA PAPA

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# Protocol for tuber bulking

## maturity assessment of elite and advanced potato clones

**Protocol for Tuber Bulking Maturity Assessment of Elite and Advanced Potato Clones**



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# **Protocol for tuber bulking** maturity assessment of elite and advanced potato clones

# Introduction

Breeders at the Genetic and Crop Improvement Global Program (GCI) know that breeding clones must be suited to the cropping systems and length of the potato growing season of a particular region within their agro-ecological area of adaptation. In this sense, tuber bulking information of clones is of great interest for recommending testing toward final adoption. This information is valuable for assessing performance and adaptation particularly in areas with short growing seasons, where harvesting has to be performed during the bulking period, that is, before top (leaf) senescence.

The present protocol aims at providing a practical procedure for the assessment and documentation of tuber bulking maturity of potential varieties and also can be useful in the selection of early bulking maturity clones

# General information of tuber bulking

The rate and duration of tuber bulking determines the yield in the potato crop. Tuber bulking rate is the slope of the linear curve described by the increase in tuber weight with time, while tuber bulking duration is the time between tuber initiation and persistence of foliage. Indeed, decline in leaf area by senescence is followed after a short time by the cessation of tuber bulking. Though both factors are important in accounting for yield differences between cultivars, tuber bulking duration is of greater importance as it seems determines final yield. For instance, an early variety with a yield advantage over a later variety during the linear phase of bulking may show a final yield lower than the later one because of earlier senescence, unless early lifting is carried out. Tuber bulking results from two basic processes, tuber initiation and tuber growth. Timing and duration depend upon geographic location, environmental factors, and cultivars.

## Tuber initiation phase

This phase occurs at about 20 to 30 days or more (up to 45 days under long day conditions) after plant emergence and last for a period of 10 to 14 days. Though additional tubers may continue to form on stolons during later stages of plant development, tubers that are harvested late during a long season will be initiated at this time. During the initiation phase in which tubers are formed on stolons, the orientation of cell division within the sub-apical portion of the stolon changes to produce radial expansion rather than longitudinal growth.

The number of developing tubers increases to a maximum of about 15-20 and then declines to some lower value that will be filled by harvest (Figure 1). Initiated tubers not carried to harvest will be re-adsorbed by the plant. Evidence also points toward the presence of more than just one tuber-setting cycle during a growing season in some cultivars (Meredith, 1988). Thus, there are cultivars with more than one tuber initiation event, whereas others appeared to set tubers just once.

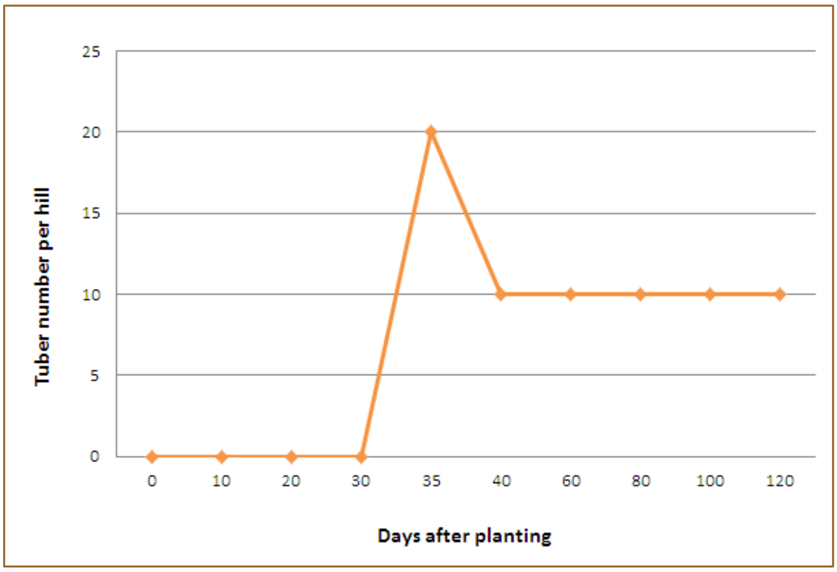



*Figure 1.Potential tuber number that can be successfully produced by a plant (tuber initiation phase).Taken from Kleinkopf et al., (2003) Physiology of tuber bulking*

The potential tuber number that can be successfully produced by a plant varies with the genotype (most cultivars having a consistent number of tubers on each stem), physiological age of seed, number of stems per hill (stem population) and environmental conditions during this initiation phase of growth. Environmental conditions affecting tuber initiation include planting date, early season temperature, nutrition and water management, and weather extremes such as hot climate, hail or frost.

Growers may have some control over this phase through seed lot selection and best management practices, while they have little control over annual environmental conditions.

## Tuber growth

This phase which follows tuber initiation is based on the number of days to maturity or length of the growing season, thus, this stage can last from 60 to over 90 days. Tuber enlargement, which takes place during this phase, continues as photosynthates are translocated from the vines into the tubers. The number of hours of daylight available for photosynthesis and the day temperatures during this phase largely influence the length of this phase.

Despite the observation that the major part of tuber growth occurs before maximum leaf area (Figure 2), higher bulking is associated with greater leaf area provide the limit at which crop growth-rate declines because of mutual shading of leaves is not surpassed

Struik et al. (1990) suggest that mechanisms controlling tuber growth or re-absorption may be more important in establishing tuber size distribution at harvest than the processes controlling tuber initiation. The number of tubers produced in season, soil moisture, and cultivar specific.

A maturation phase follows tuber growth, which is characterized by leaf area decline and a slow rate of tuber growth. This phase may not occur in the field when a medium or long season cultivar is grown in a short production season. Only approximately 10-15 percent of the total tuber weight can be obtained between the end of the tuber growth stage and the first two weeks of maturation.

Early tuber initiation and growth are necessary for acceptable production in areas where potatoes are often harvested prior to physiological maturity.

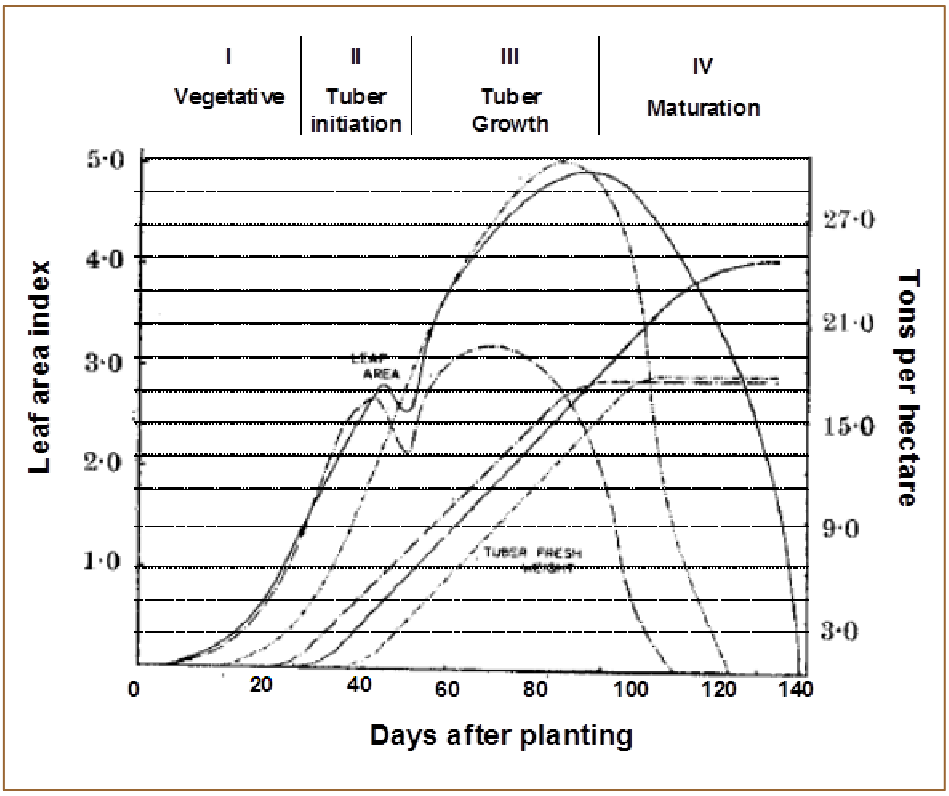



*Figure 2. Curve for increase of tuber weight with time. Taken from Radley et al., 1961 Tuber bulking in the potato crop.*

## Physiology of tuber induction

The tuberization process of potato is understood to be controlled by environmental factors, mainly photoperiod and temperature, which regulate levels of endogenous growth substances. Short days and cool night temperatures (inducing conditions) have been reported to favor tuberization while long days and high night temperatures delay or inhibit the process (Gregory, 1956; Slater, 1968)

The principal site of perception of the photoperiodic signal is in the leaves. Under favorable short day conditions, the leaves produce a mobile inductive signal that is transported to the stolons to induce tuber formation. At least two independent pathways controlling tuber formation in potato have been proposed: a photoperiod-dependent pathway and a gibberellin-dependent pathway.

The photoperiodic pathway regulating short-day tuber induction shares features with the photoperiodic flowering pathway, including involvement of Phytochrome B (PHYB), CONSTANS (CO) and FLOWERING LOCUS T (FT) proteins (Amador et al., 2001; Martínez-García et al., 2002; Rodríguez-Falcón et al., 2006).

On the other hand, gibberellins (GAs) have been reported to have an inhibitory effect on tuber induction and their activity has been shown to decrease when leaves are exposed to short day conditions (Ewing, 1995; Kumar and Wareing, 1974).

Likewise, the light stable phytochrome PHYB, a major photoreceptor, has also been shown to be involved in the regulation of tuber induction, inhibiting this process under non-favorable conditions. This photoreceptor controls the synthesis of an inhibitory signal that has a role in GA signal transduction. The PHOR1 (photoperiod responsive 1) protein has been found to have a positive function in the GA signaling cascade, suggesting that changes in GA sensitivity are involved in mediating tuber induction (Amador et al., 2001). Hence, cultivars sensitive to high GA levels under long photoperiods can be a problem for temperate regions, which have long photoperiods during their usual crop season. Fortunately, there are “day neutral” cultivars that presumably have lost GA-photoperiod response.

## Environmental factors influencing tuber bulking

Potato originated from the high altitude tropics in the Andes. Hence, tuber bulking is best promoted by short photoperiods, high light intensity and cool climates, with mean daily temperatures between 15° and 18°C as encountered in its center of origin. The meteorological factors influencing this process at a given site are basically air and soil temperatures, solar radiation, photoperiod, soil moisture, and crop water use. Sensitivity to environmental conditions varies markedly between genotypes (Brown, 2007).

The most limiting environmental factors for potato production are heat and water stresses. Time from emergence to tuber initiation is shortened by short days and temperatures less than 20°C. Higher temperatures favor foliar development and delay tuber initiation. Crop senescence is also shortened by high temperatures, especially greater than 30°C (Midmore, 1990).

Heat stress leads to a higher number of smaller tubers per plant and lower tuber specific gravity with reduced dry matter content (Haverkort, 1990).

Ewing (1981) reported that in many areas the sequence of temperatures that most often brings economic damage to potato crops is warm temperatures early in the season, followed by cool temperatures that induce strong tuberization, followed in turn by another period of high temperatures such temperature oscillations lead to heat sprouts, chain tubers, and secondary growth of tubers. Apparently the fluctuations in tuberization stimulus cause tuber formation to alternate with more stolon-like growth.

Long day adapted cultivars that produce well in full growing seasons (5-6 months) may mature too early and senesce between 60 and 70 days after planting in the equatorial highlands and consequently yield less (Haverkort,1990). On the other hand, cultivars those perform well under short days in a 3 to 4 month growing season start tuberizing late and mature too late at altitudes of 50°N.

Sands et al. (1979) showed that tuber initiation is delayed by long day lengths, though day length limit is cultivar dependent. Stolon branching is increased both by high temperatures and long photoperiods, while stolon number is not affected by photoperiod but instead by temperature and moisture.

Drought stress limits vine growth and reduces the number of tubers in larger size categories (Walworth and Carling, 2002). However, no differences have been observed in the dates of tuber initiation or beginning of the growth period (bulking) between irrigated and non-irrigated potatoes (Dwyer and Boisvert, 1990). In addition, time to foliage senescence is not affected in drought-stressed plants but top growth is, from early to mid-season (Walworth and Carling, 2002).

# Materials and Methods

# Materials

- Naturally sprouted seed tubers of approximately 80g from test clones and commonly used varieties.
- Sprouted seed tubers for border planting.
- Sprouted tubers of a red and a cream or whiteskinned cultivar. These cultivars will be used according to the skin color of the test cultivars, as markers, to separate within a plot, plants that will be harvested at different harvest dates.
- Materials list is recorded onto form (Material_List)

# Methods

## Experimental Design:

A split block (strip plot) design is appropriate for this type of assessment (Figure 3). The treatments of the factor "Clones", i.e., the test clones, are laid out in vertical strips in randomized complete block design, whereas those of the factor "Days to harvest" are laid out in strips horizontally in the same replication. At least 3 replications are recommended.

- The information is recorded onto forms (Installation)

| | Clone 6 | Clone 8 | Clone 5 | Clone 10 | Clone 3 | Clone 9 | Clone 2 | Clone 4 | Clone 1 | Clone 7 |
|---|---|---|---|---|---|---|---|---|---|---|
| Harvest date # 1 | Clone 6 HD #1 | Clone 8 HD #1 | Clone 5 HD #1 | Clone 10 HD #1 | Clone 3 HD #1 | Clone 9 HD #1 | Clone 2 HD #1 | Clone 4 HD #1 | Clone 1 HD #1 | Clone 7 HD #1 |
| Harvest date # 2 | Clone 6 HD #2 | Clone 8 HD #2 | Clone 5 HD #2 | Clone 10 HD #2 | Clone 3 HD #2 | Clone 9 HD #2 | Clone 2 HD #2 | Clone 4 HD #2 | Clone 1 HD #2 | Clone 7 HD #2 |
| Harvest date # 3 | Clone 6 HD #3 | Clone 8 HD #3 | Clone 5 HD #3 | Clone 10 HD #3 | Clone 3 HD #3 | Clone 9 HD #3 | Clone 2 HD #3 | Clone 4 HD #3 | Clone 1 HD #3 | Clone 7 HD #3 |

REP 1

| | Clone 5 | Clone 6 | Clone 9 | Clone 2 | Clone 1 | Clone 6 | Clone 4 | Clone 7 | Clone 3 | Clone 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| Harvest date # 1 | Clone 5 HD #2 | Clone 6 HD #2 | Clone 9 HD #2 | Clone 2 HD #2 | Clone 1 HD #2 | Clone 6 HD #2 | Clone 4 HD #2 | Clone 7 HD #2 | Clone 3 HD #2 | Clone 8 HD #2 |
| Harvest date # 2 | Clone 5 HD #1 | Clone 6 HD #1 | Clone 9 HD #1 | Clone 2 HD #1 | Clone 1 HD #1 | Clone 6 HD #1 | Clone 4 HD #1 | Clone 7 HD #1 | Clone 3 HD #1 | Clone 8 HD #1 |
| Harvest date # 3 | Clone 5 HD #1 | Clone 6 HD #1 | Clone 9 HD #1 | Clone 2 HD #1 | Clone 1 HD #1 | Clone 6 HD #1 | Clone 4 HD #1 | Clone 7 HD #1 | Clone 3 HD #1 | Clone 8 HD #1 |

REP 2

*Figure 3. Strip plot design for tuber bulking assessment. Shown for two replications*

Rows should consist of at least 15 hill/plots planted such, that every five seed tubers of the test cultivar, a red or white-skinned potato - according to the skin color of the test clone - is planted as a marker, followed by five more test clone tubers.

This pattern should be repeated throughout the row. A marker tuber is also planted at the head and end of each plot. A border row should be planted at each side of every block (repetition).

Planting distances should follow those standards of the location, though distances of 30 cm between hills are recommended. Agronomical management and control of pests and diseases should be according to the standard practices of the location.

## Harvest dates:

Three harvest dates as well as ranges of days to harvest for each of them are proposed:

| | |
|---|---|
| **Early**: | 80 to 90 days after planting (DAP) |
| **Intermediate**: | 100 to 120 days after planting (DAP) |
| **Late**: | 120 to 140 days after planting (DAP) |

The time of the first harvest and day-intervals to subsequent harvests will be determined according to the length of the growing season of the trial location. Short growing seasons that allow only early and intermediate harvest are not uncommon.

Plots should be harvested in five-plant increments, from one end of the plot to the other up to the last harvest date.

### Main Points

- Stop irrigation two weeks before dehaulming.

- Follow the practice of dehaulming (cutting of haulms by sickle or killing by chemicals (e.g. Gramoxone). This will facilitate separation of the tubers from the stolon at harvest.
- Harvest after 10-15 days of haulm cutting.
- The information is recorded onto forms (Crop_Management)

## Data recording

The information should be recorded onto form **Data Collector**.

| Phase | Component | Method | Registration Form |
|---|---|---|---|
| Trial, materials and site information | Minimal - basic data | List | Minimal |
| | Trial information, management and evaluation data | List | Installation |
| | Management calendar | List | Crop_Management |
| | List of materials | List | Material_list |
| | Climate data | Weather station | Weather_data |
| | Soil analysis | Soil analysis | Soil_Analysis |
| Harvest | Tuber bulking maturity | | Fieldbook |

### Meteorological data

Meteorological data must be registered in a weather station (Sheet Weather_data). Data recommended for recording are:

- Photoperiod (daylight hours)
- Daily maximum and minimum air temperatures ($C^{o}$)
- Average air temperature (°C)
- Relative air humidity (%)
- Rainfall (mm)

- Photosynthetic active radiation (PAR) (Measures Light Intensity in the 400 to 700 nm Frequencies i.e. light range that effects photosynthesis in umol/m2/sec)
- Soil temperature (10 cm depth) (Co)

### Evaluation parameters

Data to be collected on each plot during the growing season. The information is recorded onto form "Fieldbook"

- **Emergence date (EDATE):** Number of days from planting to 70% of plants emerged.

- **Number of plants/plot (NTP):** this data is collected 45 days after planting.

- **Plant vigor (Plant_Vigor):**this data is collected 45 days after planting and should be evaluated using a scale from 1 to 9. (Salas, 2007).

| Scale | State | Description |
|---|---|---|
| **1** | **Very weak** | All the plants are small (< 20 cm), few leaves, weak plants, very thin stems and/or light green color. |
| **3** | **Weak** | 75% of the plants are small (< 20 cm) or all the plants are between 20 and 30 cm, the plants have few leaves, thin stems and/or light green color. |
| **5** | **Medium** | Intermediate or normal. |
| **7** | **Vigorous** | 75% of the plants are over 50 cm, robust with foliage of dark green color, thick stems and leaves very well developed. |
| **9** | **Very vigorous** | All the plants are over 70 cm and ground coverage is complete. The plants are robust, with thick stems and abundant foliage of dark green color |

- **Flowering (D_Flower):** Starting at 60 days after planting, check treatments at weekly intervals and record the number of days from planting to 50% of plants flowering in each test clone.

- **Senescence (SE):** This is collected ten days before every harvest date.

| Scale | State | Description |
|---|---|---|
| **1** | **Very late** | All the plants still show green foliage and flowers |
| **3** | **Late** | Most of the plants are still green, flowering is over and berries might be formed. |
| **5** | **Medium** | The plants are still being green or on the onset of senescence, there may be a slight yellowing. The angle of insertion of the leaves on the stems may have become more obtuse than in the younger plants of the same clone. The formation of berries can be advanced and abundant in fertile clones. |
| **7** | **Early** | The plants have senescent foliage, yellowing is more advanced but the stems may still be upright. If berries are present, their color will turn from green to pale green or yellow green. |
| **9** | **Very early** | The plants are completely senescent, yellowing is complete and uniform, and the stems are decumbent. |

***Data to be collected at harvest:***

Size of marketable tubers: Separate marketable tubers i.e.,

- **Number Marketable Tubers Category I/plot (NMTCI):** Count the number of marketable tubers for category I with weighing between 200-300g or tubers of 60 mm.

- **Number Marketable Tubers Category II/Plot (NMTCII):** Count the number of marketable tubers category II with weighing between 80-200g or between 30 -60 mm.

These categories I and II are arbitrary and can be change according to the country or region where are being evaluated. Each evaluator is free to use locally relevant criteria; however, each category should be defined in order to facilitate comparison of data between countries.

- **Number of Non-Marketable Tubers/Plot (NNoMTP):** Count the number of Non marketable tubers with weighing less of 80 g or less of 30 mm.

- **Number of marketable tubers (kg/plot) (NMTP).**

- Record the **dominant tuber size (DTSIZE)** and **secondary tuber size (STSIZE)** by treatment and replication. Use the scale and estimate by visual inspection the **percentage of tubers with dominant size (PDTSIZE)** in the row (the remaining **percentage corresponds to the secondary tuber size (PSTSIZE))**

| Scale | State | Description |
|---|---|---|
| **1** | Large | Those greater than 60 mm (Category I) |
| **2** | Medium | Those between 30 and 60 mm (Category II) |
| **3** | Small | Non-marketable tuber |

- **Marketable tuber weight (kg/plot) MTWP.**

- **Non-marketable tuber weight (kg/plot) (NoMTWP):** Remember that at each harvest date you will harvest 5 hills from each plot i.e., those between two marker plants.

- **Average marketable tuber weight (g) (ATWM):** Calculate dividing marketable tuber weight by the number of marketable tubers per 1000.

- **Average non-marketable tuber weight (g) (ATNoMW):** Calculate dividing non-marketable tuber weight by the number of non-marketable tubers per 1000.

***Data to be collected after harvest*** **(For specific gravity analysis)**

- Dry the harvested tubers in storage shed, exposure to light causes greening of potatoes.
- Cure at 10 to 20°C with a 95% relative humidity for 15 to 20 days
- Specific gravity (see procedure in the International Cooperator's Guide) (CIP, 2007). Evaluate 2 replicates of each sample.

Specific gravity (SG) = (weight in air) / (weight in air – weight in water)

**Calculating variables. -** Several variables can be derived from the raw data

| Variable | Abbreviations | Unit | Formula |
|---|---|---|---|
| Marketable Tuber Weight/Plot | MTWP | kg | $\mathbf{MTWP} = \mathrm{MTWCI} + \mathrm{MTWCII}$ |
| Average marketable tuber weight | ATMW | g | $\mathbf{ATMW} = \left(\frac{\mathrm{MTWP}}{\mathrm{NMTP}}\right) * 1000$ |
| Average non-marketable tuber weight | ATNoMW | g | $\mathbf{ATNoMW} = \left(\frac{\mathrm{NoMTWP}}{\mathrm{NoMTP}}\right) * 1000$ |
| Specific gravity sample1 | SG1 | | $\mathbf{SG1} = \left(\frac{\mathrm{TWA\_S1}}{\mathrm{TWA\_S1} - \mathrm{TWW\_S1}}\right)$ |
| Specific gravity sample2 | SG2 | | $\mathbf{SG2} = \left(\frac{\mathrm{TWA\_S2}}{\mathrm{TWA\_S2} - \mathrm{TWW\_S2}}\right)$ |
| Specific gravity | SG | | $\mathbf{SG} = \left(\frac{\mathrm{SG1} + \mathrm{SG2}}{2}\right)$ |

**Tuber weight in air sample (TWA_S1 and TWA_S2), Tuber weight in water sample (TWW_S1 and TWW_S2)*

## Data Analysis

The data, marketable tuber yield, marketable tuber number, and specific gravity are analyzed according to the design. Analysis of variance (ANOVA) is used and can be performed using Data Collector.

Download here.

Means between harvest dates within test clones, and means between test clones at each harvest date are compared using LSD. Procedures for performing these comparisons in R appear in the same attached file immediately after the ANOVA sentences.

## Data Interpretation

For a given variable, if the interaction between harvest date and test clone is significant ($p<0.05$) then there is at least one test clone that performs significantly different across harvest dates. Another way to interpret this interaction is that statistical differences exist between test clones at a given harvest date.

The tuber growth stage is a key determinant of the marketable component of total yield, characterized by a constant rate of increase in tuber size and weight. Hence, performance of marketable tuber weight across harvest date is of great importance in determining bulking maturity.

To assign a test clone to a given tuber bulking maturity grade, the evaluator must take into account the following situations in the comparison test analysis of test clones:

- Clones that do not perform statistically different for marketable tuber weight and yield across harvest date. These clones can be regarded as early maturing.

- Clones that perform statistically better in the second harvest date are not significantly different than those in the third harvest date. These clones can be regarded as medium maturing

Clones that perform statistically better in the third harvest date. These clones can be regarded as late maturing.

Clones that show no statistical difference in marketable tuber weight in two consecutive harvest dates may show a statistically significant increase in their marketable tuber yield. Since marketable tuber yield is a function of marketable tuber weight and number, a significant increase in marketable tuber yield can be attributed only to a greater number of marketable tubers. This would be the case of clones able to form additional tubers during later stages of plant development or cultivars with more than one tuber-setting cycle. In such cases, the evaluator must check the percentage of tubers assigned to each of the two marketable tuber size categories at each harvest date in order to make a decision on the bulking maturity characteristic of the clone.

Clones of medium or late bulking maturity can be recommended for an earlier harvest date provided if the clone is among those with best marketable tuber weight and yield at the referred date. Therefore, a comparison test between clones at a given harvest date is of paramount importance for a final recommendation of the clone's harvest date. This is of particular interest for areas of short growing seasons, where early lifting is required. Specific gravity should also be a criterion to take into consideration in this decision. A specific gravity of 1.080 or greater is considered acceptable.

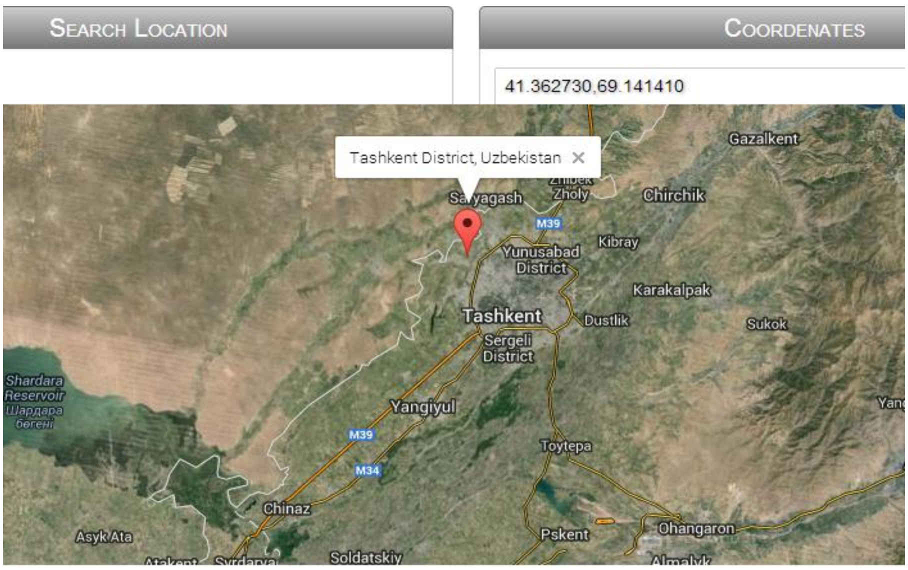
# Implementing tuber bulking protocol

## *Case Study in Tashkent*

A trial was conducted in Tashkent (Uzbekistan) for assessing tuber bulking maturity of 19 clones comprising 15 advanced and elite CIP clones, and 5 varieties from INTA, Argentina. The growing season was from mid-March till the third week of June, starting with short and ending with long photoperiods. The growing season in the lowlands of Tashkent is of less than 100 days because of extremely high temperatures soon afterwards. A strip plot design with three replications and experimental units of 5 hills/plot was used. Harvests were performed at 80 and 100 days after planting.

Sheet Minimal

| Project Name and Code | |
|---|---|
| Year | 2009 |
| Site short name | TASHKENT |
| Environment | Temperate lowlands |
| CIP Region | SWCA |
| Continent | Asia |
| Country | Uzbekistan |
| Admin1 | Tashkent Oblast |
| Locality | Tashkent |
| Elevation | 440 |
| Latitude | 41.362730 |
| Longitude | 69.141410 |



Results of the comparison tests among clones at each harvest date are shown in the following tables:

MARKETABLE TUBER YIELD HARVEST_DATE: 80D

| | Clone | means (K/m$^2$) | M | N | std.err |
|---|---|---|---|---|---|
| 1 | CIP-388676.1 | 0.50000000 | a | 3 | 0.09018500 |
| 2 | CIP-397099.4 | 0.39666667 | a | 3 | 0.15857000 |
| 3 | CIP-388615.22 | 0.32333333 | a | 3 | 0.17534094 |
| 4 | CIP-720148 | 0.32000000 | a | 3 | 0.18475209 |
| 5 | CIP-397077.16 | 0.25000000 | a | 3 | 0.07505553 |
| 6 | CIP-720150 | 0.25000000 | a | 3 | 0.08621678 |
| 7 | CIP-720141 | 0.23666667 | a | 3 | 0.12115188 |
| 8 | CIP-390478.9 | 0.22666667 | a | 3 | 0.13920409 |
| 9 | CIP-392797.22 | 0.20666667 | a | 3 | 0.20666667 |
| 10 | CIP-397099.6 | 0.15666667 | a | 3 | 0.15666667 |
| 11 | CIP-397029.21 | 0.12000000 | a | 3 | 0.04582576 |
| 12 | CIP-388611.22 | 0.11333333 | a | 3 | 0.05696002 |
| 13 | Sante | 0.11333333 | a | 3 | 0.01201850 |
| 14 | CIP-390663.8 | 0.08666667 | a | 3 | 0.04910307 |
| 15 | CIP-397054.3 | 0.07000000 | a | 3 | 0.07000000 |
| 16 | CIP-397069.11 | 0.04666667 | a | 3 | 0.04666667 |
| 17 | CIP-397073.16 | 0.03000000 | a | 3 | 0.03000000 |
| 18 | CIP-720087 | 0.02666667 | a | 3 | 0.02666667 |
| 19 | CIP-391180.6 | 0.00000000 | a | 3 | 0.00000000 |
| 20 | CIP-720139 | 0.00000000 | a | 3 | 0.00000000 |

MARKETABLE TUBER YIELD HARVEST_DATE: 100D

| | Clone | means (k/m$^2$) | M | N | std.err |
|---|---|---|---|---|---|
| 1 | CIP-397077.16 | 3.506667 | a | 3 | 0.6621765 |
| 2 | CIP-720150 | 3.160000 | ab | 3 | 0.1001665 |
| 3 | CIP-388615.22 | 3.046667 | ab | 3 | 0.1354417 |
| 4 | CIP-720148 | 2.740000 | bc | 3 | 0.4118657 |
| 5 | CIP-388676.1 | 2.666667 | bc | 3 | 0.1026861 |
| 6 | CIP-390478.9 | 2.476667 | cd | 3 | 0.1533333 |
| 7 | CIP-397099.4 | 2.210000 | cde | 3 | 0.0400000 |
| 8 | CIP-390663.8 | 2.093333 | de | 3 | 0.2028409 |
| 9 | CIP-720141 | 1.830000 | ef | 3 | 0.3023795 |
| 10 | CIP-397073.16 | 1.750000 | efg | 3 | 0.1001665 |
| 11 | CIP-388611.22 | 1.716667 | efg | 3 | 0.1745789 |
| 12 | CIP-720139 | 1.716667 | efg | 3 | 0.2377908 |
| 13 | CIP-397069.11 | 1.486667 | fgh | 3 | 0.2887521 |
| 14 | CIP-720087 | 1.410000 | fgh | 3 | 0.1386843 |
| 15 | CIP-397029.21 | 1.373333 | fgh | 3 | 0.1166667 |
| 16 | CIP-392797.22 | 1.293333 | ghi | 3 | 0.2654765 |
| 17 | CIP-397099.6 | 1.293333 | ghi | 3 | 0.2107394 |
| 18 | CIP-391180.6 | 1.103333 | hi | 3 | 0.1377599 |
| 19 | CIP-397054.3 | 0.800000 | i | 3 | 0.2300000 |
| 20 | Sante | 0.150000 | j | 3 | 0.0400000 |

MARKETABLE TUBER WEIGHT HARVEST_DATE: 80D

| | Clone | means (g/plt) | M | N | std.err |
|---|---|---|---|---|---|
| 1 | CIP-388676.1 | 159.77778 | a | 3 | 25.122908 |
| 2 | CIP-720150 | 118.33333 | ab | 3 | 21.666667 |
| 3 | CIP-388615.22 | 107.33333 | ab | 3 | 18.985374 |
| 4 | CIP-397099.4 | 100.66667 | abc | 3 | 10.477489 |
| 5 | Sante | 93.33333 | abcd | 3 | 20.275875 |
| 6 | CIP-397077.16 | 91.66667 | bcde | 3 | 4.409586 |
| 7 | CIP-390663.8 | 86.66667 | bcdef | 3 | 49.103066 |
| 8 | CIP-397029.21 | 85.00000 | bcdef | 3 | 13.228757 |
| 9 | CIP-388611.22 | 83.33333 | bcdef | 3 | 46.308147 |
| 10 | CIP-720141 | 78.88889 | bcdef | 3 | 40.383960 |
| 11 | CIP-720148 | 78.22222 | bcdef | 3 | 39.592991 |
| 12 | CIP-390478.9 | 62.22222 | bcdefg | 3 | 34.712221 |
| 13 | CIP-397099.6 | 39.16667 | cdefg | 3 | 39.166667 |
| 14 | CIP-397054.3 | 35.00000 | cdefg | 3 | 35.000000 |
| 15 | CIP-397073.16 | 30.00000 | defg | 3 | 30.000000 |
| 16 | CIP-720087 | 26.66667 | efg | 3 | 26.666667 |
| 17 | CIP-397069.11 | 23.33333 | fg | 3 | 23.333333 |
| 18 | CIP-392797.22 | 22.96296 | fg | 3 | 22.962963 |
| 19 | CIP-391180.6 | 0.00000 | g | 3 | 0.000000 |
| 20 | CIP-720139 | 0.00000 | g | 3 | 0.000000 |

MARKETABLE TUBER WEIGHT HARVEST_DATE: 100D

| | Clone | means (g/plt) | M | N | std.err |
|---|---|---|---|---|---|
| 1 | CIP-388615.22 | 141.57695 | a | 3 | 8.913501 |
| 2 | CIP-388676.1 | 131.30702 | a | 3 | 3.786803 |
| 3 | CIP-397069.11 | 129.45166 | ab | 3 | 9.512532 |
| 4 | CIP-397099.6 | 129.26984 | ab | 3 | 9.655648 |
| 5 | CIP-720087 | 127.59596 | ab | 3 | 6.825503 |
| 6 | CIP-397029.21 | 125.60101 | ab | 3 | 13.114977 |
| 7 | CIP-397077.16 | 125.59129 | ab | 3 | 1.104914 |
| 8 | CIP-397054.3 | 125.33333 | ab | 3 | 22.333333 |
| 9 | CIP-397099.4 | 124.10656 | ab | 3 | 7.873810 |
| 10 | CIP-392797.22 | 120.50000 | ab | 3 | 6.416847 |
| 11 | CIP-388611.22 | 112.64218 | ab | 3 | 5.248979 |
| 12 | CIP-390478.9 | 110.82071 | ab | 3 | 4.720753 |
| 13 | CIP-720150 | 109.41975 | ab | 3 | 6.948314 |
| 14 | CIP-720148 | 104.59140 | ab | 3 | 3.908258 |
| 15 | CIP-720141 | 103.68254 | ab | 3 | 3.539683 |
| 16 | CIP-397073.16 | 102.67725 | ab | 3 | 10.010494 |
| 17 | CIP-720139 | 90.27174 | ab | 3 | 8.306925 |
| 18 | Sante | 87.22222 | ab | 3 | 25.318953 |
| 19 | CIP-390663.8 | 82.12696 | ab | 3 | 2.426247 |
| 20 | CIP-391180.6 | 64.53277 | b | 3 | 10.190551 |

MARKETABLE TUBER NUMBER HARVEST_DATE: 80D

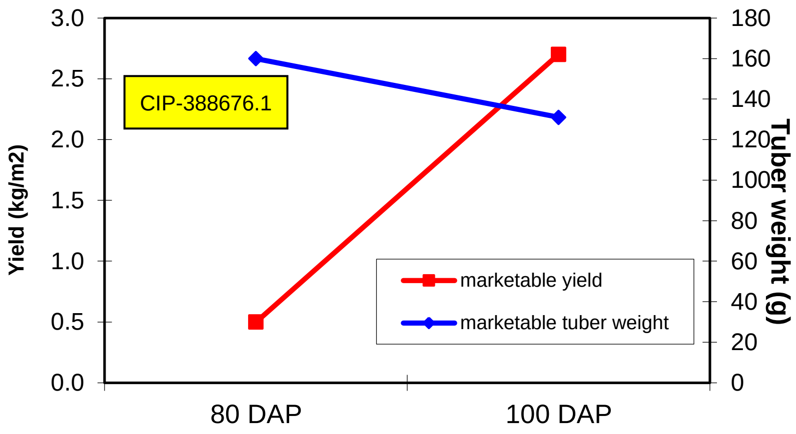
| | Clone | meansM (number/m²) | | N | std.err |
|---|---|---|---|---|---|
| 1 | CIP-397099.4 | 3.6666667 | a | 3 | 1.3333333 |
| 2 | CIP-388676.1 | 3.3333333 | a | 3 | 0.8819171 |
| 3 | CIP-392797.22 | 3.0000000 | a | 3 | 3.0000000 |
| 4 | CIP-388615.22 | 2.6666667 | a | 3 | 1.2018504 |
| 5 | CIP-397077.16 | 2.6666667 | a | 3 | 0.6666667 |
| 6 | CIP-720148 | 2.6666667 | a | 3 | 1.4529663 |
| 7 | CIP-390478.9 | 2.3333333 | a | 3 | 1.2018504 |
| 8 | CIP-720141 | 2.0000000 | a | 3 | 1.0000000 |
| 9 | CIP-720150 | 2.0000000 | a | 3 | 0.5773503 |
| 10 | CIP-397029.21 | 1.3333333 | a | 3 | 0.3333333 |
| 11 | CIP-397099.6 | 1.3333333 | a | 3 | 1.3333333 |
| 12 | Sante | 1.3333333 | a | 3 | 0.3333333 |
| 13 | CIP-388611.22 | 1.0000000 | a | 3 | 0.5773503 |
| 14 | CIP-390663.8 | 0.6666667 | a | 3 | 0.3333333 |
| 15 | CIP-397054.3 | 0.6666667 | a | 3 | 0.6666667 |
| 16 | CIP-397069.11 | 0.6666667 | a | 3 | 0.6666667 |
| 17 | CIP-397073.16 | 0.3333333 | a | 3 | 0.3333333 |
| 18 | CIP-720087 | 0.3333333 | a | 3 | 0.3333333 |
| 19 | CIP-391180.6 | 0.0000000 | a | 3 | 0.0000000 |
| 20 | CIP-720139 | 0.0000000 | a | 3 | 0.0000000 |

MARKETABLE TUBER NUMBER HARVEST_DATE: 100D

| | Clone | meansM (number/m²) | | N | std.err |
|---|---|---|---|---|---|
| 1 | CIP-720150 | 29.000000 | a | 3 | 1.0000000 |
| 2 | CIP-397077.16 | 28.000000 | ab | 3 | 5.5075705 |
| 3 | CIP-720148 | 26.000000 | abc | 3 | 3.2145503 |
| 4 | CIP-390663.8 | 25.666667 | abc | 3 | 3.1797973 |
| 5 | CIP-390478.9 | 22.333333 | bcd | 3 | 0.8819171 |
| 6 | CIP-388615.22 | 21.666667 | cd | 3 | 1.4529663 |
| 7 | CIP-388676.1 | 20.333333 | cde | 3 | 0.8819171 |
| 8 | CIP-720139 | 19.666667 | de | 3 | 3.8441875 |
| 9 | CIP-391180.6 | 19.000000 | de | 3 | 6.0277138 |
| 10 | CIP-397099.4 | 18.000000 | de | 3 | 1.5275252 |
| 11 | CIP-720141 | 17.666667 | de | 3 | 2.8480012 |
| 12 | CIP-397073.16 | 17.333333 | de | 3 | 1.7638342 |
| 13 | CIP-388611.22 | 15.333333 | ef | 3 | 1.8559215 |
| 14 | CIP-397069.11 | 11.333333 | fg | 3 | 1.4529663 |
| 15 | CIP-392797.22 | 11.000000 | fg | 3 | 2.6457513 |
| 16 | CIP-397029.21 | 11.000000 | fg | 3 | 0.5773503 |
| 17 | CIP-720087 | 11.000000 | fg | 3 | 0.5773503 |
| 18 | CIP-397099.6 | 10.333333 | fg | 3 | 2.4037009 |
| 19 | CIP-397054.3 | 7.333333 | gh | 3 | 2.6666667 |
| 20 | Sante | 2.000000 | h | 3 | 0.5773503 |

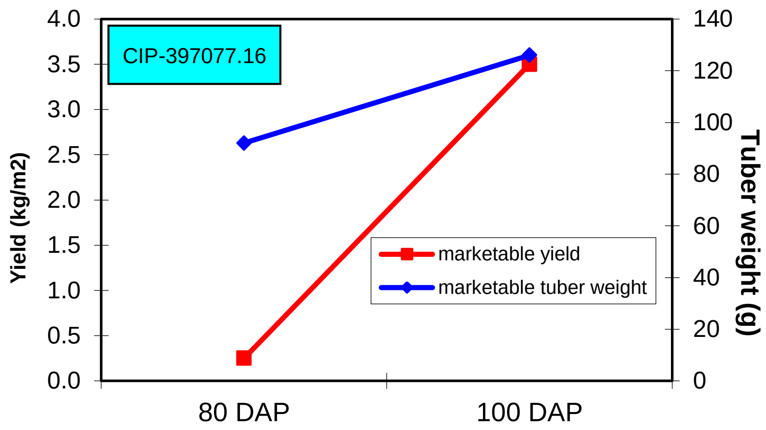
Going through the tables, we may observe that very few tubers of each clone reached marketable tuber size or weight at 80 days after planting (DAP); consequently, low marketable yields were recorded. High standard errors for marketable yield at 80 DAP led to the lack of statistical differences among clones for this variable, despite the wide range of yield values, i.e., from 0 to 0.500 kg/m2. On the other hand, by 100 DAP; most if not all of the test clones had produced a significantly greater number of tubers of a marketable tuber size or weight. Differences among clones in their yield potential and adaptation or in their bulking maturity may account for the statistical differences among clones at 100 DAP. According to the scale proposed above, all test clones can be regarded as medium maturity under the growing conditions of the lowlands in Tashkent. However, if for any reason, harvest had to be performed earlier (80 DAP), the clone CIP-388676.1 would be the best choice.

The following figures show the performance of two advanced clones (those clones highlighted in turquoise and yellow in the tables) across the two harvest dates:




| | | |
|---|---|---|
| Marketable tuber number /m$^2$ | 3 | 20 |
| Unmarketable tuber number /m$^2$ | 43 | 28 |

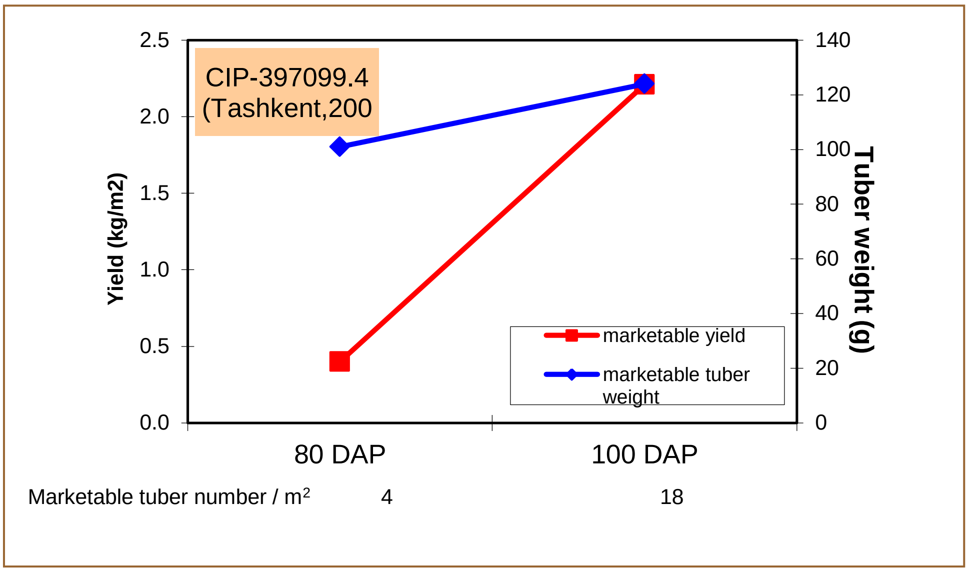
No statistical differences for marketable tuber weight across harvest

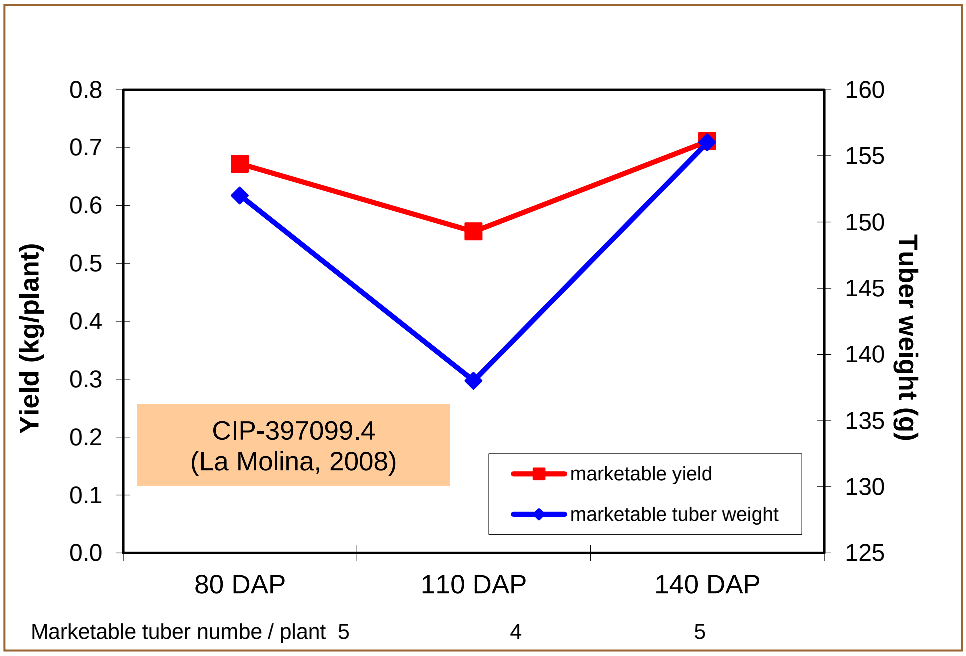



| | | |
|---|---|---|
| Marketable tuber number /m$^2$ | 3 | 28 |
| Unmarketable tuber number /m$^2$ | 59 | 40 |

dates were found for either of the two test clones. This was not true for the marketable tuber yield and number for which a significant increase was observed for both clones at 100 DAP. This indicates that earlier harvests would rend immature potatoes of unmarketable size. It is evident that bulking was interrupted at 80 DAP in all test clones and it is likely that some of them might require more than 100 days to reach maturity. Nevertheless, almost all clones showed good marketable tuber weight and number when harvested at 100 DAP.

The clone CIP-397099.4 tested in this trial was also evaluated for tuber bulking maturity during winter at CIP Headquarters in La Molina (Lima-Peru). The growing season was of 140 days and three harvests were performed at 80, 110, and 140 DAP, respectively. The next two figures show the performance of this clone in each location.



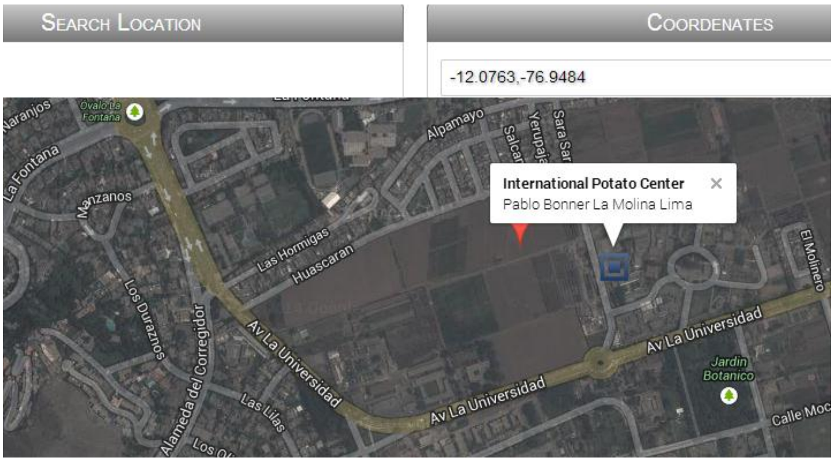



In Tashkent, CIP-397099.4 yielded significantly better at 100 DAP, even though a few marketable tubers harvested at 80 DAP weighed not significantly different from those harvested at 100 DAP. However, a significantly greater number of marketable tubers at 100 DAP, indicates that bulking was still in progress at 80 DAP, consequently CIP-397099.4 can be regarded as a medium maturing clone under the lowland conditions of Tashkent. In contrast, no significant differences for marketable tuber yield, weight and number were found across harvest dates in La Molina, indicating that CIP-397099.4 is an early maturing clone under these conditions.

It is likely that high temperatures at Tashkent may have delayed tuber initiation, and consequently affected bulking period. This highlights the importance of recording meteorological information during the growing season.

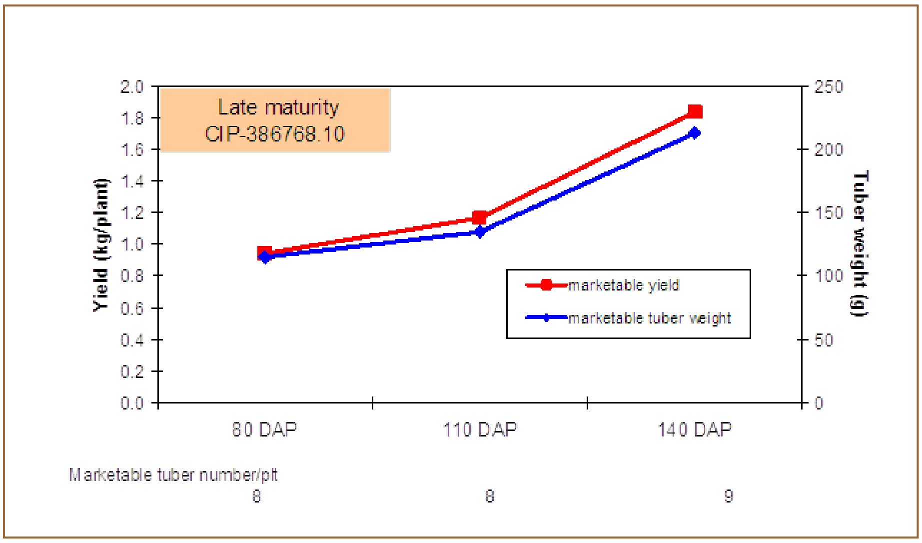
The following figures show the performance of an early, a medium, and a late maturing advanced clone from the tuber-bulking assessment trial carried out on 54 advanced clones in La Molina (Lima, Peru) in winter 2008.

| **Project Name and Code** | **Standard Evaluation Trials 310102** |
|---|---|
| **Year** | **2008** |
| **Site short name** | **CIPHQ** |
| **Environment** | **Sub-tropical lowlands** |
| **CIP Region** | **LAC** |
| **Continent** | **South America** |
| **Country** | **Peru** |
| **Admin1** | **Lima** |
| **Admin2** | **Lima** |
| **Admin3** | **La Molina** |
| **Locality** | **La Molina** |
| **Elevation** | **244** |
| **Latitude** | **-12.0763** |
| **Longitude** | **-76.9484** |

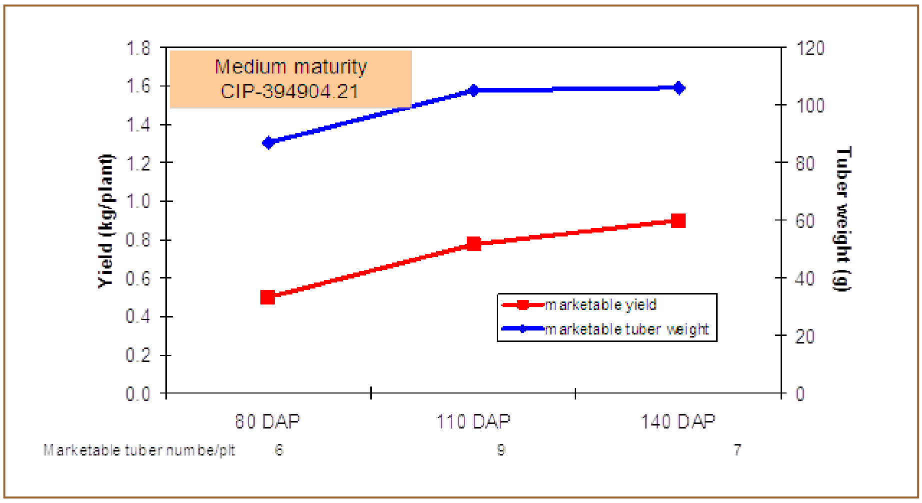


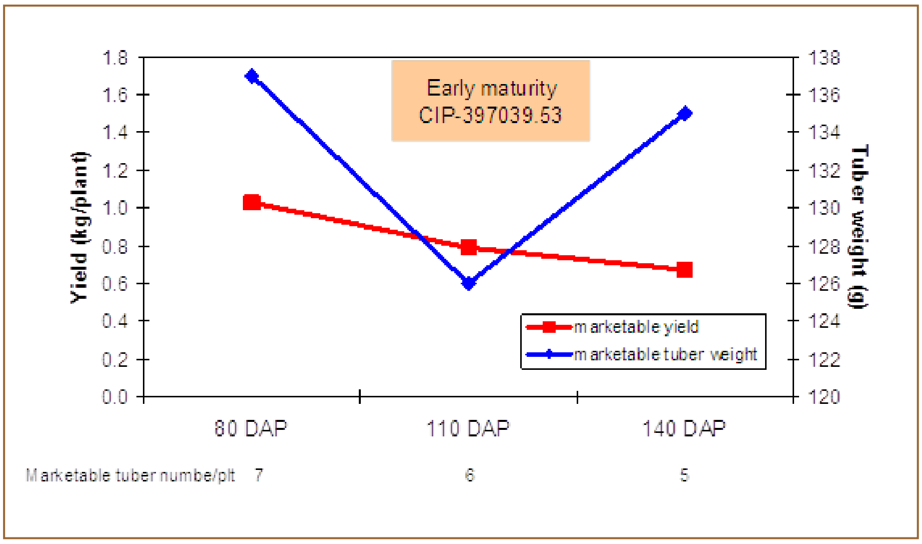

The early maturing clones CIP-397039.53 as well as the late maturing one (CIP-386768.10) were among the best yielding clones at 80 DAP. They ranked first and third among the 54 tested clones. No significant differences in marketable tuber yield were found between them though the early maturing one showed a slightly greater marketable tuber weight (137g/plant vs. 115 g/plant).

The late maturing clone has an advantage over the early one as significantly higher yields can be expected in a late harvest.




This is important when farmers need to decide their harvest date according to the markets' supply and demand. The medium maturing clone CIP-394904.21 was among the lowest yielding clones across the three harvest dates.


Medium maturity
CIP-394904.21
Yield (kg/plant)
Tuber weight (g)
marketable yield
marketable tuber weight
80 DAP
110 DAP
140 DAP
Marketable tuber numbe/plt 6 9 7


Early maturity
CIP-397039.53
Yield (kg/plant)
Tuber weight (g)
marketable yield
marketable tuber weight
80 DAP
110 DAP
140 DAP
Marketable tuber numbe/plt 7 6 5

# Appendix

Fieldbook template for tuber bulking maturity assessment and previous instructions you need before running your template.

template_PTBM.xls [Compatibility Mode]

| | A | B |
|---|---|---|
| 1 | **Factor** | **Value** |
| 2 | Short name or Title | |
| 3 | Version | V.2.1.0 |
| 4 | Crop | potato |
| 5 | Type of Trial | bulking maturity |
| 6 | Comments | |
| 7 | Begin date | |
| 8 | End date | |
| 9 | Leader | |
| 10 | Collaborators | |
| 11 | Site short name | |
| 12 | Agroecological zone | |
| 13 | CIP Region | |
| 14 | Continent | |
| 15 | Country | |
| 16 | Admin1 | |
| 17 | Admin2 | |
| 18 | Admin3 | |
| 19 | Locality | |
| 20 | Elevation | |
| 21 | Latitude | |
| 22 | Longitude | |
| 23 | Owner | International Potato Center |
| 24 | Publisher | International Potato Center |
| 25 | Type | dataset |
| 26 | Format | Excel 2003 |
| 27 | Identifier | to be done: doi |
| 28 | Language | en |
| 29 | Relation | NA |
| 30 | License | © International Potato Center |
| 31 | Audience | Breeder |
| 32 | Provenance | original |

Minimal | Installation

## Form: Minimal

Data Collector software will complete this information according with your locality. Be sure to complete the "Begin date" and the "End date". The correct format date is: yyyy-mm-dd, please write and single quote before the date e.g. '2014-04-07, with the purpose of keep the format of the date.

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## Form: Installation

Please complete this form with your data experiment.

template_PTBM.xls [Compatibility Mode]

| | A | B |
|---|---|---|
| 1 | **Factor** | **Value** |
| 2 | Experimental design | |
| 3 | Genetic design | |
| 4 | Labels for factor genotypes | Institutional number |
| 5 | Number of repetitions or blocks | |
| 6 | Block size (applicable for BIBD only) | |
| 7 | Block number | |
| 8 | Experimental Environment | Field |
| 9 | Plot start number | 1 |
| 10 | Number of plants planted per plot | 10 |
| 11 | Number of plants per sub-plot | |
| 12 | Number of rows per plot | 1 |
| 13 | Number of rows per sub-plot | |
| 14 | Number of plants per row | 10 |
| 15 | Plot size (m2) | 2.7 |
| 16 | Distance between plants (m) | 0.3 |
| 17 | Distance between rows (m) | 0.9 |
| 18 | Planting density (plants/Ha) | 37,037 |
| 19 | Row direction | |
| 20 | Planting mode | |
| 21 | Area of the experiment | |
| 22 | Additional factor name | |
| 23 | Labels for additional factor, level 1 | |
| 24 | Labels for additional factor, level 2 | |
| 25 | Labels for additional factor, level 3 | |
| 26 | Labels for additional factor, level 4 | |
| 27 | Labels for additional factor, level 5 | |
| 28 | Latitude corner 1 | |
| 29 | Longitude corner 1 | |
| 30 | Latitude corner 2 | |
| 31 | Longitude corner 2 | |
| 32 | Latitude corner 3 | |
| 33 | Longitude corner 3 | |

Installation | Material List | Soil_analysis

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## Form: Material List

Data Collector Software will complete the list of clones, please if you have pedigree information complete it.

| Numeration | Control | Institutional number | Clone or variety name | Code of clone | Family Institutional number | Female Institutional number | Female code | Male Institutional number | Male code | Seed source[1] | References to silmultaneous trials | References to previous trials |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | CIP388615.22 | | C91.640 | | | B-71-240.2 | CIP386614.16 | XY.16 | | | |
| 2 | | CIP392797.22 | | C92.140 | | CIP387521.3 | | | APHRODITE | | | |
| 3 | | CIP397029.21 | | 364.21 | | | 92.118 | | 92.187 | | | |
| 4 | | CIP390663.8 | | C91.628 | | CIP720087 | SERRANA | CIP386316.14 | XY.14 | | | |
| 5 | | CIP393465.2 | | | | CIP720087 | SERRANA | CIP387170.9 | | | | |
| 6 | | CIP391180.6 | | C90.266 | | CIP385305.1 | XY.9 | CIP378017.2 | LT-7 | | | |

[Back to "Data Recording" table]

## Form: Crop management

Please complete as this form with all information you have, summarize all procedures that were performer in the experiment. The correct format date is: yyyy-mm-dd, please write and single quote before the date. e.g. '2014-04-07.

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Intervention category | Intervention type | Date | Operator | Observations | Active Ingredient | Product concentration | Dose of application | Uncertainty of Measurement |
| 2 | Preparation | Planting | | | | | | | |
| 3 | Harvest | Vine cutting / killing | | | | | | | |
| 4 | Harvest | Harvest | | | | | | | |
| 5 | | | | | | | | | |
| 6 | | | | | | | | | |
| 7 | | | | | | | | | |
| 8 | | | | | | | | | |

Soil_analysis | Hobo_data | Weather_data | **Crop_management** | Var Lis

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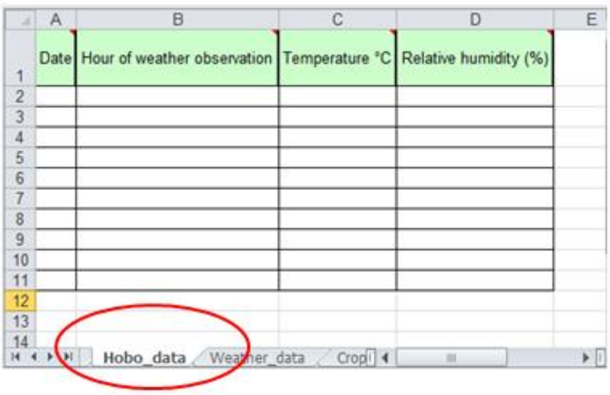
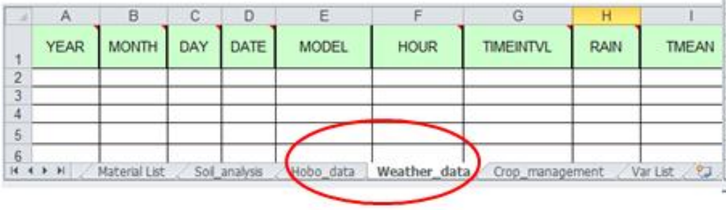
## Forms: Hobo data, Weather data, Soil analysis

If you have data, please complete this information.



| Date | Hour of weather observation | Temperature °C | Relative humidity (%) |
|---|---|---|---|
| | | | |

| Variables | Abbreviture | Unit | Data1 | Data2 |
|---|---|---|---|---|
| Date | DATE | | | |
| Requester | RQSTR | | | |
| Operator | OPRTR | | | |
| Latitude | LATD | | | |
| Longitude | LOND | | | |
| Laboratory code | LabCo | | | |
| Sample code | SCo | | | |
| Field code | FDCo | | | |
| Soil PH | pH | | | |
| Electrical conductivity | EC | mmh/cm | | |
| CaCO3 | CaCO3 | percentage | | |
| Organic matter | MO | percentage | | |
| Nitrogenum total | N | | | |
| Phosphorus | P | ppm | | |
| Potassium | K | ppm | | |
| Sand | Sand | percentage | | |
| Lime | Silt | percentage | | |
| Clay | Clay | percentage | | |
| Soil texture | STEX | | | |
| Cation Exchange Capacity | CEC | Meq/100g | | |
| Exchangeable Calcium | ExCa2 | Meq/100g | | |
| Exchangeable Magnesium | ExMg2 | Meq/100g | | |
| Exchangeable Potassium | ExK | Meq/100g | | |
| Exchangeable Sodium | ExNa | Meq/100g | | |
| Aluminium + hidrogenum | ExAl3_H | Meq/100g | | |
| Total cations | TCA | | | |
| Total of bases | TBAS | | | |
| Base Saturation | BS | percentage | | |
| Iron | Fe | ppm | | |
| Copper | Cu | ppm | | |
| Zinc | Zn | ppm | | |
| Boron | B | ppm | | |
| Manganese | Mn | ppm | | |



| YEAR | MONTH | DAY | DATE | MODEL | HOUR | TIMEINTVL | RAIN | TMEAN |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

Back to "Data Recording" table

## Form: Var_List

Data Collector Software can help to fill this form mark with and “X” those variables you want to analyze and summarize.

template_PTBM.xls [Compatibility Mode]

| | Factor.Variables | Abbreviations | Fieldbook | Summarize | Analyze | Selection direction | Selection weight |
|---|---|---|---|---|---|---|---|
| 2 | Number of tubers planted | NTP | | | | | |
| 3 | Emergence date | EDATE | | | | | |
| 4 | Number of plants emerged | NPE | | | | | |
| 5 | Percentage plants emerged | PPE | | | | | |
| 6 | Plant vigor | Plant_Vigor | | | | | |
| 7 | Days of Flowering | D_Flower | | | | | |
| 8 | Senescence (10 days before first harvest date) | SE1 | | | | | |
| 9 | Senescence (10 days before second harvest date) | SE2 | | | | | |
| 10 | Senescence (10 days before third harvest date) | SE3 | | | | | |
| 11 | Number of plants harvested (First harvest date) | NPH_1HD | | | | | |
| 12 | Number of plants harvested (Second harvest date) | NPH_2HD | | | | | |
| 13 | Number of plants harvested (Third harvest date) | NPH_3HD | | | | | |
| 14 | Number marketable tubers/plot (First harvest date) | NMTP_1HD | | | | | |
| 15 | Number of non-marketable tubers/plot (First harvest date) | NNoMTP_1HD | | | | | |
| 16 | Marketable tuber weight/plot (First harvest date) | MTWP_1HD | | | | | |
| 17 | Non-marketable tuber weight/plot (First harvest date) | NoMTWP_1HD | | | | | |
| 18 | Dominant tuber size (First harvest date) | DTSIZE_1HD | | | | | |
| 19 | Secondary tuber size(First harvest date) | STSIZE_1HD | | | | | |
| 20 | Percentage dominant tuber size (First harvest date) | PDTSIZE_1HD | | | | | |
| 21 | Percentage secondary tuber size (First harvest date) | PSTSIZE_1HD | | | | | |
| 22 | Average marketable tuber weight (First harvest date) | ATMW_1HD | | | | | |
| 23 | Average non-marketable tuber weight (First harvest date) | ATNoMW_1HD | | | | | |
| 24 | Number marketable tubers/plot (Second harvest date) | NMTP_2HD | | | | | |
| 25 | Number of non-marketable tubers/plot (Second harvest date) | NNoMTP_2HD | | | | | |
| 26 | Marketable tuber weight/plot (Second harvest date) | MTWP_2HD | | | | | |
| 27 | Non-marketable tuber weight/plot (Second harvest date) | NoMTWP_2HD | | | | | |
| 28 | Dominant tuber size (Second harvest date) | DTSIZE_2HD | | | | | |
| 29 | Secondary tuber size (Second harvest date) | STSIZE_2HD | | | | | |
| 30 | Percentage dominant tuber size (Second harvest date) | PDTSIZE_2HD | | | | | |

Crop_management | Var List

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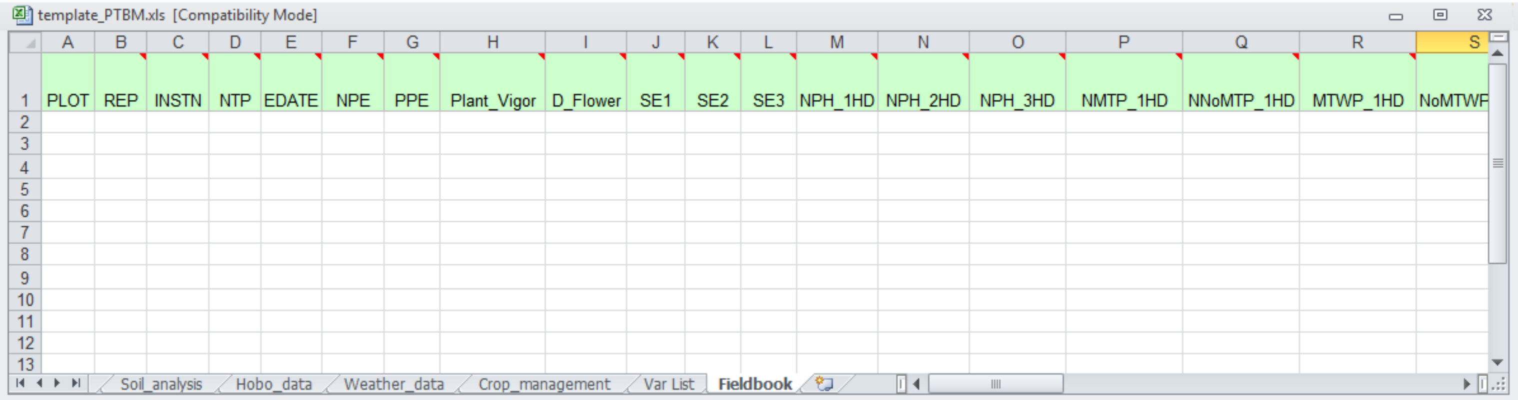
## Form: Fieldbook

Tuber bulking maturity: Please complete this form with all the information you have of the experiment.



template_PTBM.xls [Compatibility Mode]

| PLOT | REP | INSTN | NTP | EDATE | NPE | PPE | Plant_Vigor | D_Flower | SE1 | SE2 | SE3 | NPH_1HD | NPH_2HD | NPH_3HD | NMTP_1HD | NNoMTP_1HD | MTWP_1HD | NoMTWP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

Soil_analysis / Hobo_data / Weather_data / Crop_management / Var List / Fieldbook

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# References

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