



► *Manual de Muestreo de*  
***Suelo, Planta y Agua***

2a Edición



## Soil Analysis

Soil analysis is critical if we want to obtain better crop yields. Average farmers in USA and Europe cannot conceive farming without the support of soil analysis. Let us remember that plants require 12 mineral nutrients that must be obtained from soil and fertilizers. Not even the best technician can guess if those 12 elements required by the crop are available in a specific soil and farmers cannot afford applying each one of those elements, because of their high cost, especially fertilizers.

Considering that water is one of the resources with the highest impact on soil fertility, it is indispensable to carry out laboratory analysis' assessment. On the other hand, every time that we establish a fertilization program for a given crop, the next step is monitoring crop nutrition to measure the performance of the fertilization program and find out if supplementary fertilization is needed. In summary, we must analyze soil, water and plant tissue to fulfill as much as possible the fertilization needs of crops, thus achieving the best profitability.

In order to establish a fertilization schedule for an agricultural field based on the results of soil analysis, it is essential to establish the right sampling procedures. In general, sampling errors are greater than lab analysis errors. On the other hand, grazing fields are more complex, since urine and feces produce greater soil variability. Therefore, special care must be given to the number of potential sub-samples required to obtain a representative sample of the crop field.

Prior to sending the samples to a lab, we must consider the next process steps: 1) sampling time determination, 2) sampling frequency, 3) splitting the field in homogenous areas, 4) sampling's depth determination 5) number of subsamples to be taken at every homogenous area, 6) sample management and preparation, 7) sample identification, 8) laboratory selection. These are some recommendations that should be taken into consideration during the implementation of the steps herein:

### Sampling time

Soil sampling should be done before the crop is established, either before the rainy season in the case of spring-summer crops, or after, in case we are dealing with fall-winter crops, in order to have the lab results on time to implement the best fertilization schedule. On the other hand, to obtain better soil homogeneity, it is better to take soil samples before crop establishment. In case of fruit orchards, sampling must be done before the spring, in order to establish a fertilization schedule before the first buds emerge. If weather conditions allow it, sampling must be done before tillage.

### Sampling Frequency

Sampling and lab analysis frequency will depend on soil conditions and specific problems; such as sodium saturated soils remediated with calcium addition; acid soils treated with lime; saline soils that have been washed out. Growers must assess the effect of soil enhancing treatments after a certain time, so sampling should also be done during the next crop season. There are highly dynamic nutrients like N-NO<sub>3</sub> whose contents can change after few months due to leaching, soil washing and crop uptake. With regards to available N, it is indispensable to conduct a soil analysis every year just to assess the level of this element. The rest of the elements and the soil conditions do not change in short term.

On the other hand, some nutrients are highly stable, such as phosphorous and potassium, which do not present significant changes in two or three years, with the exception of coarse soils, in which fertility changes

occur faster. Changes in the organic matter occur even at longer terms, unless the soil has fresh organic matter, like manure, that breaks down quite fast. In general, a soil analysis of the same plot every two or three years should be carried out. Under specific conditions, such as in the case of N-NO<sub>3</sub>, a soil analysis must be conducted every crop season. Physical properties, such as soil texture are tested once, since they do not change with time, but it is extremely important to keep record of the analytical results identified by means of tables or plot sections.

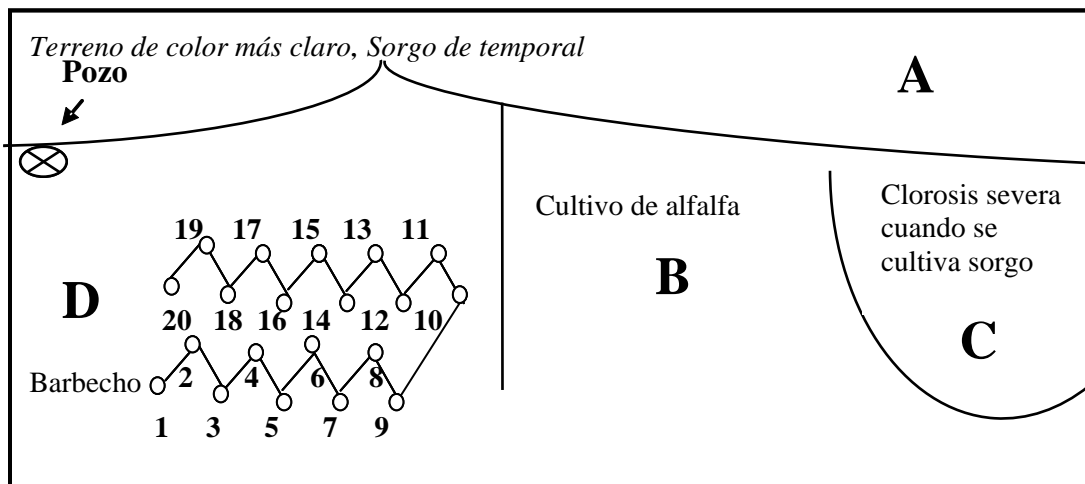
### Establishment of homogenous areas or sampling units

Before sampling and after a visit to the plot's and a short interview with the farm owner or foreman, a drawing of the land lot divided more or less evenly must be made. Splitting the field into homogenous areas or sampling units helps managing fertilization and soil enhancement independently, within the limits of the sampling units' geometry. Homogenous areas or sampling plots should not be larger than 20 ha, to lower the natural variability of the land.

In order to define the sampling units, we take into account the following factors:

1. Soil color.
2. Areas with salinity and/or sodium related problems
3. Texture
4. Slope
5. General condition of previous crops.
6. Crop history (crops and yields obtained during several past years)
7. Keep records of soil enhancers' applications, such as plaster, liming and organic matter.

Figure 1 shows a sampling drawing of an agricultural farm at "Bajío" region. We should avoid mixing samples from two plots, despite their similarity. Nutrient uptake and/or extraction rates might differ in two adjacent plots previously planted one with corn and the other one with alfalfa.



**Figure 1.** Agricultural farm in Bajío region, Guanajuato, Mexico. 18 ha planted with rain-fed sorghum; 1-3% slope with paler soil than the rest of the land. (B) 8 ha planted with alfalfa. Flat area of fine soil texture and less than 0.5% slope. (C) Area where severe chlorosis appears when sorghum is planted. (D) 10 ha of flat land, dressed and left at fallow after growing broccoli. This section of the farm is the sampling area. 20 sub-samples are distributed in zigzag within sampling unit D, used in the preparation of the compound sample. The same sub-sampling process is followed in the remaining sections.

### Sampling depth

Users usually take 0 to 30 cm-deep samples (arable layer) in order to save money. However, long-term soil enhancement planning requires knowledge of underground soil conditions. Soil surface area has greater

organic matter content than the underground layer, where nutrients uptake is more intensive, and that is precisely where samples must be taken from.

If subsoil texture is suitable, we recommend deep plowing. Instead, if subsoil conditions are too acidic, deep plowing must be avoided, because it can increase acidity of the arable layer. On the other hand, if the subsoil layer is already high in readily available nitrogen (N-NO<sub>3</sub>) the crop will have enough supply of this nutrient in a natural way. In this case, the rate of nitrogen-based fertilizations would be much lower. Besides sampling the soil layer at a depth of 0-30 cm to conduct the routine fertility analysis, we should also take samples at a depth of 30-60 cm, to determine the level of N-NO<sub>3</sub> present in the soil. The results of this analysis will provide more elements to schedule the optimal rate of nitrogen-based fertilization, leading to lower fertilization costs.

In the case of irrigated crops, most part of the root activity is conducted at 0 to 30 cm, and therefore our analysis must focus in that layer, especially if we grow crops with shallow root systems, like most vegetables. In fruit trees-established crops, samples are taken every 30 cm, until reaching a depth of 90 cm. In soils presenting recurrent low yield issues, we recommend taking samples from 30-60cm-soil layer. Samples should be free from organic residues that have not broken down.

### Sampling intensity

Table 1 shows the quantity of subsamples that must be taken, according to the surface area where we want to conduct the fertility analysis. It is worth while mentioning that an analysis of a soil sample represented by only one sub-sample does not enable us to analyze soil fertility, but in fact, it is a source of misinterpretation and wrong recommendations.

*Table 1. Number of subsamples to be taken from each sampling unit in order to prepare a compound sample.*

| Sampling unit (ha) | Number of sub-samples |
|--------------------|-----------------------|
| < 2                | 8                     |
| 2-5                | 12                    |
| 5-10               | 16                    |
| 10-20              | 20                    |

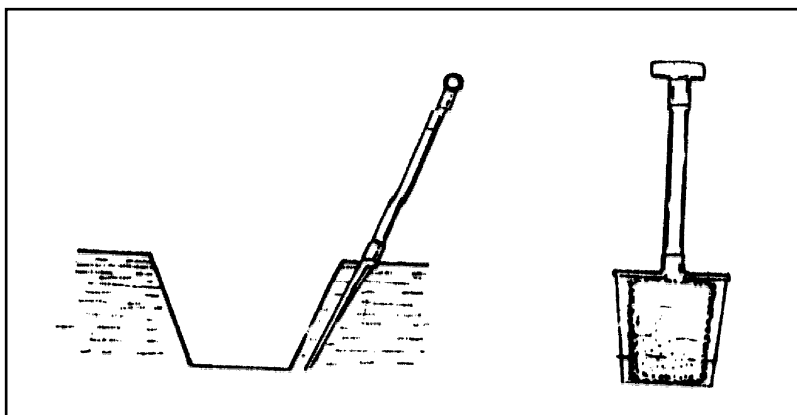
A sample of 1 kg in 10 ha represents a soil volume of 30 million Kg, without even considering further reduction of soil volume in a laboratory sample.

### Sub-samples collection

A core bit is recommended for sampling (stainless steel if possible), taking small soil quantities (at the depth and width) to prepare the compound sample. Sampling core bits can be bought at **Fertilab**.

An alternative to the core bit would be a square-point shovel, as shown in Figure 2, following hereinabove recommendations. Shoveled sub-samples might contain some aggregates (lumps), which can be used in physical determination essays, like bulk density and structure. Core bits provide faster, lower-cost, systematic and in some cases more homogenous sampling results, apart from being ideal

for samples taken at depths of 30-60 cm. In any case, preventive actions must be taken to avoid contamination of samples taken at 30 to 60 cm with soil coming from the upper 0-30 cm layer.



*Figure 2. Sampling procedure with square-point shovel.*

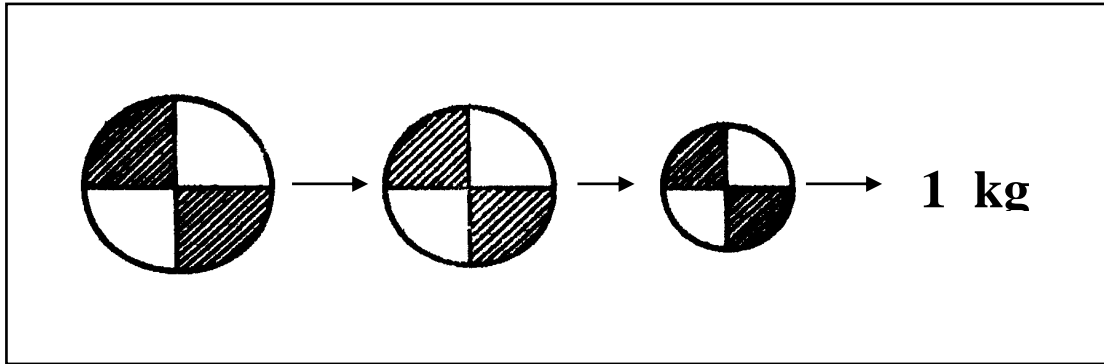
We recommend avoid taking samples from the land plot edges, where excessive quantities of fertilizer usually build up due to the tractor's turning maneuvers. Instead, samples must be taken 20 m away from edges, tree rows or fences. Sub-samples are usually collected in plastic buckets marked with the sampling depth, in case more than one soil layer is being sampled.

In crop fields with furrows and band-fertilization that are sampled before tillage, it is necessary to increase the number of sub-samples to reduce variability and stratify sampling in three furrow's positions: a) top, b) side, and c) bottom. The number of sub-samples would then be apportioned among these three positions. After mixing the total number of sub-samples we end up with a representative compound sample of the land plot, as shown bellow.

### Preparing a compound sample

Sub-samples are carefully mixed after collection, extracting a sample of 1.5 Kg. Figure 3 shows the opposite quadrants splitting method used to prepare the compound sample. Mixing and splitting are more efficient when the sample is dried outdoors before compounding. Once dried, the sample is placed on a piece of plastic, or on clean fertilizer-free cement floor, to be carefully mixed. After obtaining a homogenous mix, the sample is distributed forming a circle divided in four quadrants. Opposite quadrants are eliminated (blanks in Figure 3) while the other two quadrants are mixed again. The same procedure is repeated several times until compounding the sample to 1.5 Kg. Fresh organic matter residues (recently applied), gravel and pebbles must be eliminated during the sample compounding process, since these materials are not included in the soil analysis. The remaining soil must be dried and store for a week, until the laboratory sends confirmation of having received the sample. Wet soil samples must be dried outdoors either under direct sunlight, or under shadow (dry kilning distorts soil's chemical properties). Once dried, samples are packed, carefully labeled and sent to the laboratory.

Nitrogen mineralization is promoted in wet samples stored for a certain time, since the content of this nutrient is overestimated during the analysis. This is particularly important when there is a huge quantity of organic matter or fresh crop residues. When the sample is delivered to the laboratory the same day in which it was collected, or at the following day, there is no need to dry it out before sending it to the laboratory. The laboratory will dry the sample with the right care.



**Figure 3.** Procedure to obtain a compound sample using the opposite quadrants splitting method.

Samples must be packed in clean bags. Second-hand bags may contain fertilizer or manure residues that can contaminate the sample. In order to avoid potential sources of cross-contamination, samples should be dried and stored in areas far from the place where fertilizers are kept. Procedures to take and prepare a representative sample are as important as conducting the lab analysis, and should be done by trained staff, under the supervision of an experienced technician, if possible. To make sure that the laboratory results will be useful analytical tools, it is crucial to strictly follow the recommendations herein.

**Sample Identification**

Samples must be identified according to the land drawings marked with the sampling units (homogenous sectors) in preparation to be shipped. Samples must be identified with the following data: name of the farm, name of the farm owner, sampled sector, geographical location (GPS if possible) previous crop and yield, crop residues management (burned, field removed, field incorporated), tillage system, crop to be established, irrigation source, reasonable yield target and visible land issues, if any (Figure 4).

It is necessary to gather information about previous crop residues, especially if they were incorporated into the soil, to determine whether additional nitrogen is required at the beginning of the crop season, in order to promote breakdown of the residues and avoid lack of mobilization of mineral nitrogen or nitrogen-based fertilizer present in the soil.

| <b>Soil Sample</b>                            |  |
|---|--|
| Date: _____                                   | Control Number: _____                  |
| Farm's name _____                             | Owner: _____                           |
| Land lot, sector: _____                       | Municipality, State: _____             |
| Geo. Coord. GPS Lat. _____ Long. _____        | Intended Crop: _____                   |
| Sampling Prof.: _____ cm                      | Target Yield: _____                    |
| Previous crop residue management: _____       | Previous Crop: _____                   |
| Requested analysis: Fertility ( )             | Incorporated ( ) Burned or Removed ( ) |
| Special analysis: _____                       | Paste extract ( ) Special ( )          |
| Comments: _____                               |  |
|   |  |
| * According to a regional map or a GPS system |  |

**Figure 4.** I.D. card of a soil sample that will be sent to the laboratory

Geographical coordinates of the land field are important pieces of data. This information helps mapping future regional problems, after gathering a reasonable quantity of data. GPS can also be used to accurately locate the sampling site. GPS systems and data enable to determine field sections with specific deficiencies or special issues, providing additional services to lab users. If all the laboratories within a region use this method as a standard practice, it would be feasible to prepare a sound data base to develop soil fertility maps of a specific region.

### **Choosing a laboratory**

Samples should only be sent to laboratories using analytical procedures authorized by Mexican Official Standard: NOM-021-RECNAT-2000, published in the Federal Register on December 31<sup>st</sup>, 2002. Make sure that the laboratory that you chose has reliable control of the analytical quality, including timely delivery of the analytical results, to make the right decisions on crop fertilization requirements. Verify that that particular laboratory takes part in inter-comparison programs implemented by domestic and international organizations. Use a fast delivery system to send your samples to the lab. Avoid doing business with labs not complying with the following procedures: a) ammonium acetate for K, Ca, Mg and Na, b) DTPA for Fe, Cu, Zn and Mn; c) Bray or Olsen phosphorous assay. Do not work with labs whose methods do not comply with the standards, like Melich 3 or the acetic acid test. These methods have been rejected by the Mexican Official Standards and Mexican soil experts. These procedures, cheaper than the procedures recommended by the Mexican Official Standard will only create user's confusion.

## **Foliar Sampling**

Foliar analysis is conducted for three main reasons:

1. Troubleshooting crop's nutritional condition to correct deficiencies, before the crop presents any symptom of a particular element deficiency having impact on the yield.
2. Confirm the accuracy of the fertilization schedule; correcting or applying any additional nutrient required by the crop, based on a reliable soil analysis.
3. Identifying or confirming the source of visual symptoms, in order to locate areas presenting nutritional problems, or to compare the nutritional condition of two plant populations showing different symptoms. Under these circumstances the sampling process would focus on affected areas.

The best way of troubleshooting the nutritional condition of fruit crops is through foliar analysis. This analysis can serve as basis to recommend a fertilization program and it can even be considered a more valuable tool than soil analysis.

For plant analysis results to be useful it is necessary to follow a standard sampling methodology. The sampling procedure includes the following aspects: 1) plant tissue selection, 2) sampling and 3) sample preparation for lab analysis.

### **Plant tissue selection**

Plant tissue to be sampled is selected based on the physiological age or phenological stage of the crop. In general terms, the sampling criterion uses the most recently mature leave (MRML), that is, the leave that has just finished growing. To assess nutritional condition of a crop, we must avoid sampling tender or old leaves, as well as leaves that have been damaged by disease, insects or have suffered physical or chemical damages.

Likewise, sampling must not take into consideration plants that are located in uncommon areas, for instance in areas where the training conditions differ from the rest of the field, areas that are near from water bodies, fertilizers or manure storage areas. Plants under water and heat stress should not be sampled.

Tables 2, 3, 4 and 5 present sampling guidelines for several crops including: tissue to be sampled, age, right sampling time and sample size.

**Table 2.** Foliar sampling guidelines for extensive crops

| Crop  | Sampling stage                       | Sampling organ                                | Sample size<br>(No. Of leaves or plants) |
|---|--------------------------------------|---|--|
| ALFALFA<br>( <i>Medicago sativa</i> )                           | Before budding                       | Upper part of the plant (15 cm top to bottom) | 40-50 plants                             |
| P E A N U T<br>( <i>Arachis hypogaea</i> )                      | Seedling                             | Aerial parts                                  | 15-20 plants                             |
|   | Start of fruit forming               | MRM trifolium with petiole                    | 20-30                                    |
| BEAN<br>( <i>Phaseolus vulgaris</i> )                           | Seedling                             | All aerial parts                              | 20-30 plants                             |
|   | Beginning of Booting                 | MRML, with petioles                           | 20-30 leaves                             |
| SMALL GRAINS<br>(Barley, Oats, Rye, Wheat)                      | From seedling to tillering           | Aerial parts                                  | 15-20 plants                             |
|   | Maturity of the last leaf at booting | MRML with last leaf at booting                | 30-40                                    |
| CORN<br>( <i>Zea mays</i> )                                     | Seedling (> 30 cm- high)             | Aerial parts                                  | 15-20 plants                             |
|   | Vegetative (prior to heading)        | MRML (as of the point of growth)              |  |
|   | Heading (male flowering)             | First leaf bellow tender cob                  | 20-30 leaves                             |
|   | Prior to maturity                    | Leaf below the cob                            |  |
| GRAIN SORGHUM<br>( <i>Sorghum vulgare</i> y <i>S. bicolor</i> ) | Seedling < 30 cm-high                | Aerial parts                                  |  |
|   | Vegetative growth bellow tassel      | Fully developed leaf below the tassel         |  |
|   | Flowering or Tasseling               | Second upper leaf                             | 30-40                                    |
|   | Grain booting                        | Second upper leaf                             |  |
| SOYBEAN<br>( <i>Glycine max</i> )                               | Seedling                             | All the aerial parts                          | 20-30 plants                             |
|   | Beginning of booting                 | MRML, with petioles                           | 20-30 leaves                             |
| WHEAT<br>( <i>Triticum aestivum</i> ) winter                    | Before heading                       | MRML  | 50-70                                    |
| WHEAT<br>( <i>Triticum aestivum</i> ) spring                    | Ear emergence                        | MRML  | 50-70                                    |

MRML: Most recently mature leaf; DS: days after planting. DS:

DAT: Days after transplanting

DAE: Days after emergence

**Table 3.** Foliar sampling guidelines for horticultural crops

| Crop  | Sampling stage   | Days        | Sampling organ         | Sample size                                   |
|---|--|-------------|------------------------|---|
| GARLIC<br>( <i>Allium sativum</i> )                           | Seedling   | <30 DDS     | Aerial parts           | 30-50 plants                                  |
|   | V4   | 30-45 DDS   | MRML                   | 15-20 leaves                                  |
|   | V5   | 46-60 DDS   |                        |   |
|   | V6 y V7  | 61-80 DDS   |                        |   |
|   | V8 y V9  | 81-100 DDS  |                        |   |
|   | V10 Internodes elongation. Beginning of head's differentiation | 101-115 DDS |                        |   |
|   | V13 End of head's differentiation                              | 116-130 DDS |                        |   |
| V14 y V15 Bulb's booting. Maximum growth                      | 131-150 DDS  |             |                        |   |
| CELERY<br>( <i>Apium graveolens</i> var. dulce Mill.)         | Seedling   | <20 DAT     | Aerial parts           | 15-20   |
|   | 7 leaves   | 20-40 DAT   | MRML + Petiole         | 15-20 Leaves + petioles                       |
|   | 9 leaves   | 41-60 DAT   |                        |   |
|   | 10 leaves  | 61-80 DAT   |                        |   |
|   | 11-14 leaves   | 81-100 DAT  |                        |   |
|   |  | 101-120 DAT |                        |   |
|   |  |             |                        |   |
| EGGPLANT<br>( <i>Solanum melongena</i> )                      | Seedling   |             | Aerial parts           | 20-25 plants                                  |
|   | From vegetative stage to blossoming                            |             | MRML of the main stalk | 25-30 leaves<br>30-40 leaves in a small plant |
| BROCCOLI<br>( <i>Brassica olerace</i> var. <i>botrytisa</i> ) | 4-6 leaves   | 25-35 DAT   | MRML                   | 10-15 leaves                                  |
|   | 7-12 leaves  | 37-52 DAT   |                        |   |
|   | Beginning of budding   | 55-65 DAT   |                        |   |
|   | Floret development   | 70-75 DAT   |                        |   |
|   | Pre-harvest  | 80-85 DAT   |                        |   |
| ONION<br>( <i>Allium cepa</i> )                               | <3 leaves  | <30 DAT     | Aerial parts           | 30-50 plants                                  |
|   | 3-4 leaves   | 30-50 DAT   | MRML                   | 20-25 leaves                                  |
|   | 5-6 leaves   | 50-70 DAT   |                        |   |
|   | 7 leaves   | 70-90 DAT   |                        |   |
|   | 10 leaves  | 90-110 DAT  |                        |   |
|   |  | 110-130 DAT |                        |   |
|   |  | 130-150 DAT |                        |   |
|   |  |             |                        |   |
| CABBAGE<br>( <i>B. o.</i> var. <i>capitata</i> )              | Vegetative seedling  |             | Aerial parts<br>MRML   | 10-15 leaves                                  |
| COLIFLOWER<br>( <i>Brassica oleracea</i> )                    | Budding  |             | MRML                   | 10-15 Leaves                                  |
|   | Floret development   |             |                        |   |
| CHILI ANCHO<br>( <i>Capsicum</i> spp.)                        | Pre-flowering  | 25-40 DAT   | MRML                   | 40-50 leaves                                  |
|   | Flowering  | 41-50 DAT   |                        |   |
|   | Setting  | 60-75 DAT   |                        |   |
|   | Pre-harvest  | 80-90 DAT   |                        |   |
|   | Beginning of harvest   | 90-100 DAT  |                        |   |
|   | During Harvest   | 120-150 DAT |                        |   |
| BELL PEPPER<br>( <i>Capsicum annuum</i> )                     | Pre-flowering  |             | MRML                   | 30-40 leaves                                  |
|   | Beginning of flowering   |             |                        |   |
|   | Fruit setting  |             |                        |   |
|   | Pre-harvest  |             |                        |   |

Continue...

| Crop  | Sampling stage                                      | Days      | Sampling organ                           | Sampling size |
|---|---|-----------|--|---------------|
| ASPARAGUS ( <i>Asparagus officinalis</i> )                          | July<br>August- September                           |           | Upper part of the plant at 50 cm         | 20-25 leaves  |
| SPINACH (field)<br>( <i>Spinacia oleracea</i> )                     | 30-50 days to Ripening                              |           | MRML                                     | 35-40 leaves  |
| SPINACH (greenhouse)  | All of them   |           |  |               |
|   | Vegetative  | 0-40 DAT  |  |               |
| TOMATO (field)<br>( <i>Lycopersicon</i> spp.)                       | Beginning of flowering                              | 41-50 DAT | MRML                                     | 20-25 leaves  |
|   | Flowering-setting                                   | 51-70 DAT |  |               |
|   | Fruit development                                   | 71-90 DAT |  |               |
|   | First cut   | > 90 DAT  |  |               |
| TOMATO (greenhouse)   | Vegetative  | 0-30 DAT  | MRML                                     | 20-25 leaves  |
|   | Reproductive  | 30-90 DAT |  |               |
|   | Production  | > 90 DAT  |  |               |
|   | 7 leaves  | 24 DAT    | Wrapping leaf                            | 25-35 leaves  |
| LETTUCE (field)<br>( <i>Lactuca sativa</i> )                        | 9 leaves  | 33 DAT    |  |               |
|   | Beginning of head development                       | 39 DAT    |  |               |
|   | Head development                                    | 47 DAT    |  |               |
| LETTUCE (greenhouse)  | Head development                                    | 54 DAT    | Wrapping leaf                            | 25-30 leaves  |
|   | General   |           |  |               |
|   |   |           | Aerial parts                             | 15-20 plants  |
| SWEET CORN<br>( <i>Zea mays</i> )                                   | Seedling (> 30 high)                                |           | MRML                                     | 20-30 leaves  |
|   | Before tassel formation                             |           |  |               |
|   | Beginning of ear development to grain booting (ear) |           | Leaf below the ear                       |               |
|   | 30 cm-long shoots                                   |           | MRML                                     | 20-30 leaves  |
| MUSKMELON<br>( <i>Cucumis melo</i> , Reticulatus Group or Honeydew) | Fruit forming                                       |           |  |               |
|   | Pre-harvest   |           |  |               |
|   | Vegetative growth                                   | 0-15 DAE  | MRML                                     | 20-25 leaves  |
| POTATO<br>( <i>Solanum tuberosum</i> )                              | Tuber development                                   | 16-30 DAE |  |               |
|   | Initial tuber booting                               | 31-45 DAE |  |               |
|   | Final tuber booting                                 | 46-54 DAE |  |               |
|   | Final tuber footing and ripening                    | 55-70 DAE |  |               |
| CUCUMBER (field)<br>( <i>Cucumis sativus</i> )                      | Beginning of flowering to small size fruits         |           | 5 <sup>a</sup> leaf of the growing point | 20-30 leaves  |
|   | Small size fruits to harvest                        |           |  |               |
| CUCUMBER (invernadero)  | General   |           | MRML                                     | 20-30 Leaves  |
| HOT RADDISH<br>( <i>Amoracia rusticana</i> L.)                      | General   |           | MRML                                     | 40-50 Leaves  |
| RADDISH<br>( <i>Raphanus sativus</i> L.)                            | General   |           | MRML                                     | 40-50 leaves  |

In fruit crops it is important to sample every side of the trees. Choose a specific area of the orchard with similar conditions (soil, species, trees' age) and pick 20 trees in zigzag. The number of sample leaves will depend on the species, taken from the East, North, West and South. In fenced orchards and vineyards where it is not easy to crossover rows, it is better to sample in transects, either in U or M shapes, traced along the crop. Samples are taken at specific intervals, along each space between rows, alternating from left to right.

**Table 4.** Foliar sampling guidelines in fruit crops

| Crop   | Sampling stage   | Sampling organ   | Sample size (Leaf number) |
|--|--|--|---------------------------|
| AVOCADO<br>( <i>Persea americana</i> )               | Vegetative branches (5-7 months after flowering)                       | Leaves from the center of the terminal bud without fruiting              | 30-50                     |
| PRUNE ( <i>Prunus domestica</i> )                    | Mid summer   | Whole leaves   | 50-70                     |
| ORANGE<br>( <i>Citrus sinensis</i> )                 | 5-7 month branch   | MRML behind fruits   | 30-40                     |
|  | Flowering  | MRML behind fruits   |                           |
| GRAPE FRUIT<br>( <i>Citrus paradisi</i> )            | General  | MRML in fruitless branches   | 30-40                     |
|  | 5-7 months   | MRML behind fruits   |                           |
| MANDARIN<br>( <i>Citrus reticulata</i> )             | General  | MRML   | 30-40                     |
| LIME<br>( <i>Citrus limon</i> )                      | 5-7 months   | MRML in fruitless branches   | 30-40                     |
| PERSIAN LIME<br>( <i>Citrus aurantifolia</i> Tahiti) | General  | MRML   | 30-40                     |
| PEACH<br>( <i>Prunus persica</i> )                   | Mid summer   | Leaves from the center of fruitless shoots                               | 50-70                     |
| FIG ( <i>Ficus carica</i> )                          | July-August  | MRML   | 20-30                     |
| STRAWBERRY ( <i>Fragaria</i> sp.)                    | All  | MRML Trifolium   | 20-30                     |
| PECAN TREE<br>( <i>Carya illinoensis</i> )           | 15-31 June (60-65 days after flowering)                                | Couple of opposite foliols in leaves from the center of the terminal bud | 20-30                     |
| MANGO<br>( <i>Mangifera indica</i> )                 | Last vegetative shoot of 4-7 months before blossoming                  | Leaves from the basal area of the shoot                                  | 20-30                     |
| APPLE TREE<br>( <i>Malus</i> spp.)                   | 8-10 weeks after budding   | MRML   | 20-30                     |
| PAPAYA<br>( <i>Carica papaya</i> )                   | Between 3-4 months after transplanting (fruiting stage)                | Petioles of young fully extended leaves with recently opened flowers     | 30-40                     |
| PEAR<br>( <i>Pyrus communis</i> )                    | Mid summer   | MRML in shoot center   | 50-70                     |
| PINEAPPLE ( <i>Ananas comosus</i> )                  | Beginning of flowering   | MRML without white base  | 30-45                     |
| BANANA ( <i>Musa</i> sp.)                            | Plants about to blossom (fruit bearing) or recently emerged from bunch | Central blade of leaf number 3, from top to bottom                       | 10-20                     |
| GRAPE<br>( <i>Vitis rotundifolia</i> )               | Mid summer or after summer, before fruit booting                       | MRML next to the fruit bunch   | 50-70                     |
| GRAPE<br>( <i>Vitis labrusca</i> e <i>hybrids</i> )  | Budding  | Petioles   | 70-90                     |
| GRAPE<br>( <i>Vitis vinifera</i> )                   | June-July  | Full leaves  | 50-70                     |
|  | Full budding   | Petioles   | 70-90                     |

**Table 5.** Foliar sampling guidelines for other crops

| Crop   | Sampling stage                         | Sampling organ   | Sample size  |
|--|--|--|--------------|
| COFFEE<br>( <i>Coffea arabica</i> )            | General                                | Leaves in fruitless branches   | 40-50 leaves |
|  | Beginning of flowering in mature trees | Leaves in branches with fruits in the upper part of the tree   | 40-50 leaves |
| COFFEE<br>( <i>Coffea caephora</i> )           | Beginning in flowering in mature trees | Leaves in branches with fruits in the upper part of the tree   | 40-50 leaves |
| CACAO ( <i>Theobroma cacao</i> )               | 4 to 8 weeks after peak flowering      | 2 <sup>nd</sup> and 3 <sup>rd</sup> fully green leaves with incipient shoots   | 20-25 leaves |
| SUGAR CANE<br>( <i>Saccharum officinarum</i> ) | Up to four months of age               | 3 <sup>rd</sup> or 4 <sup>th</sup> fully developed leaf, from the upper part of the plant, at 20 cm from the center of the leaf, without central veins | 15-25 leaves |

**Sample size.** The final quantity of the laboratory sample must always exceed 50 g, once dried and ground. In the case of small size plants, the number of plants or leaves to be sampled must be higher than the number described hereunder. A sample must represent the existing open-field or greenhouse conditions, through randomized sampling throughout the field, avoiding the edges.

### Sampling and laboratory sample preparation

- Laboratory samples must represent the existing field or greenhouse plant populations.
- Sampled tissues must be of the same age, position and origin, as well as of the same type of growth.
- Physical samples must be immediately taken to the lab to be washed, before drying.
- If samples are going to be sent through parcel delivery services and shipping will take several days, wash them immediately after taking them, in particular if foliar fertilizer or chemicals containing any of the tested elements were applied.
- Samples should be washed with a phosphate<sup>1</sup>-free detergent, at 2%. Rinse the samples for 5 to 10 seconds and take them to a container with clean water to wash off the detergent during 5 seconds. If several samples are involved, it is necessary to prepare a third container to rinse the samples twice, for no more than 5 to 10 seconds. We recommend using bottled water, because it is low in salt. Drain the samples and remove the excess of water with paper towel to avoid decay during transportation. Let the samples dry out for a short while, before putting them inside a paper bag (avoid plastic bags). If samples include succulent leaves and shipping will take several days, it is better to dehydrate them before transportation.



**Figure 4.** Sampling of the most recently mature, fully extended tomato leaf

### Sample identification

Samples must contain the following information:

- Name and address of the sender, telephone, fax and e-mail, if possible, as well as billing information.
- Crop, phenological stage and crop's age at the sampling time.

<sup>1</sup>Hycel de México S.A. de C.V. Tel. 5552080026 e-mail: asesoria\_df@hycel.com.mx

- c. Sampled organ: whole leaf, petiole, etc.
- d. Field sector, table and farm or property. Identify each sample with a number and write down the total number of samples; for instance, “sample number 5 out of 12”. It is also important to keep the list of samples that were sent to the lab. Use a permanent ink marker.

## Water sampling

Water samples from wells, springs or rainfall should be of at least 250 to 500 ml, to facilitate shipping. Samples must be homogenous and representative of the water source that we want to analyze. In the case of well water, samples must be taken directly, after having the well working for at least half an hour. Do not use stagnated water.

Samples are kept in clean bottles without chlorine and other chemical residues, to avoid cross-contamination. We recommend rinsing the bottles several times with the water to be sampled. Bottles must be filled in completely and be closed, trying to leave as little air, as possible inside. To prevent variability of physical-chemical properties of the samples, they have to be shipped to the lab as soon as possible. Every sample must have an identification label on the shipping bag or box.

### Sample identification

Samples must include the following data:

- a. Name and address of the sender, telephone, fax and e-mail, as well as billing information.
- b. Farm or property, type of water (spring, well, rainfall), water temperature, well's depth.

## Where can you send the sample?

We recommend sending the sample to **Fertilab**, a laboratory specialized in soil, plant, water, nutrient solution and horticultural substrates analysis, located in Central Mexico with capacity to offer RELIABLE, fast and efficient domestic and international services.

### Our mission

Providing timely, high-quality soil, plant, water and substrate analysis, focused on increasing agricultural yield and field productivity throughout Mexico.

### Our Vision

Becoming a leader in Mexico in agricultural field analysis, constantly improving our quality and services to meet customer needs.

### Which services do we offer?

- a. Soil analysis
- b. Water analysis
- c. Plant analysis
- d. Saturation paste analysis



- e. Drip and drainage solution analysis
- f. Horticultural substrate analysis
- g. Compost

### Delivery terms

- a. Plant and soil analysis: 5 working days.
- b. Water and nutrient solution: 72 hours
- c. Substrates: 10 working days

### Analytical methodology

#### a. *Soil*

- pH, 1:2 in water and total carbonates
- Organic matter: Walkley and Black
- Exchange cations Ca, Mg, Na, K: Ammonium acetate
- Al, H and pH Buffer in acid soils, SMP single buffer
- Available phosphorous: Olsen or Bray, depending on the soil
- Fe, Mn, Cu, Zn: DTPA extraction method
- Boron: hot water
- Salinity in paste extract
- Texture
- Munsell color

#### b. *Plant*

N, P, K, Ca, Mg, Fe, Cu, Zn, Mn, B.

#### c. *Water*

CE, pH, Ca, Mg, Na, K, Cl, HCO<sub>3</sub>, CO<sub>3</sub>, SO<sub>4</sub>, B.

#### d. *Nutrient solution and greenhouse drainage*

CE, pH, Ca, Mg, Na, K, Cl, NO<sub>3</sub>, HCO<sub>3</sub>, CO<sub>3</sub>, SO<sub>4</sub>, H<sub>2</sub>PO<sub>4</sub>, Fe, Mn, Zn, Cu, B.

#### e. *Substrate*

Water release curve by De Boodt, granulometry, water holding capacity, aeration capacity, bulk density, real density

## Reporting system

Our reporting system is quite clear, showing the nutrient's level that can be interpreted in a color-coded chart, to make it clearer.

## Experience

Our lab has a great sense of professionalism, with highly trained staff, specialized in analytical methods, agronomy, and several years of experience in the field, providing consultancy services in CHEMICAL ANALYSIS APPLIED TO AGRICULTURE, soil fertility and plant nutrition.

## Quality control

Our stringent quality control system is translated into our slogan: *"Perfection in Analytical Quality"*. We are active participants of inter-comparison domestic and international programs, to ensure the analytical quality of our lab. This is the way in which we reinforce our reliability on verified analytical results with the least number of errors.

## Available equipment

Atomic absorption, spectrophotometer, distilling units, ion analyzers and everything that is needed to provide high quality services.

## Fertilab's location



### Address:

Pablo A. de la Garza # 109-A  
Frac. Siglo XXI  
CP 38024  
Celaya, Guanajuato  
México

Between Eje Norponiente and Celaya's General Hospital, half a block away from the hospital.

Tel. and Fax (461) 614 5238, 614 7951

Email: [fertilab@fertilab.com.mx](mailto:fertilab@fertilab.com.mx)

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**Laboratorio de Suelos, Plantas, Aguas y Sustratos**