RESEARCH AND BREEDING INSTITUTE OF POMOLOGY HOLOVOUSY s.r.o.

# Technical documentation for HOL-DRIS software

Ing. Martin Mészáros, Ph.D.



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**Authors’ team:**

Research and Breeding Institute of Pomology Holovousy s.r.o.

Ing. Martin Mészáros, Ph.D.

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Contact to the head of the author's team: martin.meszaros@vsuo.cz

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## Description of the HOL-DRIS apple tree nutritional diagnostics software

### *Basic information concerning the software*

The software is designed to assess the nutritional status of samples using the DRIS method. The purpose of the software is to diagnose the nutritional status of the apple plantation under evaluation, based on the input data from the analyzed leaf samples. The data for specific nutrients are entered in a row labelled 'Sample' and must be entered in the specified order (Figure 1). The macronutrient content is given in g.kg$^{-1}$ (value in % dry matter * 10) in the dry matter of the sample and the micronutrient content in mg.kg$^{-1}$. Next to the cells for recording the values of each nutrient, the phenological stage should be indicated at which the sample was taken. The choices are BBCH 72, 74, and 77. Using a programmed algorithm, the sample is compared with reference values for optimum nutrient content or ratio and DRIS indices are calculated simultaneously.

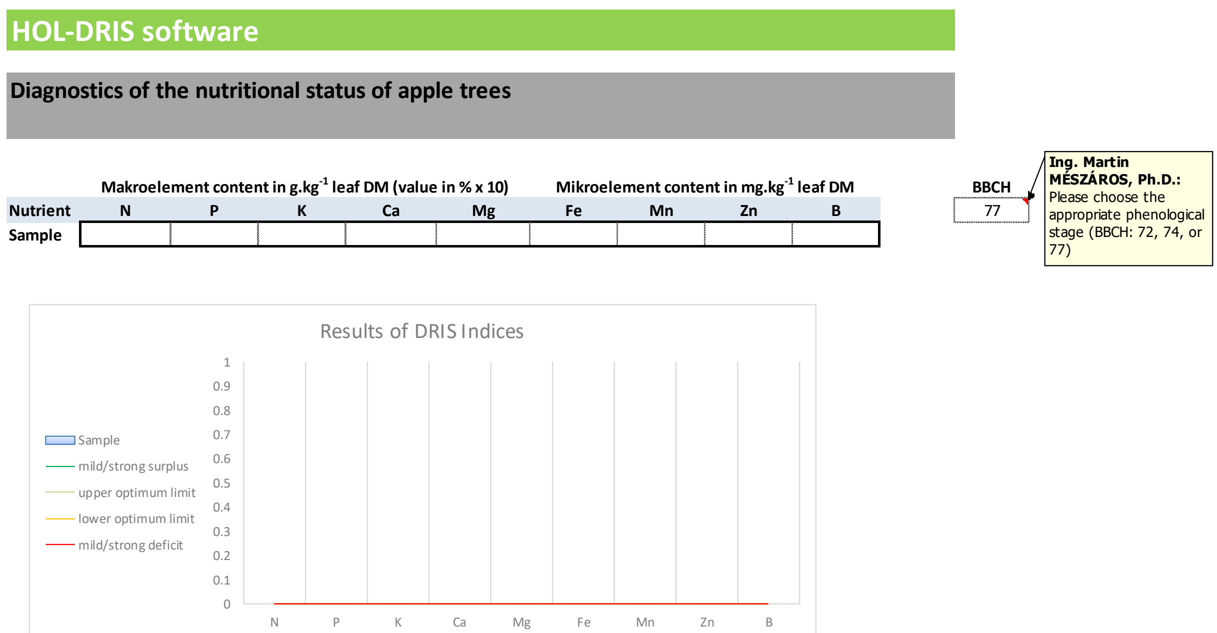


Figure 1: Display of the cells used for inputting the nutrient content values of the sample and the corresponding phenological phase BBCH.

### *Preparation of DRIS standards*

The results of leaf analyses from apple orchards of the variety 'Golden Delicious' entering full fruiting, grown in the region of eastern Bohemia, were used to create DRIS standards. The basic database was created from 162 analyzed samples collected at phenological stages BBCH 72, 74, and 77 in 2015-2017 and includes nutrient contents of N, P, K, Ca, Mg, Fe, Mn, Zn, and B. The average yield per tree was assessed for each sample. Plantations with yields exceeding 60 t/ha were selected to establish a reference population. The relationship of nutritional status to yield of the apple tree populations evaluated in each year was verified by correlating NBIa with yield (r value = 0.72***). Table 1 shows the optimum values of nutrient content in dry leaf matter of apple trees at the phenological stages BBCH 72, 74, and 77 used as reference in the program.

Table 1: Optimum leaf dry matter nutrient content of apple trees at phenological stages BBCH 72, 74, and 77 for reference.

| **BBCH** | **Macronutrient content in g.kg$^{-1}$ dry matter** | | | | | **Micronutrient content in mg.kg$^{-1}$ dry matter** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | Fe | Mn | Zn | B |
| **72** | 25.0 | 2.5 | 16.0 | 16.5 | 3.0 | 75.0 | 60.0 | 30.0 | 33.0 |
| **74** | 24.5 | 2.3 | 15.0 | 18.0 | 3.1 | 85.0 | 70.0 | 28.0 | 30.0 |
| **77** | 24.0 | 2.2 | 14.0 | 20.0 | 3.2 | 100.0 | 80.0 | 25.0 | 28.0 |

***Programming algorithm***

From the database for the reference population, the averages of the dual and inverse ratios of all the nutrients evaluated were generated and the corresponding coefficient of variation was calculated. These averages form the norm for the purpose of subsequent evaluation of the samples. The input data of the diagnosed sample are processed in a similar way, where the nutrient content values are converted to dual ratios. The choice of dual (A/B) or inverse (B/A) nutrient ratios is made on the basis of their correlation with apple yield. Thus, the dual ratio with the higher value of the correlation coefficient R was selected and used for further calculation. Once the norm is established, the DRIS indices for each nutrient are calculated as follows, where first the function for each dual nutrient ratio is calculated according to the following formula:

$$f(A/B) = (A/B - 1)\ 1000\ /\ a/b\ CV;\ if\ A/B \geq a/b$$

or:

$$f(A/B) = (1 - a/b)\ 1000\ /\ A/B\ CV;\ if\ A/B < a/b$$

Where:

A/B is the dual nutrient ratio in the sample being analyzed

a/b is the optimal dual nutrient ratio in the standard

CV is the coefficient of variation associated with the given dual ratio in the standard

These functions are then summed and divided by the number of functions in the index according to the formula:

$$Index\ A = \frac{[f(A/B) + f(A/C) + f(A/D) \ldots + f(A/N)]}{n}$$

$$Index\ B = \frac{[-f(A/B) + f(B/C) + f(B/D)\ldots + f(B/N)]}{n}$$

$$Index\ N = \frac{[-f(A/N) - f(B/N) - f(C/N)\ldots - f(M/N)]}{n}$$

Each index thus represents the average of the functions containing the given nutrient. The CV used in each function of the index represents the relative importance of each function in the index in relation to fruit tree productivity. In the case of the use of an inverse ratio of nutrients, the sign of the function of the respective ratio is reversed. From the sum of the absolute values of all the calculated DRIS indices, the so-called Nutritional Balance Index is calculated, which is used to evaluate the relative ratio of nutrients, or their deviation from the optimum. From this, the calculated average NBIa is used for data interpretation.

### *Interpretation of DRIS indices*

After inputting the nutrient content and phenological stage of the corresponding sample, the DRIS indices are automatically calculated by the program. The output is a graphical representation of the DRIS indices for each nutrient (Figure 2).

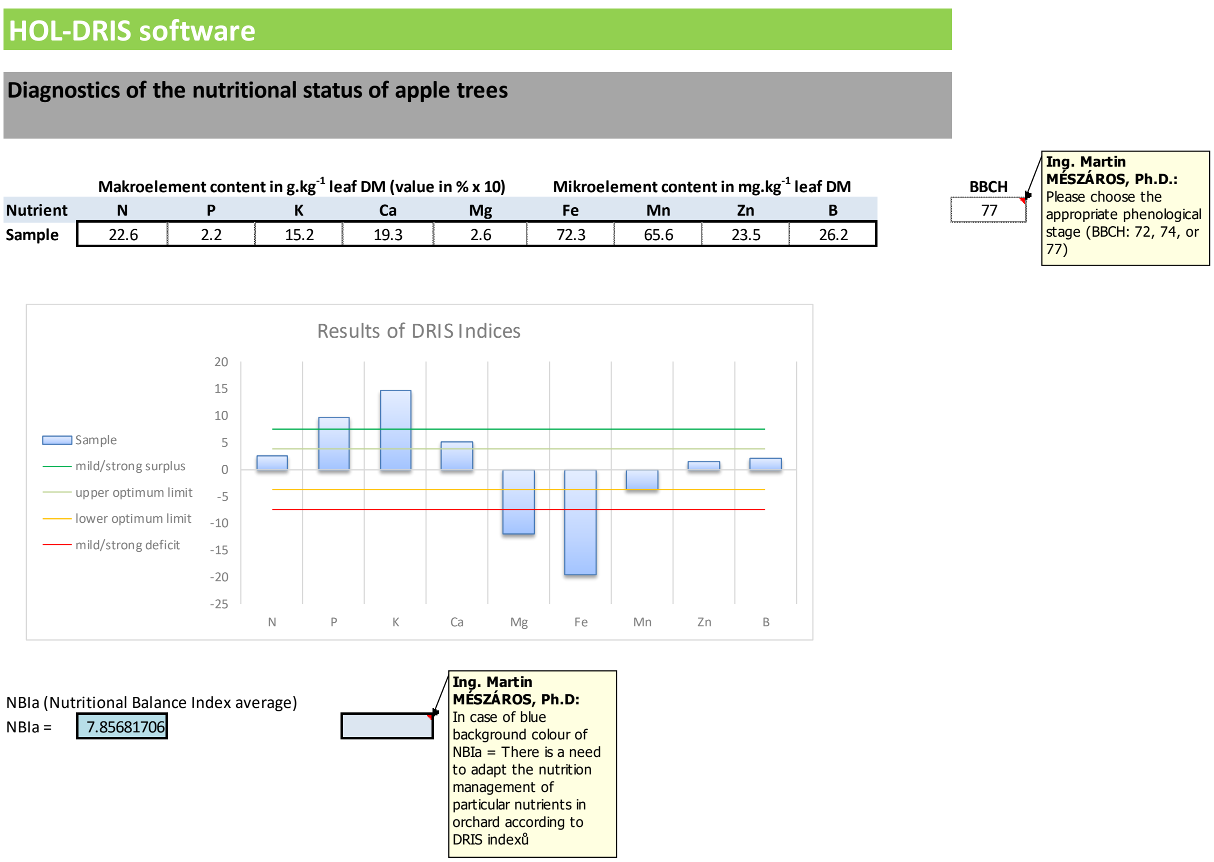


Figure 2: Graphical representation of the DRIS indices including the limits of the optimal, deficient and luxury content of each nutrient in the sample.

From the chart, the relative abundance of each nutrient compared to the others can be read off, thus determining the order of nutrients from the most deficient nutrient to the elements most exceeding the optimal ratios. The chart also shows the critical limits of the optimal nutrient content as well as the limits for distinguishing a moderate or significant deficiency or excess of a particular nutrient. These thresholds are proposed based on the assumption that nutrient content becomes imbalanced when NBIa is above 1.50 and becomes severely imbalanced when NBIa is above 3.00. The following relationship is used to calculate these thresholds (positive and negative):

$$MAX\ |Index\ A|\ 1.5\ /\ NBIa$$

for the lower and upper bounds of the optimum with a slight deficit and surplus, respectively:

$$MAX\ |Index\ A|\ 3\ /\ NBIa$$

for the lower and upper bounds of moderate and significant deficit and surplus, where 'MAX |Index A|' represents the DRIS index with the highest absolute value. Given the linear relationship between the DRIS index and NBIa = 4,5:1, it is thus possible to maintain the same level of the indicated optimum or deficit/surplus thresholds weighted by the specific value of the common index NBIa, irrespective of the number of DRIS indices deviating from the optimum.

Note: If the nutrients are in the optimum representation (as shown in Table 2) in the sample being evaluated or if any of the nutrients are not present in the sample, all DRIS index and critical values will be zero in the graph.

The detailed interpretation of the results is described in the methodology for the use of the program entitled 'Diagnosis of the nutritional status of apple trees using DRIS'.