# Plant Nutrition Fertility Scheme in organic farming systems: Apples and Barley

**ORGANIKO LIFE+ PROJECT**

*Revamping organic farming and its products in the context of climate change mitigation strategies*

*Type of deliverable: Report*

*Action C1*

*Partner: Agricultural Research Institute*

*Author: Michalis Omirou*

*Contributors: Damianos Neocleous, Dionysia Fasoula, Panagiotis Dalias, Andreas Stylianou, Soteroula Ioannidou, Ioannis M. Ioannides*

# Executive summary


## Σκοπός

Στόχος του παραδοτέου είναι να δώσει λεπτομερείς πληροφορίες για τη διαχείριση της θρέψης των μήλων και του κριθαριού στο σύστημα της βιολογικής γεωργία και να παρουσιάση ένα οδηγό για τη θρέψη των φυτών στα πλαίσια της δράσης C1. Τα παραδοτέα "Review report of Plant Nutrition Fertility Scheme" και "Plant Nutrition manual for each crop" συνενώθηκαν για σκοπούς συνοχής.

## Αντίκτυπος

Για την επαρκή και ποιοτική παραγωγή βιολογικών προϊόντων στο κριθάρι και στα μήλα, η διαχείριση της θρέψης αποτελεί τον σημαντικότερο συντελεστή παραγωγής. Ειδικότερα στην έκθεση περιλαμβάνονται λεπτομέρειες που αφορούν την φυλλοδιαγνωστική, τις εισροές θρεπτικών στοιχείων στο σύστημα από οργανικές πηγές, σειρά από πρακτικές που αφορούν τη διαχείριση της θρέψης τόσο στο κριθάρι όσο και στα μήλα. Τέλος παρουσιάζονται απλά βήματα που πρέπει να ακολουθεί ο βιοκαλλιεργητής στις συνθήκες της Κύπρου για την ορθολογική θρέψη των φυτών.

## Αποτελέσματα

Η ανασκόπηση των πρακτικών οι οποίες εφαρμόζονται στη βιολογική γεωργία, για τη θρέψη των φυτών είχε ως αποτέλεσμα τη δημιουργία ενός πίνακα που παρουσιάζει το εύρος των τιμών έλλειψης των κυριοτέρων θρεπτικών στοιχείων για τις δυο καλλιέργειες. Παρουσιαστηκαν με μεγάλη λεπτομέρεια εξισώσεις υπολογισμού της χρήσης N για την παραγωγή συγκεκριμένης παραγωγής. Επιπρόσθετα από τα αποτελέσματα φαίνεται ότι για την αποθήκευση άνθρακα στο έδαφος η διαχείριση των υπολειμμάτων της καλλιέργειας είναι ιδιαίτερα σημαντική.

## Συμπεράσματα

Αυξημένη γνώση των βιοκαλλιεργητών σε θέματα απομάκρυνσης των θρεπτικών στοιχείων θα βοηθήσει σημαντικά στον καθορισμό στρατηγικών πιο ορθολογικής θρέψης στο σύστημα της βιολογικής γεωργίας τόσο στο κριθάρι όσο και στα μήλα με στόχο τη μείωση των εκπομπών αερίων του θερμοκηπίου.

# Executive summary

## Purpose

The aim of this report is to provide detail information for plant nutrition in barley and apples grown under organic farming schemes. In particular, "Review report of Plant Nutrition Fertility Scheme" και "Plant Nutrition manual for each crop" have been brought together for consistency purposes

## Outcome

For a sufficient production of high-quality organic products in barley and apples, nutrient management is the most important factor. This report includes details of plant analysis, the input of nutrients derived from organic resources into the system, a range of practices on plant nutrient management schemes in both barley and apples. Finally, we present a plant nutrition manual in the form of simple steps to be taken by the organic grower under the climatic conditions of Cyprus for the reasonable plant nutrition of both crops..

## Results

The review of organic farming practices for plant nutrition has resulted in a table showing the concentration range for the optimum nutrient content of the main nutrients both for barley and apples after plant analysis. Crop rotations and apple orchards floor management are fundamental to design a sustainable nutrient management scheme. We presented in detail equations for calculating the use of N as a manual for plant nutrition both in barley and apples. Also, it seems that to sequestrate carbon into the soil crop residues management is of particular importance.

## Conclusion

Increased knowledge of organic farmers regarding the nutrient budget in the system is expected to reduce organic inputs and subsequently GHG emissions. Nutrient management practices should be designed to maximize C inputs and to maintain and promote sustainability in soils.

## Πίνακας Περιεχομένων

## Introduction

In organic apple and barley production nutrient management is of prime importance because it determines plant productivity and the quality of the products. In this report we present the nutrient requirements of apple fruits and barley, the tools that are currently available to investigate the nutrient status of the crop, the inputs that are available for use in order to satisfy the needs of the crop and finally specific management practices that should be followed by the farmers in order to improve the current practices.

## Plant Analysis

The diagnosis of nutrient deficiencies or excess in deciduous trees and particularly in stone fruits like apples and pears can be performed through plant analysis. The presence of a deficiency of a nutrient using this method is based on its critical concentration within plant at a specific growth stage. Particularly the critical concentration is defined as the concentration of a nutrient in plants that results in 90% of maximum yield or growth of the crop that is of interest. Plant leaves are usually the most appropriate part of plants that can be used to determine the nutrition status of the crop.

The concentration of nutrients in plant leaves depends on several abiotic and biotic factors. For example plant age, leaf position, growth stage, pest and diseases are crucial biotic factors controlling plant nutrition and the accumulation of nutrients in plant leaves. Abiotic factors such as temperature, soil moisture, pH, light intensity, precipitation and RH are affecting nutrients concentration in plant leaves. Cultural practices such as pruning, soil cultivation, orchards floor management and organic inputs are also affecting the concentration of nutrients in plant leaves.

During the growing period the fluctuation of plant nutrients concentration are observed and this is related to the growth stage of the trees (bloom, fruit set, fruit fill and maturity). The change of nutrient levels is attributed to their translocation within different plant organs in order to satisfy the increased needs at a specific time. Plant analysis will therefore reveal hidden nutrient stresses, will confirm visual deficiency symptoms, and test the effectiveness of nutrient management scheme. The use of plant analysis results as a guide will also provide significant and important information regarding yields and quality issues of the crop especially in organic farming systems. Therefore sampling of plant leaves of specific growth stage and time is important in order to have the most accurate estimation of crop nutritional condition.

Under Cyprus conditions, for apples the youngest fully mature leaf including the petiole is sampled from mid-shoots of the current season, are taken between late June and late July (4 to 8 weeks after bloom) depending on the area and the cultivar. Totally 30 to 40 leaves are sufficient to assess the nutrient condition of an apple cultivar. The amount of macronutrients and some micronutrients in apple leaves are presented in the following table:

Table 1. Nutrient limits in apple leaves depicting nutrient statues of the trees.

| Nutrient | Excess | Adequate | Low | Deficient |
|---|---|---|---|---|
| **Nitrogen (%)** | >3 | 2.0 – 2.4 | 1.6 – 1.9 | < 1.6 |
| **Phosphorus (%)** | > 0.30 | 0.15 – 0.20 | 0.10 – 0.14 | < 0.10 |
| **Potassium (%)** | > 2 | 1.1 – 1.5 | 0.8 – 1.0 | < 0.8 |
| **Calcium (%)** | > 2.5 | 1.1 – 2.0 | 0.7 – 1.0 | < 0.7 |
| **Magnesium (%)** | > 0.50 | 0.25 – 0.35 | 0.18 – 0.24 | < 0.18 |
| **Zinc (ppm)** | > 50 | 16 – 50 | 10 - 15 | < 10 |
| **Manganese (ppm)** | > 200 | 25 - 100 | 20 - 24 | < 20 |
| **Boron (ppm)** | > 200 | 20 – 60 | 15 – 19 | < 15 |

For barley, samples can be taken during feekes stages 3 to 9 and the entire above ground portion of plant is sampled. Totally 30 to 40 plants are sufficient depending on the size. The critical levels of nutrients for barley are presented in the following table:

Table 2. Critical nutrient levels for barley

| N (%) | P (%) | K (%) | S (%) | Ca (%) | Mg (%) | Fe (ppm) |
|---|---|---|---|---|---|---|
| 3 | 0.15 | 2 | 0.10 | 0.15 | 0.10 | 25 |

A drawback of plant analysis for barley is the fact that the results are less reliable as crop approaches maturity. Besides nitrogen, for barley it is extremely important to maintain N/S ratio between 10 and 15 in order to have optimum yields. Ratio of N/S greater than or equal to 20 indicate that sulfur is limiting in relation to nitrogen causing significant disorders resulting to yield decrease and loss of quality.

## Organic inputs for nutrient management

In organic farming, closed cycles using internal resources and inputs are preferred to open cycles based on external resources. If the latter are used, they should be organic materials from other organic farms natural substances materials obtained naturally, or mineral fertilizers with low solubility. Exceptionally, however, synthetic resources and inputs may be permissible if

**Figure 1.** Composting facilities at ARI

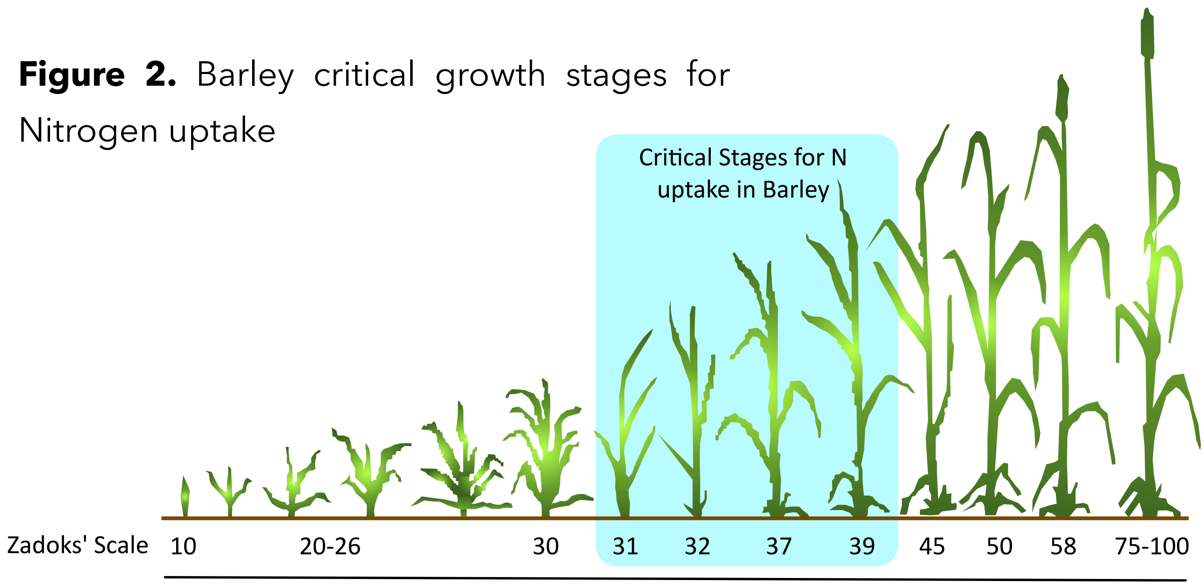
there are no suitable alternatives. Such products, which must be scrutinized by the Commission and EU countries before authorization, are listed in the annexes to the implementing regulation (Commission Regulation (EC) No. 889/2008).

In Cyprus the most regularly used organic inputs are commercial composts and farmyard manures while lately an increase of humic substances and biofertilizers as well as biostimulants was noticed. Composting of pruning material is not a practice that is systematically performed. This is a major drawback for the system because the nutrients present in the pruning material are excluded from the nutrient balance of the crop. In addition, in an environmental point of view, the carbon that is removed from the crop never returns to the system and a sequestration potential is lost. At ARI a drum composting system was developed and plant residues and animal manures are composted.

For a successful apple nutritional scheme the following growth stages are critical: 1) but burst 2) fruit set and 3) post harvest period (depending on the variety and climate). During these stages nutrient availability should be the maximum and the synchronization of organic inputs mineralization with the crop demand is critical to achieve maximum production and improve fruit quality. There are no available data regarding the performance of organic inputs in apple orchards.

For barley crop rotation and organic inputs are critical for the efficient use of nutrients within the system. Particularly, the application of manures to soil is the

**Figure 2.** Barley critical growth stages for Nitrogen uptake




main source of nutrients for the crop. This is attributed to the fact that barley cultivation and livestock production in Cyprus are linked and farmyard manure is regularly incorporated into the soil. The difficulties matching nutrients (especially N) to barley demands is well recognised. The highest demand for nitrogen for barley are noticed during growth stages 31 to 39 (Figure 2). Usually nutrients are released from organic sources at a time when the demand of the crop is minimum leading to excess amount of nutrients prone to leaching and runoff. Similarly, large N concentration in green manure crops creates a potential risk of N loses (ground water leaching or gaseous emissions).

For a successful barley nutrient scheme nitrogen and potassium are the nutrients required in the highest quantity. In Cyprus potassium deficiencies have not been noticed so far. Usually, the nutrient requirements of barley are covered from soil reserves, legumes incorporation and manures or compost applications. The nutrient management scheme in barley seems to be closely related with soil fertility buildup since there is room for improving the environmental performance and the productivity of the system.

## Nutrient management practices for organic apples and barley

The objective of the farmer according the aforementioned data is to satisfied crop demands when this is necessary. At the same time environmental issues and orchard soil management should be also taken into account in order to further build up soil fertility. So far farmers are not including soil or plant analysis in their strategy how to fertilize their orchards in both systems. Thus the first step for a successful management scheme is to assess and estimate the nutrient condition of the crop. Before the incorporation of organic inputs (farmyard manure, composts, blood meals etc) farmers should at least know the amount of nitrogen contained in the input that will be used. This is extremely important since this figure gives an estimate of the nitrogen that will be available to the crop and the nutrient causing $N_2O$ emissions. The challenge at this point is to synchronise apples nutrient demands with the mineralization of the nutrients from the organic input. The rate at which nitrogen is immobilised or released from organic inputs depends on several factors. The most important is C/N ratio of the applied material. Organic inputs with low C/N ratio (15/1 to 20/1) such as legumes are releasing nitrogen more rapidly compared to material with higher C/N ratio (i.e 40/1). In addition, farmer should be aware regarding the amount of nutrients that are removed from the cultivated soil during harvest. In organic farming systems especially in apple orchards, the plant biomass that is generated during pruning should be introduced eventually into the system to minimise losses of N as well as other nutrients. Similarly, incorporation of barley stalk residue into the soil should be performed after harvesting in barley.

---

## General steps that must be followed in a balanced nutrient management practices for barley and apples

The following steps should be therefore followed to determine the organic input rate needed for the crop. The values used for the following estimations have been calculated from unpublished data that are available at Agricultural Chemistry Laboratory of Agricultural Research Institute

***Step 1. Estimate the amount of nutrients removed after harvest***

Yield in kg of apples or barley (seed or hay) per hectare x (Dry Matter content) x Y1 g = **R1**

The average dry matter value of apple fruits ranges between 0.11 to 0.15

*Y1 use 4.2 g for apples (the average amount of N in apple fruits).*

*Y1 use 3.2 g for barley seeds (the average amount of N in barley seeds)*

*Y1 use 3.7 for barley hay (the average amount of N in barley hay)*

***Step 2. Determine the amount of nutrients inputs from soil, irrigation water and external inputs (green manures, manure, compost, others)***

**Step 2.1 Determine the mineralization potential of nitrogen from soil organic matter**

Amount of soil organic matter (%) x Soil weight per hectare x Amount of Nitrogen in soil organic matter (%) x 0.012 x 0.7= **R2**

Soil weight per hectare is calculated to a specific depth, usually 15 or 20 cm. The weith of soil is determined using the bulk density of the soil which is depended on soil texture. For example good structute clay soils exhibiting bulk densities ranking between 1.1 to 1.4 tn/$m^3$ while sandy soils usually have higher bulk densities ranking from 1.3 to 1.7 tn/$m^3$. Thus the total weight of a clay loam soil in 15 cm depth with bulk density of 1.45 tn/$m^3$ is 2175 tn/ha

The quantity of nitrogen in organic matter is ranking from 0.6 to 5% depending on the type of soils and the environmental conditions (Brady and Weil, 2002)

The mineralization percent of soil organic matter for one year 0.012 (unpublished data, Laboratory of Agricultural Chemistry ARI)

N recovery from the crop, 0.7 (unpublished data, Department of Soil Sciences ARI)

**Step 2.2 Determine the available amount of nutrients in irrigation water**

$NO_3$-N in mg/L x Water applied in the orchard (L) x 0.65 = **R3**

0.65 is the recovery factor of nitrogen from the crop (unpublished data, Department of Soil Sciences ARI)

**Step 2.3. Determine the total and the available nutrient content of the organic input (especially for manure and composts). This step is strongly recommended for the successful nutrient management scheme of the orchard. Then apply the results of the analysis in the following equation**

Amount applied (tn per hectare) x Dry matter content (%) x N content (%) x Mineralization rate of the organic input (%) x 0.5 = **R4**

0.5 is the recovery factor of nitrogen from the crop .

The mineralization rate of manures and composts depends on the maturity of the material, the origin as well as environmental factors. Incubation studies of different organic amendments revealed that compost mineralization rate is 0.05 while the mature manure mineralization rate is 0.3 (Dalias et al., unpublished data).

**Step 2.4 If legumes are included in the scheme then biomass and N content should be determined.**

Dry biomass production (tn per hectare) x N content (%) x Mineralization rate of the organic input (%) x 0.5 = **R5**

0.5 is the recovery factor of nitrogen from the crop

The mineralization rate of manures and composts depends on the maturity of the material, the origin as well as environmental factors. Incubation studies of different organic amendments revealed that green manure is 0.6.

***Step 4. Calculate the rates of application needed to supply the recommended amounts of nitrogen.***

R1-(R2+R3+R4+R5)= **R6**

If R6 is positive then proceed to extra inputs

If R6 is negative don't take any action

During the manure incorporation into the soil, organic farmer should be aware of the amount of P and K inputs in the system. Regular application of these types of inputs without knowing the amount of P that is added into the soil might cause excessive P buildup that should also be avoided. Plant analysis should be performed during the growing season to evaluate the nutritional condition of the crop and the nutrient management strategy that was followed particularly for apples.

## Conclusions

The implementation of a balanced nutrient management scheme is essential to increase yields of high quality. A major challenge in organic farming is to synchnonize mineralization rates with nutrient uptake from the cultivated crop. Nutrient inputs in organic farming systems are derived from manures, composts and green manures that are included in the crop rotation scheme particularly for barley. Increased knowledge of organic farmers regarding the nutrient budget in the system is expected to reduce organic inputs and subsequently GHG emissions. Nutrient management practices should be designed to maximize C inputs and to maintain and promote sustainability in soils.

# References

Romanyà, J., N. Arco, I. Solà-Morales, L. Armengot, and F. X. Sans. 2012. Carbon and Nitrogen Stocks and Nitrogen Mineralization in Organically Managed Soils Amended with Composted Manures. J. Environ. Qual. 41:1337-1347. doi: 10.2134/jeq2011.0456

Brady, Nyle C., and Ray R. Weil. 2002. The nature and properties of soils. Upper Saddle River, N.J.: Prentice Hall.

Orphanos P.I.1994 Performance of grain and hay barley in different rotations and nitrogen and phosphorus fertilization in a Mediterranean environment European Journal of Agronomy 3(3): 227-233