HEALTHY PLANTS
Determining the potassium content of fertilisers and soil

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Languages available
English, Hungarian, Slovenian

Summary
Potassium is one of the elements necessary in large amounts for the cultivation of plants, a so-called macronutrient. Its presence influences the uptake of other nutrients (N, Ca, Mg), too. Growing in soils with a good potassium supply, plants are less sensitive to frost and drought stresses and their fruits taste better.

As members of a team in an agrochemical laboratory, students have to suggest a chemical fertilising procedure for a soil with a potassium deficiency. For this, they have to analyse the soil, as well as the chosen artificial fertiliser. They also have to carry out calculations including resource and budget management of the procedure. Quantitative determination of the potassium content of the soil and the fertiliser is carried out using flame photometry; the other ions are determined by titrimetric methods.

Activity type H
Use of scientific knowledge and understanding to solve problems
Working in teams to solve problems
Communication
Resource/budget management
Time and workload management

Techniques
Flame photometry
Volumetric analysis (complexometry, argentometry)
Determination of pH

Field
Agrochemistry

Time
Practical lessons: 540 minutes
Theory lessons: 180 minutes
Out of class time: 360 minutes

StandardBase procedures
Determination of the potassium ion content of artificial fertilizers using flame photometry
Determination of calcium in calcium carbonate using complexometric titration
Determination of the hardness of water using complexometric titration
Determination of the salt content of butter using potentiometry
Determination of the pH and conductivity using electrochemical techniques

StandardBase techniques
Flame photometry
Complexometric titration

Other resources
Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Budapest, Hungary, www.taki.iif.hu

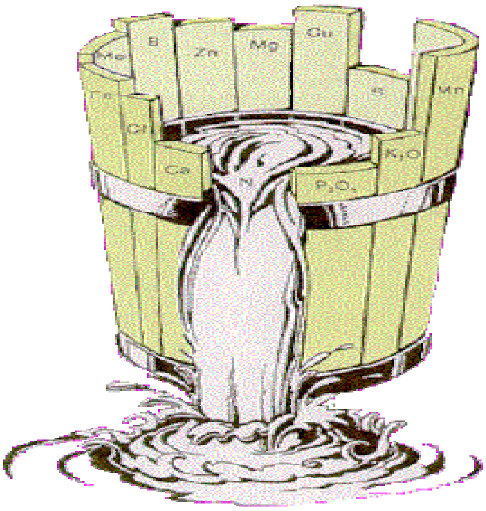
International forums
International Potash Institute, www.ipipotash.org
FAO Food and Agriculture Organization of the United Nations http://www.fao.org/
International Plant Nutrition Institute: www.ipni.net
Soil examination standards
Hungarian Bureau of Standards, www.mszt.hu
Series of standards for the examination of soils: MSZ 08 and MSZ 12757
Legal provisions in force: decree 29/2006(IV.10)FVM
http://www.fvm.hu/main.php?folderID=2082&articleID=8727&ctag=articlelist&iid=1
http://www.bsi-global.com/en/Shop/Shop-Product-List-Page/?d=N)0&q=examination+of+soil%7cstandard+of+soil&f=&ps=10&pg=2&no=10&c=10
http://www.bsi-global.com/
Articles on agrochemicals
http://www.ecochem.com/t_agriculture.html
http://ezinearticles.com/?Understanding-Soil-Nutrients&id=216966
Articles on nutrients
http://www.voyasoft.hu/auroma/kalium.htm
http://www.rodsgarden.50megs.com/plantnutrients.htm
http://www.agr.state.nc.us/cyber/kidswrld/plant/nutrient.htm
http://www.urbanext.uiuc.edu/gpe/links/index.html

Some more links are listed in the activity.

Student’s document

HEALTHY PLANTS: Determining the potassium content of fertilisers and soil

Minimum law of Liebig



The yield of a crop is determined by the element present in the smallest quantity relative to the needs of the plant. (http://www.mkk.szie.hu/dep/talt/rg/agrokemia_BSC_levelezo.ppt).

Besides nitrogen and calcium, potassium is necessary in the largest quantity for the growth of plants; it is a so-called macronutrient. Generally, it is found in the cellular fluid in the protoplasm. It plays an important role in water transport in cells and in the regulation of catalytic processes, for example in protein and carbohydrate synthesis. Its presence benefits acid content and flavour in fruits e.g. grapes.

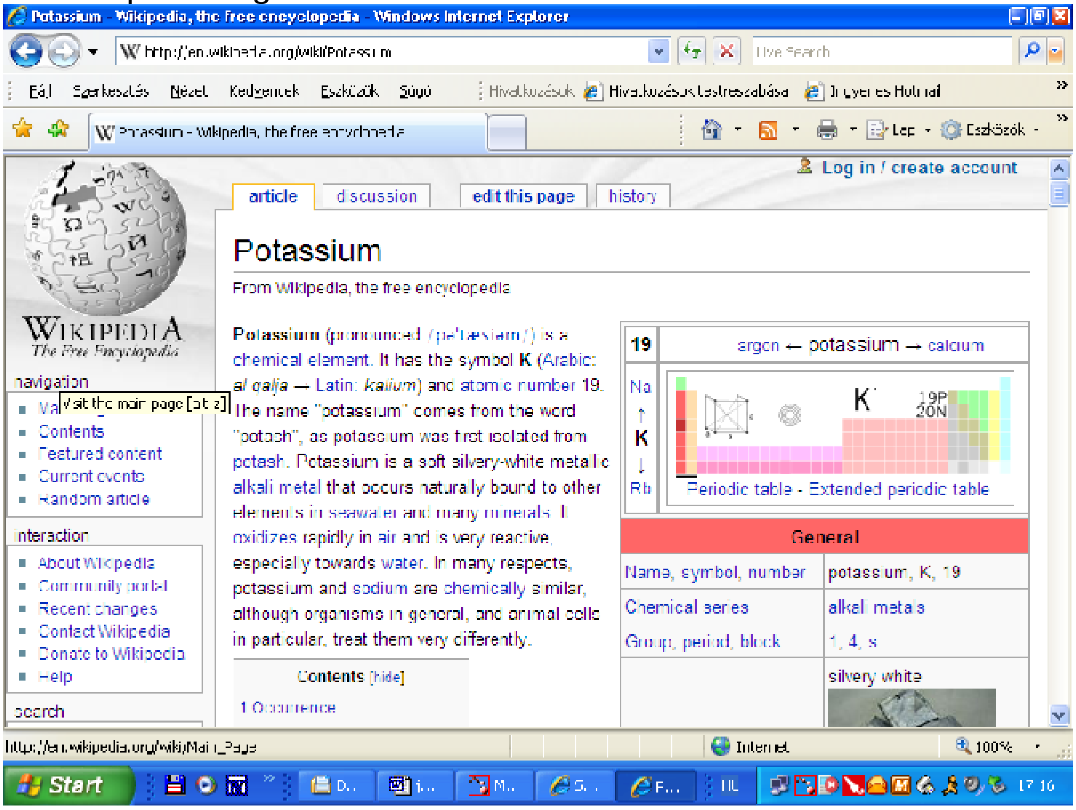
Growing in soils with a good potassium supply (80-120 mg K^+/kg soil), plants are also less sensitive to frost and drought stresses. Because of these aspects, for an appropriate yield of crop, the potassium demand of the plant and the potassium content of the soil need to be in balance. Potassium is involved in the regulation of the metabolism of other nutrients, too. This is the phenomenon of the so-called ion antagonism. Because of the antagonisms K^+/Mg^{2+}, K^+/Ca^{2+} and Ca^{2+}/Mg^{2+}, the advantageous effect of these nutrients can be seen only if the ions are present in an appropriate molar ratio. For example, a molar ratio of $K^+/Mg^{2+} = 0.5$ and $Ca^{2+}/Mg^{2+} = 6$ are ideal. A high potassium supply will act against the uptake of other nutrients like nitrogen, calcium and magnesium. In this instance, symptoms of overdosing K^+ and because of the K^+/Mg^{2+} ion antagonism, symptoms of lack of Mg^{2+} can be detected.

History: http://en.wikipedia.org/wiki/Portal:Science
Potassium was discovered in 1807 by Sir Humphry Davy, who derived it from caustic potash (KOH). Before the 18th century, no distinction was made between potassium and sodium. Potassium was the first metal that was isolated by electrolysis. Potassium was not known in Roman times, and its names are not

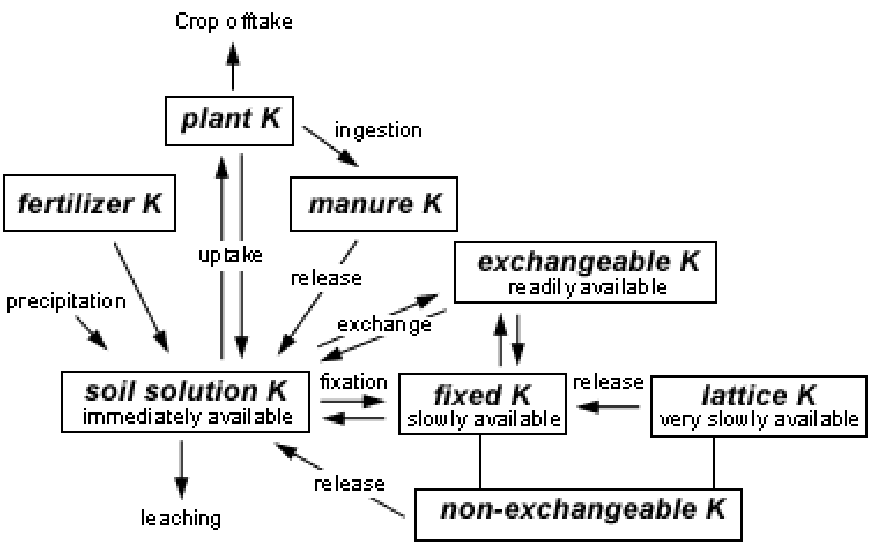
Classical Latin but rather neo-Latin. The name kalium was taken from the word "alkali", which came from Arabic *al qalīy* = "the calcined ashes". The name potassium was made from the word "*potash*", which is English, and originally meant an alkali extracted in a *pot* from the *ash* of burnt wood or tree leaves.

For more information about potassium, use the Internet lexicon WIKIPEDIA.

http://en.wikipedia.org/wiki/Potassium

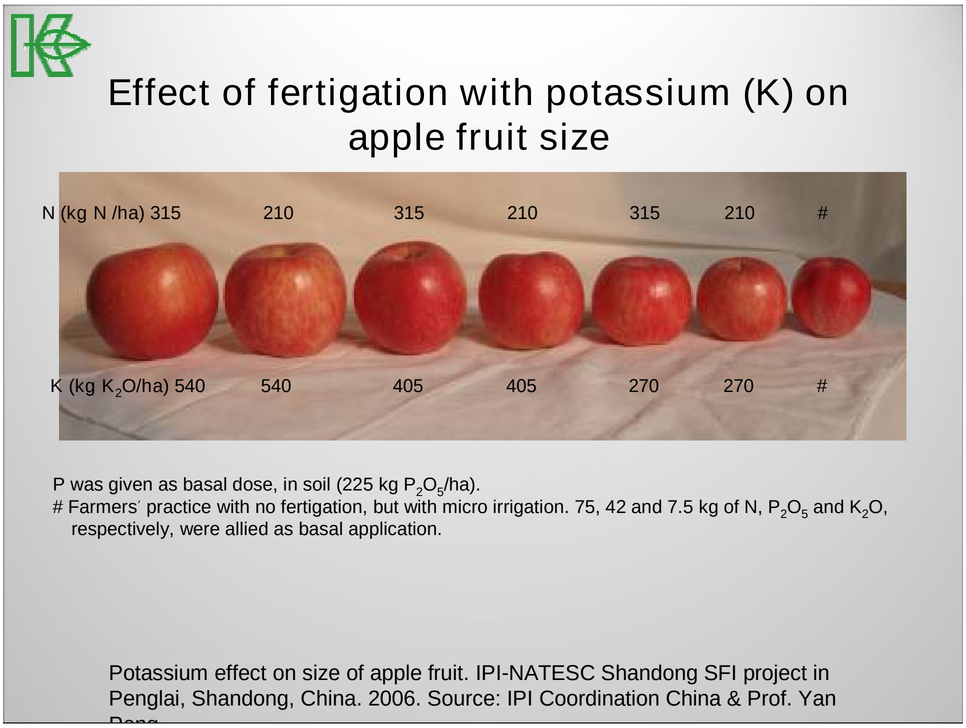


Similarly to nitrogen and phosphorus, potassium has a cycle within nature. This figure is taken from http://www.ipipotash.org/presentn/aspcwdb.html



The potassium cycle in the soil-plant-animal system (from SYERS, 1998)

Visiting your older relatives, you might have observed that they were taking K-containing medicines. Doctors order these if the K^+ level of cells in the body affected by diuretics decreases below the normal value of 3.5-5.6 mmol/L in the blood. These drugs most often contain KCl. Our K^+ intake can be supplied by a healthy diet, especially by consuming enough fruit. Nice big and tasty fruits certainly have enough K^+. However, fruits grown in soils with a potassium deficiency are smaller in size, as proved by agrochemical experiments.



from http://www.ipipotash.org/KGallery/KGallery.pps#47

Your brief

Imagine that the soil in a neighbouring vineyard was found to have a potassium deficiency. The farmer asks your laboratory how to improve the soil in the most effective and efficient way. Examine the soil as necessary. Look for suitable fertilisers on the market. Choose the best one for the given K_2O content of the soil. Make calculations regarding the management of resources and budget. In teams, plan the work and how you will manage the time. Summarise the results of the groups and write a report or a presentation for the customer.

This activity will help you develop the following skills:

- Collecting and using scientific knowledge and understanding to solve problems
- Working in teams to solve problems
- Resource and budget management
- Time and workload management
- Communication when collecting information, data processing and at the presentation of the results.

Your investigation
For the following, work in three groups, each containing at least 3-5 members. Carry out investigations in accordance with the **Student sheets** and the corresponding time management:

- Investigation of the main components and properties of the soil sample.
- Investigation of several K^+ containing fertilisers; choice of the appropriate one.
- Based on the measurements, planning the potassium supply of the soil; budget management.
- Documentation of the results for the customer.

Planning

- Groups should study each other's projects.
- Groups should study and discuss the corresponding student sheets.
- In their groups, students should manage sharing out the work independently.
- Together with their teachers, groups should check what equipment and materials are necessary to do their work.
- Based on the description of the measurements, students should study and prepare the relevant equipment.
- When planning the work, every group should look for the critical points when they will need results from other groups to continue working.
- Every group should nominate a person to be responsible for the documentation and transmission of the experimental data to ensure steady processing of work in parallel groups.
- Delegates from the different groups should agree on the appropriate potassium supply by checking their calculations for potassium input.
- Groups should agree on a harmonised form and contents for the documentation of results.
- Before beginning the experiments, groups should decide which part of the experimental results and in what form (tables, diagrams, etc.) will be enclosed with the documentation of the work.
- Groups should decide whether they give a report, a lecture or a PowerPoint presentation about their work.

A risk assessment must be carried out before starting practical work.

Task 1
Using **Student sheet***: Preparation of an aqueous soil extract*, prepare an aqueous extract of the soil under investigation, before and after treatment for the corresponding experiments.

Task 2
Using **Student sheet***: Determination of the K^+ content of the soil by flame photometry*, measure the K^+ content of the soil sample, before and after treatment.

Task 3
Using **Student sheet***: Complexometric determination of the Ca^{2+} and Mg^{2+} content of the soil*, measure the Ca^{2+} and Mg^{2+} content of the untreated soil sample.

Task 4
Using **Student sheet***: Determination of the Cl^- content by argentometric titration*, measure the Cl^- content of the untreated soil sample.

Task 5
Using the StandardBase procedure: *Determination of the potassium ion content of artificial fertilisers using flame photometry* at www.standardbase.com, measure the K^+ and K_2O content of two commercially available fertilisers containing KCl.

Task 6
Treat the soil sample with a calculated amount of the chosen fertiliser. To do so, mix the 80 g air-dried soil sample with the calculated amount of K^+-containing solid fertiliser (this latter is only a few milligrams, therefore it does not cause a significant change in the mass of the soil sample).

Task 5
Using **Student sheet***: Determination of pH(H_2O)* and **Student sheet**: *Determination of pH(KCl)*, measure the pH(H_2O) and pH(KCl) values of the soil sample, before and after treatment.

AN EXAMPLE FOR ORGANISING WORKING GROUPS

1st group
- Prepare an aqueous extract from the soil to be studied (**Student sheet**: *Preparation of an aqueous soil extract*).
- Measure the potassium ion content of the soil sample using flame photometry (**Student sheet***: Determination of the K^+ content of the soil by flame photometry*).
- Calculate the necessary K^+ input - if possible - taking into consideration the Ca^{2+}/Mg^{2+} ratios measured by the *2nd group* and the K^+/Mg^{2+} ratios which can be calculated from them.
- Administer the potassium ion supply to the 80 g soil sample using a calculated amount of the fertiliser and then continue preparing the soil extract in accordance with **Student sheet**: *Preparation of an aqueous soil extract*.
- Measure the potassium ion content of the soil sample treated with the chosen fertiliser using flame photometry (**Student sheet**: *Determination of the K^+ content of the soil by flame photometry*).

2nd group
- Measure the calcium ion content of the soil by complexometric titration using the aqueous soil extract prepared by the *1st group* (**Student sheet**: *Complexometric determination of the Ca^{2+} and Mg^{2+} content of the soil*).
- Measure the sum of calcium ion and magnesium ion content of the soil by complexometric titration, using the aqueous soil extract prepared by the *1st group* (**Student sheet**: *Complexometric determination of the Ca^{2+} and Mg^{2+} content of the soil*).
- Based on these measurements, calculate the magnesium ion content of the soil.
- From the results, calculate the Ca^{2+}/Mg^{2+} ratio in the soil sample under investigation.
- Using results from the *1st group*, calculate the K^+/Mg^{2+} ratio in the soil.

- Measure the chloride ion concentration in the soil by argentometric titration, using the aqueous soil extract prepared by the *1st group* (**Student sheet**: *Determination of the Cl^- content by argentometric titration*).
- Calculate the theoretical chloride ion input when potassium is supplied using a KCl containing fertiliser.

3rd group

- Research the K^+-containing fertilisers available on the market (in agricultural merchants, garden centres, fertiliser suppliers or in the Internet). Make a note of their prices and their nominal potassium content expressed in K_2O % by mass.
- Measure the K^+ content of at least two K^+-containing fertilisers using flame photometry and express the results in K_2O % by mass (see the corresponding StandardBase procedure: *Determination of the potassium ion content of artificial fertilizers using flame photometry* at www.standardbase.com)
- Compare the results of your measurements with the given nominal potassium content expressed in K_2O % by mass.
- Select one of the two investigated K^+-containing fertilisers, based on economic aspects. (Take into consideration the price and the nominal potassium content.)
- From the selected fertiliser, prepare a diluted aqueous solution. Use distilled water for the preparation.
- Measure the pH value of the aqueous solution of the fertiliser with indicator paper. Compare the value with the pH of a diluted pure KCl solution prepared with distilled water.
- Measure the pH (H_2O) values of the aqueous soil extracts prepared by the *1st group* from the untreated and treated soil samples (**Student sheet**: *Determination of pH(H_2O)*).
- Measure the pH (KCl) values of the aqueous soil extracts prepared by the *1st group* from the untreated and treated soil samples (**Student sheet**: *Determination of pH(KCl)*).

All groups

- Carry out necessary calculations for the calibration curves and for the conversion of the number of moles.
- Throughout your work, keep to the instructions of the corresponding safety regulations; write them in your laboratory notes.
- Calculate and measure the time needed to perform different parts of the project.
- Present your measured data in the clearest form e.g. by diagrams, tables, etc.
- Find out about the importance of studying the nutrient concentration of the soil and the implications for agriculture.
- Collect arguments for the choice of fertiliser, taking into account both economic and environmental aspects.
- Research and make notes on the dangers of overdosing. Collect information from the Internet, interviews, different media.

Your findings

Groups should summarise their results in tables. These should contain the measured numerical data, economic calculations and the time taken for work. Among these data, students should emphasise the importance of particular information and they should present important information in the clearest form, as follows:

- Based on your experimental results, present the salt composition of the soil sample (K^+, Ca^{2+}, Mg^{2+} content) on a diagram and compare it with another diagram showing the state of the soil after fertilisation, according to your calculations.
- List the data of the chosen fertiliser such as the corresponding nominal and measured K^+ and K_2O content, as given by the producer and as you have measured it.
- Summarise in a table the results of your calculations on how to reach the desired potassium content.
- Collect arguments regarding environmental and economic aspects.
- Write reasoned comments on your findings, using your economic calculations and the results of your measurements of the pH of the soil.

Student self assessment

- Formulate in 50-100 words, or list, what prior and new (theoretical and experimental) scientific knowledge you used as members of the team and how effectively you used them.

- After studying the problem to be solved, what groups would you organise to manage work? Show the groups in a table. Compare it with the table given by your teacher. What is the difference regarding the members of different teams? After completing the work, summarise, in a few sentences, what the advantages and disadvantages are of the two different team compositions in relation to communication.

- List the different forms of communication you used in the course of your work. Classify them according to different parts of the work, for example communication used in effective laboratory work, during collecting information (in lessons or out of class hours), during calculations or in evaluating your results. Illustrate communication in a diagram or in writing, citing some examples.

- Make calculations regarding the budget for the suggested fertilisation of the given soil. Give the price for the adequate fertilisation of one kg soil. Take into account the additional costs of such fertilisation that emerged as the tasks were carried out.

- Make a table summarising time management. List the planned length of work and compare it with the actual time taken. Analyse the differences, in a few sentences. When did the timings agree and what was the source of differences? Based on your experience, make a new time management plan incorporating the aspects you could not take into consideration at the beginning but now, based on your experience, can.

Student sheet: Preparation of an aqueous soil extract

Prepare an aqueous extract from a 1:5 mixture of the soil and water. For example, weigh 80.00 g of air-dried soil, with 0.01 g accuracy, and dissolve it in 400 cm^3 of boiled and cooled distilled water. To aid dissolving, use a 500 cm^3 shaking flask and let it shake for 1 hour in a shaking apparatus.

Filter the suspension through a folded filter paper. The filtrate might be cloudy at first. Once the drops of filtrate become clear (because the tiny solid particles are blocking the smallest holes of the filter paper), the filtrate should be poured through the filter again to obtain a clearer solution. Store the filtered solution in a closed flask in a refrigerator until needed.

Comment: The filtered solution can be preserved by adding a few drops of toluene or xylene. These substances are cell poisons and prevent reproduction of bacteria. Thus, they save the soil sample from decomposing.

Student sheet: Determination of the K^+ content of the soil by flame photometry

Prepare a calibration series from a 0.01 mol/dm^3 KCl standard solution. Pipette 0.5, 1.0, 2.0, 4.0, 10.0, 20.0, 40.0 cm^3 stock solution, respectively into 100 cm^3 volumetric flasks and fill them till the mark with distilled water. Before making any measurements, look for maximum absorbance at about 770 nm wavelength by nebulising the most concentrated solution into a flame. Then set the absorbance value at zero using distilled water.

Nebulise each of the calibration series once, in increasing and then in decreasing order, into the flame and take the mean (average) of the measured values.

Nebulise the sample of the filtered solution of the aqueous soil extract directly or after appropriate dilution several times into the flame and take the mean (average) of the measured values.

Using its absorbance value, determine the concentration of the sample from the calibration curve. Depending on how the calibration curve is constructed, read or calculate the potassium content in mg K^+/100 g soil.

Comment: The disturbing effect of Na^+ ions can be eliminated by using a Na filter.

Student sheet: Complexometric determination of the Ca^{2+} and Mg^{2+} content of the soil

Determination of Ca^{2+} ions
Pipette 10 cm^3 aqueous soil extract into a 100 cm^3 conical flask and dilute it to 50 cm^3 with distilled water. Add 2 cm^3 basic sodium tetraborate buffer solution and 0.1 g Murexid indicator to the solution. Titrate with 0.01 mol/dm^3 EDTA until the colour of the solution turns from red to violet.

Preparation of the solutions
Preparation of sodium tetraborate buffer: dissolve 13.5 g Na tetraborate decahydrate ($Na_2B_4O_7.10\ H_2O$) in distilled water in a 1 dm^3 volumetric flask; add 80 g NaOH and fill the flask to the mark.

Preparation of 0.01 mol/dm^3 EDTA solution: dissolve 3.7225 g EDTA in distilled water in a 1 dm^3 volumetric flask; add 0.86 g NaOH and fill to the mark with distilled water.

Comment: The exact concentration of the EDTA can be determined by calculation from the exact amount of EDTA weighed in.

Calculation

$$\text{mg } Ca^{2+}/100 \text{ g soil} = \frac{100}{2} \times V_{Ca} \times c \times M(Ca^{2+})$$

Where:
V_{Ca} = volume of titrant used in cm^3
c = exact concentration of titrant in mol/dm^3 units determined by 0.01 mol/dm^3 $CaCl_2$ standard solution
$M(Ca^{2+})$ = 40.080 g/mol
10 cm^3 soil extract corresponds to 2.00 g air-dried soil and hence, a factor of 100/2 should be used for 100 g soil.

Determination of Mg^{2+}
Pipette 10 cm^3 aqueous soil extract into a 100 cm^3 conical flask and dilute it to 50 cm^3 with distilled water. Adjust the pH of this sample to about 10 by adding 2 cm^3 NH_4Cl/NH_4OH buffer solution; add 0.1 g Eriochrome Black T indicator.

Titrate the solution with 0.01 mol/dm^3 EDTA until its colour turns from red to blue. This way, you determine the sum of Ca^{2+} and Mg^{2+} ion content of the soil, from which the Mg^{2+} content can be calculated by using the previously determined Ca^{2+} content, as given below.

Preparation of the solutions
Preparation of ammonia/ammonium-chloride buffer solution: dissolve 8.3 g NH_4Cl in distilled water in a 1 dm^3 volumetric flask; add 113 cm^3 cc. NH_4OH and fill to the mark.

Preparation of 0.01 mol/dm^3 EDTA solution: the same as above.

Calculation

$$\text{mg Mg}^{2+}/100\text{ g soil} = \frac{100}{2} \times (V_{total} - V_{Ca}) \times c \times M(\text{Mg}^{2+})$$

Where:
V_{total} = volume of titrant used in cm^3
$M(Mg^{2+})$= 24.310 g/mol
Other abbreviations are the same as above.

Student sheet: Determination of the Cl^- content by argentometric titration

For the titration, use 10 cm^3 aqueous soil extract corresponding to 2 g soil. Adjust the pH of the solution to 8.2 by adding 0.05 mol/dm^3 H_2SO_4 and 0.1 mol/dm^3 NaOH solution in the presence of phenolphthalein indicator. After that, add 1 cm^3 of 10 g/100 cm^3 K_2CrO_4 indicator and titrate it with 0.1 mol/dm^3 $AgNO_3$ solution until the appearance of a reddish brown colour.

Give the result with reference to 100 g air-dried soil, as described below.

Comment: The 0.1 mol/dm^3 $AgNO_3$ solution should be stored in a dark flask and its exact concentration should be determined with a 0.1 mol/dm^3 NaCl solution. The volume of titrant used by the indicator can be determined by a blank titration.

Calculation

$$\text{mg Cl}^- \text{/100 g soil} = \frac{100}{2} \times V \times c \times M(\text{Cl}^-)$$

Abbreviations:
V = volume of titrant used in cm^3
c = exact concentration of titrant in mol/dm^3
$M(Cl^-)$ = 35.450 g/mol

Student sheet: Determination of pH(H_2O)

Measure 15 cm^3 distilled water into a test tube and add 6.00 g air-dried soil sample to it. Close the test tube, shake it several times and measure it after at least half an hour.

Immediately before the measurement, shake the test tube again and measure the pH by immersing a combined glass electrode into the suspension. Before the measurement, calibrate the pH meter with a buffer solution of pH 7.00.

Comment: The pH of a sample made from an air-dried soil is generally lower than the pH of a soil in its natural state. Even in the former case, there are differences between the pH values measured in suspensions and in solutions. The pH of solutions is generally higher than the value measured in suspensions. The acidity measured in a suspension prepared in distilled water is usually called effective acidity.

Student sheet: Determination of pH(KCl)

For the measurement, prepare a 1 mol/dm^3 KCl solution. Pour 15 cm^3 of 1 mol/dm^3 KCl solution into a test tube and add 6.00 g air-dried soil sample to it. Close the test tube, shake it several times and measure it after at least half an hour.

Immediately before the measurement, shake the test tube again and determine the pH by immersing a combined glass electrode into the suspension. Before the measurement, calibrate the pH meter with a buffer solution of pH 7.00.

Comment: The pH of a suspension prepared in KCl is a close approximation of the pH near the roots of plants where the medium is more acidic because of the uptake of K^+ ions and release of H^+ ions into the soil. This pH value is about 0.5 smaller than the one measured in an aqueous suspension. The acidity measured in a suspension prepared in neutral KCl solution is usually called hidden acidity.

Student sheet: Tables for documentation of the results of groups 1st group

Table for measurement results

Measurement of K^+ content untreated soil		**Measurement of K^+ content treated soil**	
measurement 1		measurement 1	
measurement 2		measurement 2	
measurement 3		measurement 3	
mean		mean	
mg K^+ / 100 g soil		mg K^+ / 100 g soil	

Table for determination of time for the measurements

Type of work		**Time minutes**
Determination of K^+ (untreated soil)	Preparation	
	Measurement	
	Calculation	
Determination of K^+ (treated soil)	Preparation	
	Measurement	
	Calculation	
Preparation of soil extracts	Untreated	
	Treated	
	Total	

Table for economic analysis

Molar ratio K^+/Mg^{2+} in the soil (see *2nd group*)	**Factor of suggested K^+ input**	**Suggested K^+ input mg/100 g soil**	**Suggested KCl mg/100 g soil**

Student sheet: Tables for documentation of the results of groups
2nd group

Table for measurement results

Soil	Measurement Ca^{2+} content	Measurement Mg^{2+} content	Measurement Cl^{-} content
Volume of titrant used (cm^3)	1:	1:	1:
	2:	2:	2:
	3:	3:	3:
	mean	mean	mean
Studied ion mg/100 g soil			

Table for determination of time for the measurements

Determination	Type of work	Time minutes
Determination of Ca^{2+}	Preparation	
	Measurement	
	Calculation	
Determination of Mg^{2+}	Preparation	
	Measurement	
	Calculation	
Determination of Cl^{-}	Preparation	
	Measurement	
	Calculation	
	Total	

Table for economic analysis

Molar ratio Ca^{2+}/Mg^{2+} in the soil	Molar ratio of K^{+}/Mg^{2+} in the soil (see *1st group*)	Suggested K^{+} input mg/100 g soil (see *1st group*)	Connected Cl^{-} input mg/100 g soil

Student sheet: Tables for documentation of the results of groups
3rd group

Table for measurement results

Fertiliser	K^+ mg/dm^3	K_2O % by mass calculated	K_2O % by mass nominal	% by mass salt	Solution	pH
I.						
measurement 1					fertiliser	
measurement 2					KCl	
measurement 3					untreated soil pH(H_2O)	
mean						
II.						
measurement 1					untreated soil pH(KCl)	
measurement 2						
measurement 3					treated soil pH(H_2O)	
mean						
Chosen fertiliser					treated soil pH(KCl)	

Table for determination of time for the measurements

Type of work	Sample I. minutes	Sample II. minutes
Preparation		
Measurement		
Calculation		
Preparation of solutions	fertiliser:	KCl:
Soil extract pH(H_2O)	untreated:	treated:
Soil extract pH(KCl)	untreated:	treated:
Totals		

Table for economic analysis

Fertiliser	K_2O % by mass calculated	Price /kg fertiliser	Price /kg K^+ content
Sample I.			
Sample II.			

Student information sheet: Nutrients and their role

Translated extract from
www.hik.hu/tankonyvtar/site/books/b155/ch07s02s03.html

For the regulation of nutrient supply to plants and fruits, a broad knowledge of the physiological and agrochemical role of nutrients is needed. Mineral nutrients have an important role in the metabolism of plants especially in that of fruits. Consequently, they also influence the regulation of this metabolism. Physiological advantages of the uptake of nutrients can only act if a balanced ratio of the nutrients is maintained in different parts of the plant. Excess or deficiency of each of the nutrients disturbs the balance of nutrient supply. In practice, this happens most often when N and K nutrients are used in relatively large quantities.

The number of nutrients identified in fruits so far is more than 70. Of these, 15-17 are really essential. They are:
Macronutrients: C, H, O, N, P, K, Ca, Mg, S
Micronutrients: Fe, Mn, B, Cu, Zn, Mo, Ti

Physiological research is continuously finding the importance of further elements. In fruit-bearing plants, relatively large amounts of sodium and chlorine may accumulate; according to agrochemical investigations, this has more disadvantages than advantages.

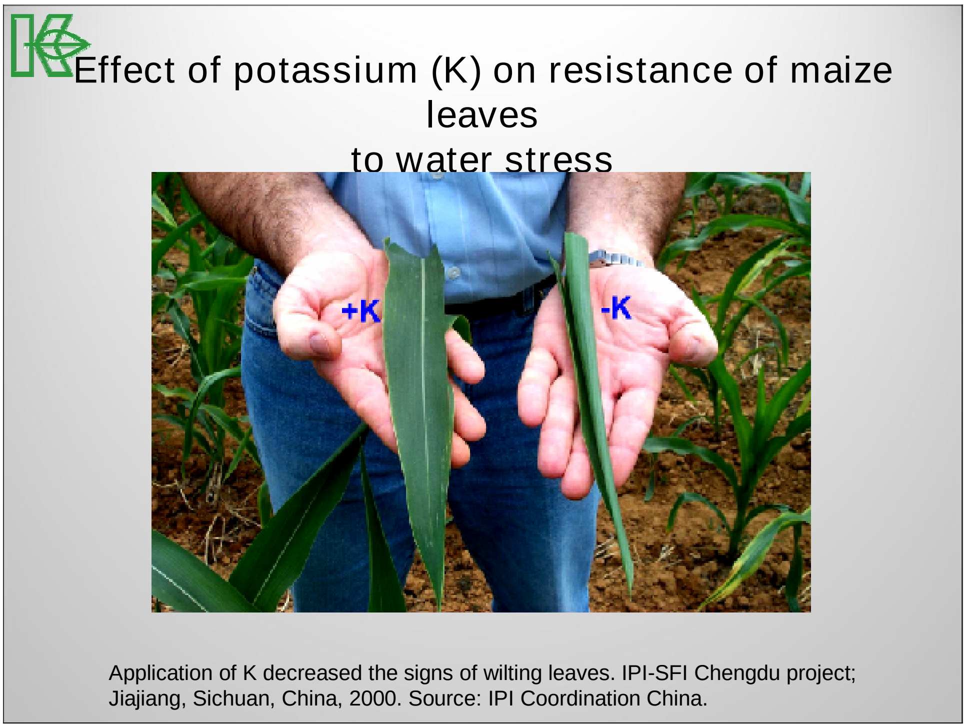
Plants take up most of the nutrients through their roots, in form of ions, but an uptake through their leaves is also possible. In the case of fruit-bearing plants, uptake of nutrients is mainly determined by two factors. One of these factors is genetics and the other is a function of the chemical properties of nutrients and the properties of soil. Different parts of fruit-bearing plants take up nutrients in different quantities, influenced by their own special metabolism.

Nutrient uptake of the fruit-bearing plants can be determined by the metabolism of the plant only in the case of a good balance of nutrient and water supply in the soil. Otherwise, uptake of the nutrients is hindered or certain nutrients can be oversupplied. The so-called ion antagonism causes serious problems in fruit growing. The most important ion antagonisms in practice are as follows: N/K, N/P, K/Mg, K/Ca, P/Zn, Ca/Mg, Ca/B, Ca/Fe, Ca/Zn and Fe/Mn.

Important properties of nutrients taken up by fruit trees are transportability and reutilisation. Most of the macro elements (N, P, K, Mg) are reused in practice and so their deficiency shows symptoms on older, lower leaves. Unfortunately, Ca, which is an important macro element for fruit quality, and also micro (trace) elements cannot be reused. Deficiency symptoms of these elements appear on young shoots first.

Potassium
Along with nitrogen and calcium, potassium is one of the three essential nutrients necessary in large amounts. Generally, it is found in a dissolved state in the fluids of the plant or absorbed in the colloids of the protoplasm. Potassium is involved in enzymatic processes of the plant cells. It has an important role in the synthesis of proteins and regulates the water status in the plant. It takes an

essential part in the formation, translocation and decomposition of carbohydrates. In cases of potassium deficiency, synthetic processes are weakened.



http://www.ipipotash.org/KGallery/KGallery.pps#47

By changing the hydration state of protoplasm colloids, potassium plays an essential role in the regulation of water transport in the plant. It influences the acid content of fruits and improves their taste and flavour. Practical observations support that plants with an advantageous potassium supply have an increased resistance to abiotic stresses such as cold and drought stresses and biotic stresses such as pests and fungicide attacks.

The potassium uptake of fruit trees is essential from when the first shoots appear until the end of the growth of the fruits. Afterwards, the need decreases. The rate of processes, like formation, translocation and decomposition of carbohydrates, strongly depends on the potassium content of cells. In cases of potassium deficiency, growth of cells is hindered and fruits are therefore smaller in size.

Most potassium is stored in the leaves and fruits of plants. But potassium is the most mobile macro element and therefore, where there is deficiency in the nutrient uptake, potassium is transported from older leaves to younger ones and from leaves to fruits.

Symptoms of potassium deficiency
The most characteristic symptoms develop on longer shoots. Lower-lying old leaves are affected first and symptoms gradually reach the extremities of the plant. In leaves, first a well-defined light stripe appears because of dehydration of the protoplasm and because of other disturbances in the metabolism. Later, especially in dry weather, the tissues of the light stripes become necrotic because of plasmolysis. The size of the burned, brown, necrotic edges on the

leaves depends on the degree of potassium deficiency. In cases of severe potassium deficiency, the majority of the leaf can be affected and even premature leaf fall can occur. Low yield of crops and small size of fruits can also be related to potassium deficiency. In most of the cases, potassium deficiency appears under extreme dry weather conditions after the end of the growth of fruits, indicating the deficiency of potassium transported away from the leaves.

Typical deficiency symptoms of potassium (K) in oilseed rape

Typical potassium deficiency symptoms in oilseed rape leaves. Source: Bulletin 16, 2003, IPI, Horgen, Switzerland. Courtesy of K+S KALI.

http://www.ipipotash.org/KGallery/KGallery.pps#47

Potassium plays an important role in the uptake and regulation of the transport of other nutrients, too. If the potassium supply is too high in the soil, the uptake of calcium, magnesium and nitrogen decreases. Fruit-bearing plants have a tendency to store so-called luxurious amounts of potassium. Therefore, though potassium has an essential importance in the nutrient supply of the soil of fruit-bearing plants, excess of potassium has disadvantageous effects on plants. In practice, unbalanced K/Ca ratios can injure the hardness of apples and seriously damage fruits in storage (Faust, 1989). Because of K/Mg antagonism, over fertilisation with potassium can cause magnesium deficiency, too.

The danger of oversupply of potassium is higher in well-watered fruit gardens where the soil has a low colloid content. Grass-growing, using herbicides and covering the soil increase the potassium supply of fruit-bearing plants in fruit gardens. The same is valid for well-watered fruit farms.

Student information sheet: Soil pH and plant nutrients

Extract from
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex6607#potassiu
m

Farmers frequently ask, "What effect does pH have on availability of nutrients in the soil?" There is no simple answer to this question, since the effects of pH are complex and vary with different nutrients. However, some broad generalizations are useful to keep in mind when making nutrient management decisions.

Soil pH
The first order of business is a quick review of pH and the associated terminology. Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units. The pH scale goes from 0 to 14 with pH 7 as the neutral point. As the amount of hydrogen ions in the soil increases, the soil pH decreases, thus becoming more acidic. From pH 7 to 0, the soil is increasingly more acidic, and from pH 7 to 14, the soil is increasingly more alkaline or basic. Using a strict chemical definition, pH is the negative log of hydrogen ion (H^+) activity in an aqueous solution. The point to remember from the chemical definition is that pH values are reported on a negative log scale. So, a 1 unit change in the pH value signifies a 10-fold change in the actual activity of H^+, and the activity increases as the pH value decreases.

To put this into perspective, a soil pH of 6 has 10 times more hydrogen ions than a soil with a pH of 7, and a soil with a pH of 5 has 100 times more hydrogen ions than a soil with a pH of 7. Activity increases as the pH value decreases.

Agronomists generally use soil pH as measured in a 2:1 water-to-soil mixture as an index of a soil's acidity or alkalinity. In a soil test report, pH is often reported with descriptive modifier as shown in the table:

Soil pH and interpretation						
5.0	**5.5**	**6.0**	**6.5**	**7.0**	**7.5**	**8.0**
strongly acid	medium acid	slightly acid	neutral	neutral	mildly alkaline	moderately alkaline
			best range for most crops			

Nitrogen

One of the key soil nutrients is nitrogen (N). Plants can take up N in the ammonium (NH_4^+) or nitrate ($N0_3^-$) form. At pH's near neutral (pH 7), the microbial conversion of NH_4^+ to nitrate (nitrification) is rapid, and crops generally take up nitrate. In acid soils (pH < 6), nitrification is slow, and plants with the ability to take up NH_4^+ may have an advantage.

Soil pH also plays an important role in volatization losses. Ammonium in the soil solution exists in equilibrium with ammonia gas (NH_3). The equilibrium is strongly pH dependent. The difference between NH_3 and NH_4^+ is a H^+. For example, if NH_4^+ were applied to a soil at pH 7, the equilibrium condition would be 99% by mol NH_4^+ and 1% by mol NH_3. At pH 8, approximately 10% by mol would exist as NH_3.

This means that a fertilizer like urea is generally subject to higher losses at higher pH. But it does not mean that losses at pH 7 will be 1% by mol or less. The equilibrium is dynamic. As soon as a molecule of NH_3 escapes the soil, a molecule of NH_4^+ converts to NH_3 to maintain the equilibrium.

There are other factors such as soil moisture, temperature, texture and cation exchange capacity that can affect volatilization. So pH is not the whole story. The important point to remember is that under conditions of low soil moisture or poor incorporation, volatilization loss can be considerable even at pH values as low as 5.5.

Soil pH is also an important factor in the N nutrition of legumes. The survival and activity of Rhizobium, the bacteria responsible for N fixation in association with legumes, declines as soil acidity increases. This is the particular concern when attempting to grow alfalfa on soils with pH below 6.

Phosphorus

The form and availability of soil phosphorus (P) is also highly pH dependent. Plants take up soluble P from the soil solution, but this pool tends to be extremely low, often less than 1 lb/ac. (ProBase note: 1 lb/ac = 1.13 kg/ha)

The limited solubility of P relates to its tendency to form a wide range of stable minerals in soil. Under alkaline soil conditions, P fertilizers such as mono-ammonium phosphate (CAS number 11-55-0) generally form more stable (less soluble) minerals through reactions with calcium (Ca). Contrary to popular belief, the P in these Ca-P minerals will still contribute to crop P requirements. As plants remove P from the soil solution, the more soluble of the Ca-P minerals dissolve, and solution P levels are replenished. Greenhouse and field research has shown that over 90 percent of the fertilizer P tied up this year in Ca-P minerals will still be available to crops in subsequent years.

The fate of added P in acidic soils is somewhat different as precipitation reactions occur with aluminum (Al) and iron (Fe). The tie-up of P in Al-P and Fe-P minerals under acidic conditions tends to be more permanent than in Ca-P minerals.

Potassium

The fixation of potassium (K) and entrapment at specific sites between clay layers tends to be lower under acid conditions. This situation is thought to be due to the presence of soluble aluminium that occupies the binding sites.

One would think that raising the pH through liming would increase fixation and reduce K availability; however, this is not the case, at least in the short term. Liming increases K availability, likely through the displacement of exchangeable K by Ca.

Sulfur

Sulfate ($S0_4^{2-}$) sulfur, the plant available form of S, is little affected by soil pH.

Micronutrients

The availability of the micronutrients manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), and boron (B) tend to decrease as soil pH increases. The exact mechanisms responsible for reducing availability differ for each nutrient, but can include formation of low solubility compounds, greater retention by soil colloids (clays and organic matter) and conversion of soluble forms to ions that plants cannot absorb.

Molybdenum (Mo) behaves counter to the trend described above. Plant availability is lower under acid conditions.

Conclusion

So, soil pH does play a role in nutrient availability. Should you be concerned on your farm? Be more aware than concerned. Keep the pH factor in mind when planning nutrient management programs. Also, keep historical records of soil pH in your fields. Soils tend to acidify over time, particularly when large applications of NH_4^+ based fertilizers are used or there is a high proportion of legumes in the rotation.

Recent years have shown the pH decline occurring more rapidly in continuously cropped, direct-seeded land. On the other hand, seepage of alkaline salts can raise the pH above the optimum range. So, a soil with an optimum pH today may be too acid or alkaline a decade from now, depending on producer land management.

Prepared by:
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Student information sheet: Sustaining fertilisation

Extract from www.ipipotash.org

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Before planting, the nutrient content of the soil should be measured and the optimum supply should be maintained. Especially important is to supply potassium and organic nutrients.

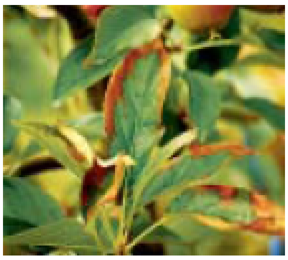
Increasing the concentration of organic nutrients is enhancing the uptake of nitrogen along with other elements among them potassium, too. Below 0.7-1% by mass humus content, no soil can be used for fruit-growing.

For the calculations of the amount of sustaining fertilizers, the potassium content of the soil should reach a *well-supplied* category which means 9.3 kg/hectare K_2O fertilizer pro ppm potassium need.

The calculated amount of fertilizer can be further increased according to the amount of humus, lime and clay, as well as the type of clay minerals in the soil. Because of bad soil structure, lack of air and insufficient water supply, deficiency of organic substances decreases the uptake of all nutrients.

Because of absorption of potassium on certain types of clay minerals, soils with high clay content need higher doses of potassium fertilizers. This is called meliorative potassium fertilizing.

Aspects to be taken into account for potassium fertilizing
- A harmonious nutrient supply for a fruit farm can only be guaranteed in case of an ideal potassium content of the soil.
- The ion antagonism between certain nutrients must be taken into consideration. Organic substances, humidity and airing of the soil influence the uptake of potassium. Therefore, yearly digging and soil covering plant cultivation improve the effect of fertilization.
- Overdoses of potassium lead to magnesium deficiency. This can be compensated by magnesium spray fertilizing.
- High potassium supply, especially on acidic and sandy soils damages stored apples which can be corrected by several calcium fertilizing of the soil.
- At the choice of potassium fertilizers, the chlorine sensitivity of plants, especially that of berries must be taken into account.



Teacher's document

Overview

Based on investigations of soils and fertilisers, students work in groups to make a proposal for sustained fertilisation of a soil with potassium deficiency. Before making their proposal, students take into account the available methods, as well as different agricultural and environmental aspects. In addition, they carry out economic calculations for the solution of the problem. They work in efficient and well-organised teams. Finally, they summarise their results and document them in a clear form.

Developing students' skills

Teachers can check their students' knowledge of theory using written test sheets corresponding to the work of each team. Manipulative skills, during experimental work, and correct handling of chemicals and equipment may also be assessed. Other laboratory competencies could be assessed by, for example, considering how long they take to do the work, how well they arrange their laboratory equipment and keep their workspace tidy, or how they organise their work etc.

An assessment of the way that students present their results can be based on how well they have handled all the data and ensured that it conforms to any protocols, and from the diagrams and tables constructed and filled using these data. When arranging teams, teachers should draw students' attention to the data that they will have to provide for other teams, in order that they may solve problems together.

Organising and managing the class

The availability of laboratory space and equipment will affect the way that teachers can plan the teams, tasks and methods. Depending on the ability and field of interest of the students, teachers could assign laboratory work, searching the Internet, data management, summarising and presentation of results to different members of the teams.

Teachers need to provide suitable conditions for drying and adequate storage of the soil sample.

Teachers need to review the methods to be used. They may need to show students the equipment and how to use it for the required measurements. When planning exact timing of analytical determinations, take into account that students make three replicate measurements. If suspicious results occur, these should be rejected and the analysis should be repeated - time may need to be allowed for this. Teachers should provide guidance for the evaluation of data. Results will need to be given clearly and precisely in tables so that teams can readily use each other's data.

Students should use computers to evaluate and document their work to meet the given requirements. It is therefore important that there is access to computers in the laboratory. Own or other computers can be used during out of class time, for example, to collect information for the work. For this, teachers could provide useful Internet links as a starting point. Students can, of course, also make use of classical literature references found in libraries.

Teachers are free to arrange students into different teams as they see fit. It could be according to different aspects, for example:

- measurement: analysis of soil sample, analysis of fertiliser, other measurements
- analytical method: photometric team, titrimetric team, etc.
- the elements to determine: teams to measure K^+, Ca^{2+}, Mg^{2+}, Cl^-, etc.

Teamwork can be used to best advantage if single teams work, evaluate their results and present them alone and then, a plenary session is arranged where the teams will discuss and summarise the results together. Depending on the number of students, they can work in groups of 3-5. If there are at least 3 members in a group, division of work is straightforward. For example, different team members can be involved in preparing calibration series, carrying out measurements or organising the results. Where there are groups with 3 or less members, teachers can omit part of the work. For example, for the *1st group*, the last three steps and for the *2nd group* the last two steps can be omitted; for the *3rd group*, only one sort of fertiliser could be measured and then the fifth and sixth step omitted and in the two last steps, only the pH of the untreated soil determined. Where this happens, the corresponding working sheets should be modified.

Practical laboratory work can be achieved in 2 x 6 x 45 = 540 minutes or 3 x 4 x 45 = 540 minutes or a similar arrangement. In longer practical lessons, preparative work (e.g. sample preparation, calculation and preparation of calibration series, evaluating and setting up results tables) can be included as well as the actual direct measurement. With shorter practical lessons, a full extra lesson should be provided for these additional activities. After the practical work, at least two lessons should be allowed for summarising and discussing the results and then, based on this, students can prepare the final report at home.

Session plan for teachers

<u>Theory lessons (180 minutes</u>)
Teachers provide theoretical knowledge:

- Physiological role of potassium and potassium cycle.
- Effect of optimum potassium level on plants, and supply of potassium by fertilisation.
- Disadvantageous effects and risks of overdoses, the role of ion antagonism in the healthy growth of plants.
- Environmental problems of artificial fertilising (nitrate and phosphate input).
- Disadvantages of the input of other ions (e.g. chloride, sulfate) for plants.
- The role of advising on fertilisers.
- Example for approximate calculation of a K^+ input.

Teachers provide practical knowledge:

- Possibilities of determining different components in the soil.
- Overview of each individual measuring procedure (repeating basic theory, practical procedure and aspects of the evaluation).
- Planning the work, exact timing, protocols and possibilities for a joint proposal to solve the given problem.

Literature:
Jackson, M. L., 1958. Soil Chemical Analysis. Prentice-Hall. Inc. Englewood Cliffs. New York.
Guide to the Classical Field Experiments, 1984. Rothamsted Experimental Station. Lawes Agric. Trust. Harpenden.
www.amazon.com/Introduction-Soil-Chemistry-Instrumentation-Applications
M. Cresser, Soil Chemistry and its Applications
M. I. Harpstead, Soil Science Simplified
Alfred R. Conklin, Introduction to Soil Chemistry, Wiley-Interscience 2005.

Practical lessons (540 minutes)
Students complete the practical project in 12 x 45 = 540 minutes or
9 x 60 = 540 minutes.

- Teachers provide equipment and space in the laboratory and computer room to complete the project.
- Before beginning the experiments, teachers check if students are prepared for the practical work, using test sheets with questions about the given topics.
- Teachers distribute descriptions of the experimental procedures and data sheets for the evaluation of the results.
- Students work alone and can be left to their own resources, but teachers may need to give guidance. If necessary, teachers might suggest new or supplementary procedures to complete the project.
- Students keep records during all their experimental work and, after the measurements are complete, document their results in the required format. If necessary, they share the results with other teams and they provide the results for them in a clear format. Teachers check evaluation and quality of the results to ensure they will be suitable for use at subsequent stages.
- At the final stage, students summarise their results and propose the final format of their report which they will complete at home.

Out of class time (360 minutes):

- Students prepare themselves for the practical work and for the problem-solving.
- Using as many sources of information as possible, students should familiarise themselves with the theory that will prepare them for the knowledge checks.
- Using the knowledge they have collected, they can prepare part of their reporting procedure in advance.
- Background information necessary to complete the project can be collected by visiting the Internet or the library.
- Collected information can be documented in written or printed form and included with their reporting tables etc.
- If necessary, students can buy the fertiliser samples themselves.
- After having measured all data, students prepare a report or presentation about their work.

Technical notes

- **Preparation**

For the soil extract, the soil should be prepared (dried, homogenised, ground to powder in a mortar and sieved) a day before the measurement. The measurement of the potassium content of the soil can be accelerated when the soil extract is made in advance by a technician because filtering the aqueous soil extract can take 2-5 hours depending on the structure of the soil.

For the titrations, the necessary standard solutions of exact concentrations and buffers should be prepared in advance. During the measurements, standard solutions will be diluted by the students.

- **Equipment and materials**

Preparation of the soil

Equipment

- drying oven
- sample holder
- pestle and mortar
- series of sieves

Preparation of the aqueous soil extract

Materials and their CAS numbers

distilled water

Equipment

- semi-micro balance (sensitive to 0.01 g)
- laboratory shaking machine
- access to refrigerator
- funnel holder
- filter paper
- clamp
- funnel
- beaker
- cylinder
- reagent bottle
- 500 cm^3 shaking flask

Determination of the K^+ content of the soil by flame photometry

Materials and their CAS numbers

distilled water	
KCl	7447-407
aqueous soil extract	

Equipment

- flame photometer
- analytical balance
- volumetric flask (500 cm^3)
- 10-12 volumetric flasks (100 cm^3)
- pipette (10 cm^3)
- burette

Complexometric determination of the Ca^{2+} and Mg^{2+} content of the soil

Materials and their CAS numbers

distilled water	
$Na_2B_4O_7.10\ H_2O$	1303-96-4
NaOH	1310-73-2
NH_4Cl	12125-02-9
NH_4OH	1336-21-6
EDTA	139-33-3
Murexid indicator	3051-09-0
Eriochrome Black T	1787-67-7
aqueous soil extract	

Equipment

- 6 x conical flasks (100 cm^3)
- 2 x calibrated burettes (50 cm^3)
- pipette (10 cm^3)
- 3 x volumetric flasks (1000 cm^3)
- 3 x volumetric flasks (100 cm^3, 250 cm^3 and 500 cm^3)
- 2 x graduated cylinder (10 cm^3, 200 cm^3)
- analytical balance

Argentometric determination of the Cl^- content

Materials and their CAS numbers

distilled water	
H_2SO_4	7664-93-9
NaOH	1310-73-2
phenolphthalein	77-09-8
K_2CrO_4	7789-00-6
$AgNO_3$	7761-88-8
aqueous soil extract	

Equipment

- 3 x conical flasks (100 cm^3)
- calibrated burette (50 cm^3)
- pipette (10 cm^3)
- 3 x volumetric flasks (100 cm^3, 250 cm^3 and 500 cm^3)

Determination of pH(H_2O)

Materials and their CAS numbers

distilled water	
buffer solution of pH 7.00	7778-77-0
air-dried soil sample	

Equipment

- pH meter (with combined glass electrode)
- semi-micro balance (sensitive to 0.01 g)
- test tubes

Determination of pH(KCl)

Materials and their CAS numbers

distilled water	
KCl	7447-407
buffer solution of pH 7.00	7778-77-0
air-dried soil sample	

Equipment

- pH meter (with combined glass electrode)
- semi-micro balance (sensitive to 0.01 g)
- analytical balance
- volumetric flask (1000 cm^3)
- test tubes

TESTING PRIOR KNOWLEDGE

1. Which property of the alkali and alkaline earth metals enables them to be determined by flame photometry?
    a. Their standard potential is a positive value
    b. They have a characteristic colour in the flame
    c. They form strong complexes

2. Which are the alkali and alkaline earth macro elements among the ones listed?

N, O, S, P, K, Ca, Mg, B, C, Fe, Cu

3. What does the *minimum law* state for nutrient supply to plants?

The minimum law states that the yield of a crop is determined by the element present in the smallest quantity relative to the need of the plant.

4. Write the formulae of the following salts in order of their increasing K content (% by mass): KNO_3, KCl, K_2SO_4.

$KNO_3 < K_2SO_4 < KCl$

5. Calculate how many grams of KCl must be weighed to prepare 500 cm^3 0.01 mol/dm^3 KCl solution?

0.37275 g

6. Why is it important to add a preservative to the soil if analysis may take a long time?

Bacterial action can cause changes in the physical and chemical properties of the filtered soil extract. For example, the clear filtered solution may become turbid and acquire an unpleasant odour. Also, its chemical composition can change, e.g. the pH can be shifted because of fermentation or decomposition.

7.) What is a combined glass pH electrode?

A glass pH electrode with an internal reference electrode.

8.) What maintenance do glass electrodes need?

The glass membrane in a glass electrode must not dehydrate. Therefore, it must be stored in distilled water. The internal space of the electrode must be filled with 1 mol/dm^3 KCl solution and, for long term storage, must be submerged in a KCl solution. For regeneration, they must be dipped in a 0.1 mol/dm^3 HCl solution and then in distilled water for 24 hours.

9. The name EDTA is an abbreviation of the disodium salt of ethylenediaminetetraacetic acid. Write the formula for the compound.

$(NaOOC\text{-}H_2C)_2N\text{-}CH_2\text{-}CH_2\text{-}N(CH_2\text{-}COONa)_2$

10. State whether Mg^{2+} ions can be measured directly using the given complexometric determination procedure of Ca^{2+} and Mg^{2+} ions.

No. In the procedure described, the sum of Ca^{2+} and Mg^{2+} ions is measured. The amount of Mg^{2+} ions is determined indirectly by calculation using the previously determined amount of Ca^{2+} ions.

11. In argentometric titrations, K_2CrO_4 indicator is used. Write a balanced equation for the reaction of silver ions with chromate ions.

$2Ag^{+} + CrO_4^{2-} = Ag_2CrO_4$

12. Explain the role of K_2CrO_4 indicator, based on the solubility of Ag_2CrO_4 (formed from the indicator) and the solubility of AgCl.

First, less soluble AgCl precipitates. Just when the precipitation of Cl^- ions is complete, silver ions react with the indicator CrO_4^{2-} forming coloured Ag_2CrO_4 precipitate, indicating this way the excess of Ag^+ ions.

Note: answers are given in red. These need to be removed before the test is used.

TESTING PRIOR KNOWLEDGE

1. Which property of the alkali and alkaline earth metals enables them to be determined by flame photometry?
   a. Their standard potential is a positive value
   b. They have a characteristic colour in the flame
   c. They form strong complexes

2. Which are the alkali and alkaline earth macro elements among the ones listed?

N, O, S, P, K, Ca, Mg, B, C, Fe, Cu

3. What does the *minimum law* state for nutrient supply to plants?

4. Write the formulae of the following salts in order of their increasing K content (% by mass): KNO_3, KCl, K_2SO_4.

.... < .... < ....

5. Calculate how many grams of KCl must be weighed to prepare 500 cm^3 0.01 mol/dm^3 KCl solution?

6. Why is it important to add a preservative to the soil if analysis may take a long time?

7.) What is a combined glass pH electrode?

8.) What maintenance do glass electrodes need?

9. The name EDTA is an abbreviation of the disodium salt of ethylenediaminetetraacetic acid. Write the formula for the compound.

10. State whether Mg^{2+} ions can be measured directly using the given complexometric determination procedure of Ca^{2+} and Mg^{2+} ions.

11. In argentometric titrations, K_2CrO_4 indicator is used. Write a balanced equation for the reaction of silver ions with chromate ions.

12. Explain the role of K_2CrO_4 indicator, based on the solubility of Ag_2CrO_4 (formed from the indicator) and the solubility of AgCl.