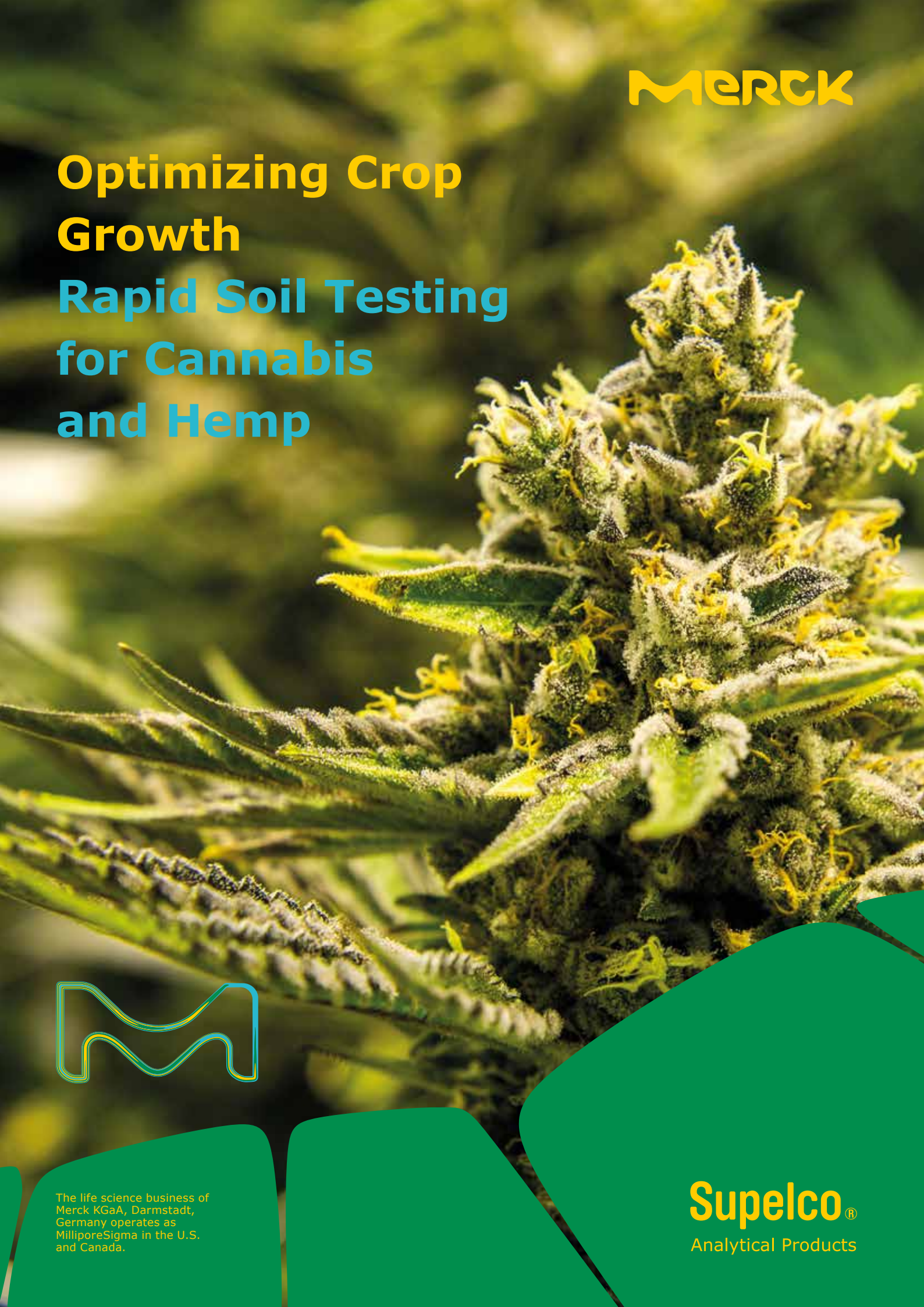

Optimizing Crop Growth

Rapid Soil Testing for Cannabis and Hemp

Supelco®
Analytical Products

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1. Cannabis and Soil Hemp Testing

Cannabis is suspected to have originated in central Asia and it has been used for its alleged healing properties for millennia. Nowadays, research studies have advanced our knowledge on the multiple and complex properties of its different constituents. In the development of any final cannabis product, assured quality and accuracy are key.

As a leading supplier to the global Life Science industry, we understand the analytical and regulatory challenges involved in cultivation, processing, extraction, and quality control of the cannabis products. We offer expertise and a range of products and services to support your cannabis testing workflow.

Hemp is a crop grown across the world. It's production offers broad opportunities for farmers, industrial sectors and consumers, and contributes with a number of environmental benefits. Hemp-derived products are used in different industries and for different purposes including hemp fiber in the textile industry, construction and paper production as well as hemp seeds in food and feed.

Whether you cultivate your plants in- or outdoors, using soil, hydroponics, or practice micropropagation – knowing that your plants get the right amount of nutrients they need is imminent to a successful harvest.

The right concentration of parameters such as nitrate, phosphate and potassium, the right pH and water hardness, as well as metals should be monitored as the availability of nutrients is essential for the growth of plants to keep them healthy and help them thrive.

To ensure this, a quick analysis of the substrate the plant is grown on, as well as the water used enables you to optimize the use of fertilizer. Test strips like MQuant® test strips are designed for easy use by individuals, so cannabis and hemp growers can use this method to check the pH and nutrient levels in soil to optimize plant growth. Test strips are easy to use and can be disposed readily without the need for chemical waste management. They provide quick semi-quantitative results for direct in-process control with instant results for fast decision making.

Support at every step of the cannabis testing workflow

As cannabis is being legalized in many countries around the world, there is an increasing need for accurate and precise testing methods, as well as quality control and microbial analysis. We offer the most comprehensive selection of analytical and microbial tools to promote the safety and efficacy of cannabis products. From sample prep and chromatography columns to certified reference materials, water purification systems and hygiene monitoring, we offer solutions for your end-to-end cannabis testing workflow.

2. Rapid Chemical Testing

Test strips are a simple, effective, and low-cost analytical tool used for the rapid detection of an analyte in the field or on-site. A test strip impregnated with a chemical that reacts with the analyte is either dipped in the sample solution or the sample is loaded onto the test strip. The use of test strips for in-process detection is advantageous due to the ease of use and the high specificity offered by them. The results of the test strips are based on visual observation using MQuant® test strips. The color change on the test strip is compared to a color scale provided with the product. This allows to determine the concentration or presence/absence of the target substance in the sample.

Liquid tests include colorimetric and titrimetric tests that allow the quick measurement of all major parameters for soil and water analysis on the spot. MQuant® liquid tests offer easy, fast, and direct read-out using color cards, disks, or vessels for quick and precise testing from high, to medium, to low concentrations. No special training is required – simply follow the illustrated instructions. Despite their simplicity, rapid visual tests offer unparalleled reliability.

Both MQuant® test strips and MQuant® liquid test kits are suitable for a time-saving semi-quantitative determination of important ions and compounds.

3. Method Overview: Soil Testing

Table 1: Rapid test methods for soil and water testing

Parameter	MQuant® Test	Measuring Range	Method principle	page
Nitrogen				**5**
Nitrate	1.10020	10 – 25 – 50 – 100 – 250 – 500 mg/l NO_3^-	Test strips	5
Ammonium	1.14657	0.5 - 1 - 2 - 3 - 5 - 10 mg/l NH_4^+	Liquid test with color card	6
Phosphate	1.10428	10 – 25 – 50 – 100 – 250 – 500 mg/l PO_4^{3-}	Test strips	**7**
Potassium	1.17985	250 – 450 – 700 – 1,000 – 1,500 mg/l K	Test strips	**8**
pH	1.09542	pH 4.0 - 4.4 - 4.7 - 5.0 - 5.3 - 5.5 - 5.8 - 6.1 - 6.5- 7.0	Test strips	**9**

Table 2: Further tests for water analysis

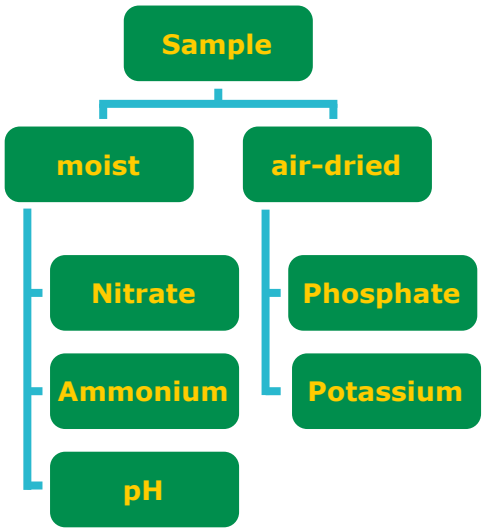
Parameter	MQuant® Test	Measuring Range	Method principle	page
Carbonate Hardness	1.10648	5–10–15–20–30 °e	Test strips	**13**

By using the MQuant® tests mentioned above it is possible to determine very quickly how many grams/kilograms of potassium, phosphate, and mineralized nitrogen in the form of nitrate and ammonium are present in the soil/substrate and what the pH value is. However, precise work is essential to obtaining valid results.

4. Soil Sampling Procedure

Sampling is an essential step in the soil/substrate analysis. Samples should be taken as appropriate for the parameter to be tested.

Samples are taken by using a spade (soil layer < 30 cm) or a sampling tube (soil layer > 30 cm). The sample should be representative of the tested cultivation field/container. In addition, an appropriate number of samples should be taken from different parts of the field/container. Samples are taken from the topmost layer (< 30 cm). After sampling, mix the samples thoroughly. Depending on the parameter to be tested, the samples should be air-dried before preparing the sample solution, see the following diagram:



5. Nitrogen

Nitrogen plays a very special role in agriculture and is probably the most important nutrient for many plants, including cannabis and hemp. It is a component of amino acids, nucleic acid, enzymes and the pigment chlorophyll. To obtain the best yields and high-quality products, this nutrient must be made available to the plants in adequate quantities. A lack of nitrogen results in poor plant nutrition and corresponding reduction in yield. Overfertilization also results in poor-quality products, pollution of the environment and unnecessary expense. It is therefore necessary to determine the available nitrogen concentration (nitrate NO_3^- and ammonium NH_4^+) prior to every fertilization with nitrogen (N).
The quantity of fertilizer can then be dosed accordingly, or omitted altogether if the concentration available in the soil is adequate.
By measuring at growth onset, the natural nitrate supply (mineralization) of the ground can be utilized. The more nitrate (NO_3^-) the soil supplies, the smaller the amount of fertilization required.

5.1 Preparation of the soil suspension

Preparation of the extraction solution (KCl-solution 0.1 mol/l)

Dissolve 7.46 g potassium chloride (Cat. No. 1.04936) in distilled water and make up to 1,000 ml with distilled water in a volumetric flask.

Preparation of the soil suspension

Add 100 ml of extraction solution to each 100 g soil sample and stir vigorously with the spoon for at least 2 minutes to prepare the soil suspension.

5.2 Filtration of the soil sample

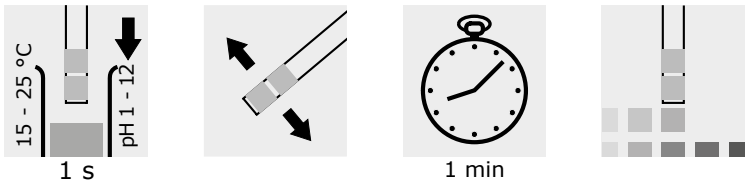
The soil suspension is filtered as followed:
A circular filter is folded twice and placed in the soil suspension in such way, that the filtration takes place from the outside to the inside.

Note: This filtrate is suitable for measuring the nitrate and ammonium contents as well as the pH value of the soil sample.

5.3 Determination of nitrate-nitrogen

Nitrate determination with MQuant® Nitrate Test (test strips), Cat. No. 1.10020:

1. Take the test strip and immerse both reaction zones of the test strip in the resulting filtrate sample (15 - 30 °C) for 1 sec.
   If the soil suspension filters too slowly, briefly press the test strip against the moist inner surface of the filter.
2. Fully wind up the timer and set the pointer to exactly 1 minute.
3. Shake off excess liquid from the strip and after 1 min (ring) determine with which color field on the label the color of the NO_3^-- reaction zone coincides most exactly.
   Read off the corresponding result in mg/l NO_3^- or NO_3-N.



Notes:

- The values given on the color scale, e.g. 100 mg/l NO_3^- are equivalent in this procedure to mg/kg and also to 100 kg of N per ha in the corresponding 30 cm layer of soil.
- To assess the water content of the sample, see chapter 10.1, "Assessing the water content of the soil".

5.4 Determination of ammonium-nitrogen

The soil suspension is prepared according to 5.1 - 5.2. Instead of the extraction solution, distilled water can be used.

Ammonium determination with MQuant® Ammonium Test (colorimetric), Cat. No. 1.14657:

1. Transfer 5 ml of the filtrate to the test tube with the syringe.
2. Add 10 drops of reagent NH_4-1 and mix.
3. Add 1 level blue microspoon (in the cap of the NH_4-2 bottle) of reagent NH_4-2, close the tube and shake vigorously until the reagent is completely dissolved.
4. Leave to stand for 5 minutes (use the timer).
5. Add 6 drops of reagent NH_4-3 and mix.
6. Leave to stand for 5 minutes (use the timer).
7. Place the test vessel on the white area next to the color zones of the color card and determine with which field of the scale the color of the measurement solution - viewed from above - coincides most exactly. Read off the result in mg/l NH_4^+ from the color card. If necessary, multiply the result by 0.778 to converse the result into mg/l NH_4-N.

Notes:

- The values given next to the color scale e.g. 3 mg/l NH_4^+, are equivalent to mg NH_4^+/kg of naturally moist soil (respect. 3 mg/l NH_4-N are equivalent to 3 mg NH_4-N/kg of naturally moist soil.)
- To consider the water content of the sample, see chapter 10.1, "Considering the water content of the soil".
- If the value found lies above 10 mg/l NH_4^+, the filtrate must be diluted. Transfer only 1 ml of filtrate to the test tube with the syringe and make up to the 5-ml mark with extraction solution. Multiply the value read off the scale by the dilution factor 5.

6. Phosphate

6.1 Phosphorus ranges and significance of phosphorus in soil

Phosphorus is one of the three macro nutrients for plants. It is essential to many biochemical processes, e.g. metabolism and energy balance. It is also a component of cell walls, DNA, proteins and enzymes. Phosphorus is absorbed by the plants in the form of water-soluble phosphates.

6.2 Preparation of the soil suspension

Preparation of the DL-solution for extraction

Stock solution:

Add 800 ml boiling water to 120 g calcium lactate (Cat. No. 21185) and stir until the lactate is completely dissolved. Add 40 ml 32% hydrochloric acid (Cat. No. 1.00319) to the warm solution and fill up to 1 l by adding distilled water after the solution has cooled down to room temperature.

DL solution for use: (prepare the solution daily!)

Dilute 50 ml stock solution to 1 l using distilled water. The pH of the solution for use must be 3.6.

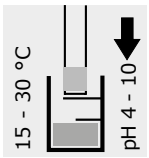
Preparation of the soil suspension

Weigh approx. 5 g (exactly weighed) of air-dried, sieved (using the fraction < 2 mm) soil into a beaker and add 250 ml DL solution for use. Shake for 90 minutes and filter through a folded filter.

6.3 Determination of phosphate

Phosphate determination with MQuant® Phosphate Test (test strips), Cat. No. 1.10428:

1. Take the test strip and immerse the reaction zone of the test strip in the resulting filtrate sample (15 - 30 °C) for 1 sec.
2. Allow excess liquid to run off via the long edge of the strip onto an absorbent paper towel.
3. Place 1 drop of reagent PO_4-1 on the reaction zone. Hold the bottle vertically while adding the reagent!
4. Wait for 15 sec.
5. Allow excess liquid to run off via the long edge of the strip onto an absorbent paper towel. (Caution! Reagent contains sulfuric acid!)
6. Wait for 1 min.
7. Determine with which color field on the label the color of the reaction zone coincides most exactly. Read off the corresponding result in mg/l PO_4^{3-} or PO_4-P.



1 s | 1 x PO_4-1 | 15 s | 1 min

6.4 Calculation of the result

The phosphate content in mg/kg is calculated as follows:

$$\text{Phosphate content [mg/kg]} = \frac{\text{Measured value} \cdot \text{Volume extract.sol [ml]}}{\text{Weight of sample [g]}}$$

$$\text{Phosphate content [mg/kg]} = \text{Measured value} \cdot 50$$

7. Potassium

7.1 Potassium ranges and significance of potassium in soil

Potassium is one of the three macro nutrients for plants. It is essential to many biochemical processes, e.g. sustaining osmotic pressure in the plant cells, and therefore to cell growth. It is also essential to water transportation and enzymatic reactions. Due to its major role in plant growth, an adequate amount of potassium is required to achieve an optimal harvest.
The potassium content of mineral soils ranges from 0.04% to 3%. Most of this potassium is bound and only a small amount is directly available. This test determines only directly available potassium.

7.2 Preparation of the soil suspension

Preparation of the 0.0125 molar calcium chloride solution

Weigh approx. 2 g of calcium chloride dihydrate (Cat. No. 1.02382) using the balance.
This amount is given into a 1 l bottle, and it is filled to the neck with distilled water to 1 l.

Preparation of the soil suspension

Add 100 ml of extraction solution to 100 g air-dried soil sample and stir vigorously with the spoon for at least 2 minutes to prepare the soil suspension.

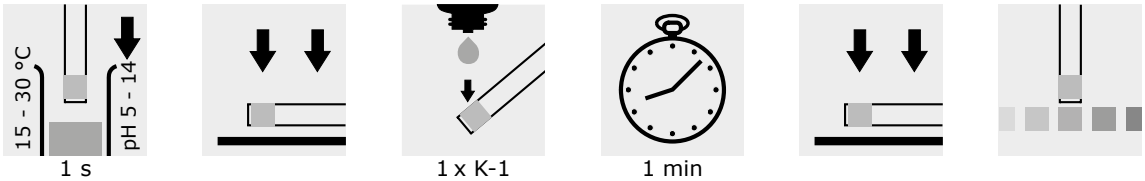
7.3 Filtration of the soil sample

The soil suspension is filtered as followed:
A circular filter is folded twice and placed in the soil suspension in such way, that the filtration takes place from the outside to the inside.

7.4 Determination of potassium

Potassium determination with MQuant® Potassium Test (test strips), Cat. No. 1.17985:

1. Take the test strip and immerse the reaction zone of the test strip in the resulting filtrate sample (15 - 30 °C) for 1 sec.
2. Allow excess liquid to run off via the long edge of the strip onto an absorbent paper towel.
3. Place 1 drop of Reagent K-1 on the reaction zone. Hold the bottle vertically while adding the reagent!
4. Wait for 1 min.
5. Allow excess liquid to run off via the long edge of the strip onto an absorbent paper towel.
6. Determine with which color field on the label the color of the reaction zone coincides most exactly. Read off the corresponding result in mg/l K.



8. pH Value (soil reaction)

8.1 pH value ranges

Soils are classified as strongly acidic, acidic, weakly acidic, neutral and alkaline according to their lime content which has an influence on the soil structure. Science has introduced the concept "pH value" (soil reaction) for this. If soil tested with the kit reacts neutrally, it will have a pH value of 7, while values over 7 indicate alkaline soil and below 7, acidic soil.

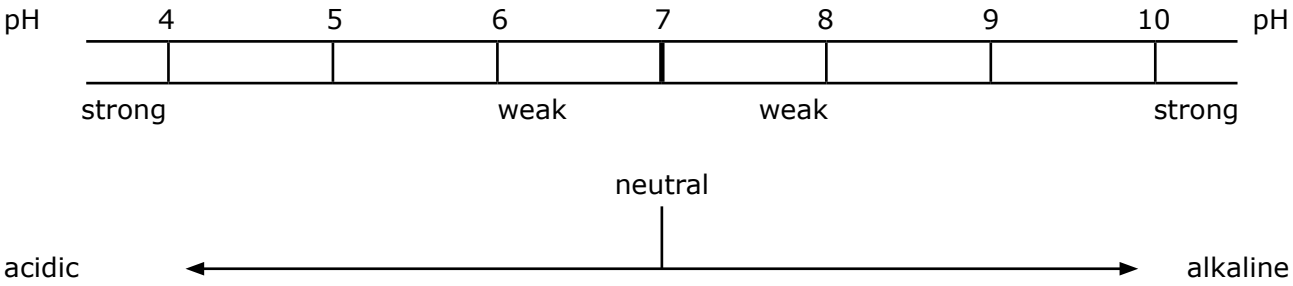


Fig. 1: pH-ranges

8.2 The significance of the pH value for plant growth

Besides soil structure, the pH value is another important factor in nutrition availability. Cannabis and hemp plants tolerate a relatively wide soil pH range without visible effects (pH 5.0 - 7.0). If the pH value is too low, one possibility is that iron and manganese intake might be too high, resulting in brown and/or black leaf speckle. At pH levels above 7.0, the amounts of other nutrients available to the plants are reduced.
The pH range for optimal nutrient supply depends on the soil/substrate used and should be determined in advance.
To ensure optimal growth, soil pH should be tested at regular intervals.

8.3 Preparation of the soil suspension

If a sample solution for measuring nitrate or ammonium has already been prepared proceed with step 7.6, "Measurement of the pH value". Otherwise prepare the soil suspension as follows:

Preparation of the extraction solution (KCl-solution 0.1 mol/l)

Dissolve 7.46 g potassium chloride (Cat. No. 1.04936) in distilled water and make up to 1,000 ml with distilled water in a volumetric flask.

Preparation of the soil suspension

Add 100 ml of extraction solution to each 100 g soil sample and stir vigorously with the spoon for at least 2 minutes to prepare the soil suspension.

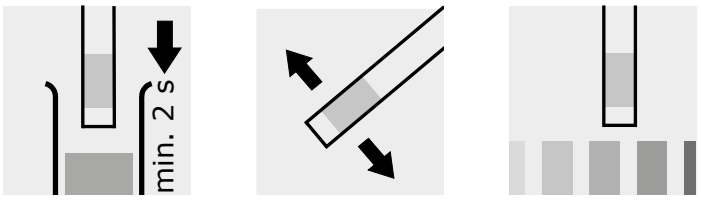
8.4 Filtration of the soil sample

The soil suspension is filtered as followed:
A circular filter is folded twice and placed in the soil suspension in such way, that the filtration takes place from the outside to the inside.

8.5 Measurement of the pH value

pH determination with MQuant® pH-indicator strips pH 4.0 - 7.0, Cat. No. 1.09542:

1. Take an indicator test strip and dip or hook it for at least 3 minutes in the resulting filtrate sample (see chapter 5.3, "Measuring the nitrate-nitrogen"). To hook the strip in the filtrate, fold the upper end to form a hook.
2. Remove the indicator test strip, shake off excess solution and determine the pH value by comparison with the color scale.



8.6 pH simple test

To obtain a rough idea of the soil reaction (pH value), the pH indicator test strips can be used as follows:
Press a pH indicator test strip against the naturally moist ground for at least 2 minutes. Dry or roughly structured soils can be moistened with a small amount of water. The colors on the pH indicator test strip are compared with the color chart supplied and the pH value is read off.
If the reaction zones of the indicator test strip are covered with soil, they can be briefly rinsed with distilled water or extraction solution without significantly changing the pH value.

Alternatively: Use the MQuant® pH-indicator strips pH 2.0 - 9.0, a special indicator test strip for pH measurement in turbid solutions (suspensions), Cat. No. 1.09502. Using a transparent carrier foil for this specific test strip, the reaction zones can be easily compared on the back of the test strip.

9. Testing the Irrigation Water

Rapid test methods such as test strips or visual test kits can be used for checking both soil nutrients and the irrigation water. Many tests besides those listed above can be used to check water quality. Carbonate hardness is an especially important test parameter since it has a direct influence on the pH value and is therefore important for nutrient bioavailability. It can be tested using MQuant® Carbonate Hardness test strips (Cat. No. 1.10648). Additional tests are available online.

10. Correction and Calculation of the Results

10.1 Considering the water content of the soil

To obtain reliable results from the rapid test, the content of water in the soil should also be considered. As the aqueous phase becomes larger with an increasing proportion of water, the results obtained in practice tend to be too low. For this, the soil sample is dried under normal atmospheric conditions to determine the moisture content, for which the correction factor is given in the following table:

Exact addition values after drying the soil to take into account the water content													
Soil water content in percent by weight	1	2	3	4	5	6	7	8	9	10	11	12	13
Factor	1.02	1.04	1.06	1.08	1.11	1.13	1.15	1.17	1.20	1.23	1.25	1.27	1.30

Soil water content in percent by weight	14	15	16	17	18	19	20	21	22	23	24	25
Factor	1.33	1.35	1.38	1.41	1.44	1.47	1.50	1.53	1.56	1.60	1.63	1.67

Example:

Water content: 10%
Factor: 1.23
Measured Value: 140 kg N/ha
Corrected Value: 120 kg N/ha · 1.23 = 148 kg N/ha

Water content estimation
As a rough guide it is sufficient to multiply the nitrate/ammonium value read off the scale by 1.1 for **dry soils**, 1.3 for **normal soils** and 1.5 for **wet soils**.

Example:

If the color on the scale matching that of the test strip corresponds to 60 mg/l, the corrected value for normal soils is then 50 · 1.3 = 65 kg N.

10.2 Conversion referring to areas

Measurement using the test strips shows the result in mg/l, which is then converted to mg/kg. The concentration of nutrients contained in specific soil areas is of particular interest in outdoor farming. For example, the mg/kg result can be converted to kg/ha as follows for this purpose:

Result in kg/defined area = V · A · LT · D · F

where:

V Measured value in mg/kg (possibly corrected for water content)
A area in m^2
LT Layer thickness in m
D Soil density (1.5 kg/dm^3)
F factor of 0.001

Example:

Measured value	100 mg/kg NO_3-N
Area	1 ha (= 10,000 m^2)
Layer thickness	30 cm (= 0.3 m)
Soil density	1.5 kg/dm^3

Result in kg NO_3-N/ha = 100 mg/kg · 10,000 m^2 · 0.3 m · 1.5 kg/dm^3 · 0.001
Result in kg NO_3-N/ha = 450

10.3 Dilution factor

If the measured concentration of the parameter is too high, or if the prepared soil suspension is too mushy, more extraction solution may be required. This increased dilution must be considered when the result is calculated. Proceed as follows:

$$\text{Corrected result [mg/kg]} = \text{Measured result [mg/kg]} \cdot \frac{\text{Extraction volume acc. to manual [ml]}}{\text{Used extraction volume [ml]}}$$

11. Troubleshooting

This chapter is about what you can do, if the results are not as expected, or if any errors occur.

What happened	What to do
Value is too high	Prepare a soil suspension in a higher dilution and repeat the test. Multiply the result by the corresponding dilution factor.
Value is too low	If possible, increase the amount of soil in the soil suspension and repeat the test. Multiply the result by the corresponding dilution factor. Otherwise: Use a more sensitive method (Reflectoquant®, Spectroquant® or others)
Soil suspension cannot be filtered	Depending on the soil you are using, some soil substrates absorb almost all of the added extraction solution, making proper filtration impossible. If this is the case, prepare a soil suspension in a higher dilution. Multiply the result by the corresponding dilution factor.
Values are invalid	Check the test strips using standard solutions as described in the test strip or test kit Instructions for Use or contact our Technical Service.

12. Ordering Information

Cat. No.	Description
1.14657	**MQuant® Ammonium Test** Method: colorimetric with color card 0.5 - 1 - 2 - 3 - 5 - 10 mg/l NH_4^+
1.02382	**Calcium chloride dihydrat for analysis EMSURE®**
21185	**Calcium L-lactate hydrate**
1.10648	**MQuant® Carbonate Hardness Test** Method: colorimetric with test strips 4 - 8 - 12 - 16 - 24°d
1.00319	**Hydrochlorid acid solution 32% for analysis EMSURE®**
1.10020	**MQuant® Nitrate Test** Method: colorimetric with test strips 10 - 25 - 50 - 100 - 250 - 500 mg/l NO_3^+
1.09502	**MQuant® pH-indicator strips pH 2.0 - 9.0** for pH measurements in turbid solutions (suspensions) non-bleeding pH 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9
1.09542	**MQuant® pH-indicator strips pH 4.0 - 7.0** non-bleeding pH 4.0 - 4.4 - 4.7 - 5.0 - 5.3 - 5.5 - 5.8 - 6.1 - 6.5 - 7.0
1.10428	**MQuant® Phosphate Test** Method: colorimetric with test strips and reagent 10 - 25 - 50 - 100 - 250 - 500 mg/l PO_4^{3-}
1.17985	**MQuant® Potassium Test** Method: colorimetric with test strips and reagent 250 - 450 - 700 - 1000 - 1500 mg/l K
1.04936	**Potassium chloride for analysis EMSURE®**
1.16754	**Water for analysis EMSURE® [1)]**

[1)] Water for analysis EMSURE® can be used as an alternative for distilled water

13. Other Methods: Reflectoquant® and Spectroquant®

If there is a need for more accurate results, we recommend more sensitive test methods i.e., reflectometry or photometry. Our Reflectoquant® series is a comprehensive system with an easy-to-use reflectometer, test kits, and test strips for high-quality, quantitative, and cost-effective on-site analysis of a broad range of parameters. The Reflectoquant® system includes Reflectoquant® test strips and the portable RQflex® 20 instrument for on-site, direct sample analysis.

Liquid test systems like the Spectroquant® photometric test kits in combination with the colorimeter Move 100 provide more precise results and additional supporting quality documentation. Spectroquant® Move 100 is a portable colorimeter for fast, precise on-site analysis of every important parameter for soil and water testing. Spectroquant® tests additionally offer solutions for total nitrogen analysis and analysis of lower concentrations of metals like copper and iron.

Below is a small selection of available tests. More test parameters and measurement ranges can be found at sigmaaldrich.com/test-strips or sigmaaldrich.com/photometry.

Cat. No.	Description
1.17246	**Reflectoquant® instrument:** RQflex® 20
1.16892	Reflectoquant® Ammonium Test
1.16125	Reflectoquant® Calcium Test
1.16124	Reflectoquant® Magnesium Test
1.16971	Reflectoquant® Nitrate Test
1.16996	Reflectoquant® pH Test
1.16978	Reflectoquant® Phosphate Test
1.16992	Reflectoquant® Potassium Test
1.16997	Reflectoquant® Total Hardness Test
1.73632	**Spectroquant® instrument:** Colorimeter Move 100
1.14739	Spectroquant® Ammonium Cell Test
1.00858	Spectroquant® Calcium Cell Test
1.14553	Spectroquant® Copper Cell Test
1.14549	Spectroquant® Iron Cell Test
1.14542	Spectroquant® Nitrate Cell Test
1.14547	Spectroquant® Nitrite Cell Test
1.14543	Spectroquant® Phosphorus (total- and ortho-Phosphate) Cell Test
1.14537	Spectroquant® Total Nitrogen Cell Test

14. Literature

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