HI 3896
HANNA Soiltest

Soil Test Handbook

Soil Science and Management

MAN3896R3 07/04

HANNA instruments

www.hannainst.com

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Allow the tube to stand for at least 5 minutes. The clearer the extract becomes the better. However, some cloudiness will not affect the accuracy of the test.

- Nitrogen (NO_3) test
  Use the pipette to transfer 2.5 ml of the clear general soil extract to a clean test tube. [Pay attention not to transfer any soil. To avoid agitation of the soil, squeeze the bulb of the pipette before inserting it into the soil extract solution.] Add the content of one packet of HI3896-N reagent. Replace the cap and shake vigorously for 30 seconds to dissolve the reagent. Allow the tube to stand for 30 seconds. Match the pink color with the NO_3 color-card, and note the NO_3.

- Phosphorus (P_2O_5) test
  Use the pipette to transfer 2.5 ml of the clear general soil extract to a clean test tube. [Pay attention not to transfer any soil. To avoid agitation of the soil, squeeze the bulb of the pipette before inserting it into the soil extract solution.] Add the content of one packet of HI3896-P reagent. Replace the cap and shake vigorously for 30 seconds to dissolve the reagent. Match the blue color with the P_2O_5 color-card, and note the P_2O_5.

- Potassium (K_2O) test
  Use the pipette to add 0.5 ml of the clear general soil extract to a clean reaction tube. [Pay attention not to transfer any soil. To avoid agitation of the soil, squeeze the bulb of the pipette before inserting it into the soil extract solution.] Fill the tube to the lower graduation mark (2.5 ml) with the HI3896 Extraction solution. Add the content of one packet of HI3896-K reagent. Replace the cap and shake vigorously for 30 seconds to dissolve the reagent. A blue color develops. Read the TURBIDITY formed on the K_2O reading-card as explained in the “Test Procedure”, and note the K_2O.

Note: prolonged exposure to light may damage the colors of the comparing cards and cause them to shift or fade. Please store them out of light when not in use.

Health & Safety

The chemicals contained in this test kit may be hazardous if improperly handled. Read carefully Health & Safety Data Sheets before performing the tests. Keep your kit out of reach of children. Store it indoors in a clean, dry location. Keep away from food, drink and animal feed. Always wash your hands thoroughly after making your tests.
Health and safety data sheets are available on line: www.hannainst.com

Contents

240 ml of HI 3896 Extraction solution; 100 ml of HI 3896 pH indicator reagent; 75 powder packets (25 each for N, P and K); 3 pipettes (1 ml); 5 test tubes; 1 tube-stand; 1 spoon; 1 brush; 4 color cards; 1 graduated card; 1 handbook.

4) Depth of extraction:
General: dig and discard the 5 cm (2") of topsoil
For lawns: take the sample at a depth of 5 to 15 cm (from 2" to 6").
For other plants (flowers, vegetables, shrubs): from 20 to 40 cm of depth (8" to 16")
For trees: Samples from 20 to 60 cm of depth (8" to 24").
5) Mix all the samples together to obtain a homogeneous mixture of soil.
6) From this mixture, take the quantity of dried soil that you need for the analysis, discarding stones and vegetable residues.

Test Procedure

1) Reading the color-card
– The pH, phosphorus (P_2O_5), and nitrogen (NO_3) tests are colorimetric tests. During the test a color is developed which corresponds with the fertility of the soil for e.g. P_2O_5. To read the fertility, the color developed has to be compared with a color-card.
To match the color, hold the tube with the test solution approximately 2 cm away from the color-card. Stand with the light source behind the card and read: Trace, Low, Medium or High. If the color of the test tube falls between two standard colors, e.g. between Medium and High Report the test result as Medium-High. Eight different readings are possible, Trace, Trace-Low, Low, Low-Medium, Medium, Medium-High, High, and very-High.
– The potassium (K_2O) test is a turbidimetric test. If potassium is present, turbidity is formed. A blue color will also develop to help reading the test result.
To read the test result, hold the tube against the reading-card over the reading area. Stand with the light source behind your back. Start at Trace, looking through the tube, and go to Low, Medium or High until you just can see the white line in the middle of the reading area. Report the reading only in Trace, Low, Medium or High.

2) Performing the tests
– pH test
Fill a reaction tube up to the lower graduation mark (2.5 ml) with the HI 3896 pH indicator reagent (use the graduated card for the measure). Use the small spoon to add six measures of soil sample. Replace the cap and shake gently for one minute. Allow the tube to stand for 5 minutes (use the tube-stand). Match the color with the pH color-card, and note the pH value.
– Nitrogen (N), Phosphorus (P), Potassium (K)
• General Extraction procedure [for the P, N, and K tests]
Fill a reaction tube to the third graduation mark (7.5 ml) with the HI3896 Extraction solution. Use the small spoon to add the following: nine measures of soil sample, in case of field soil testing; six measures of soil sample, in case of garden soil testing.
Replace the cap and shake gently for one minute.

SOIL AND PLANT LIFE

Soil is very important for the plants. It is not merely a support system, but a complex world from which the roots obtain water and other required elements. In addition, soil is inhabited by small animals, insects, microorganisms (e.g. fungi and bacteria) which all influence the plant life in one way or another.
One can talk about a soil evolution, that is, change in its characteristics based upon climate, presence of animals and plants as well as man's action. Therefore, a natural soil, in which evolution is slow, is very different from a cultivated one.
Soil is composed of solids (minerals and organic matters), liquids (water and dissolved substances), gases (mostly oxygen and carbon dioxide) and contains living organisms. All these elements provide its physical and chemical properties.
Managing the soil properly is necessary in order to preserve its fertility, obtain better yield and respect the environment. Testing the soil on the other hand is a must in order to manage it properly.

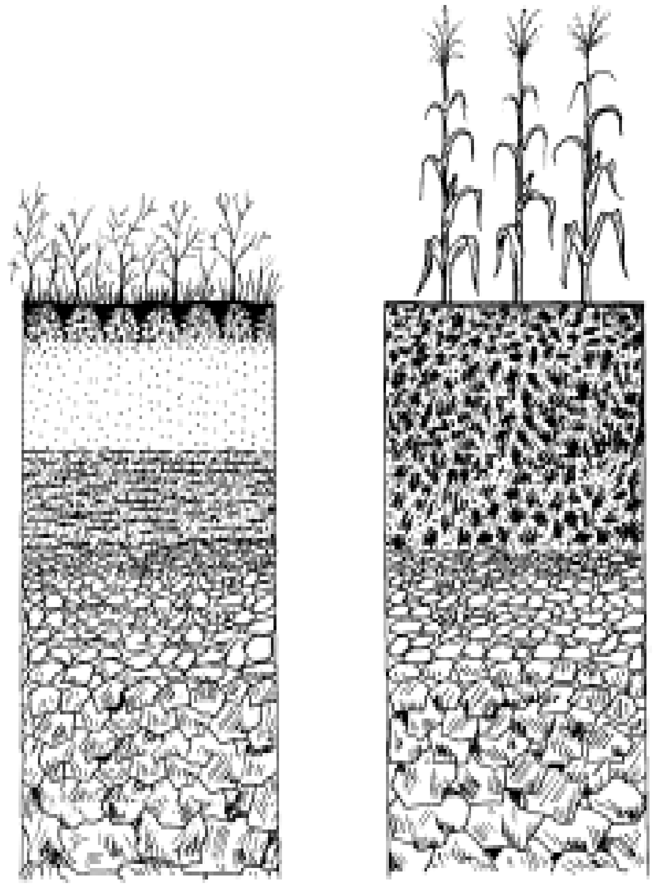


Fig. 1. Stratography of a natural soil (left) and of a cultivated soil (right) (L.Giardini)

PHYSICAL STRUCTURE

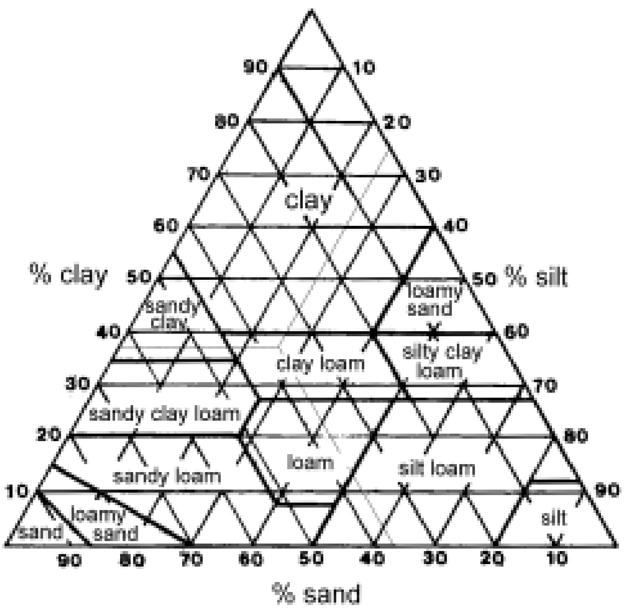
The physical structure of the soil depends on the dimension of the particles of its make up (Tab. 1). In addition, the particles also differ based on their shape and volumic mass (mass per unit of volume)

Tab. 1. Particles classification according to "International Society of Soil Science" (ISSS)

DIAMETER OF THE PARTICLES (mm)	CLASSIFICATION
> 2	stony texture
2 - 0.2	coarse sand
0.2 - 0.02	fine sand
0.02 - 0.002	silt
< 0.002	clay

Soil is divided into many classes of texture, according to the percentage of the basic particles (clay, sand and silt). If, for example, we have a soil with 37% clay, 38% sand and 25% silt, the soil is classified as "clay loam" (Fig. 2).

Fig. 2. Types of soil in relation to the texture



Among different types of soil, the loam soil is considered as being suitable for crop growth. However, other types of soil, with a rational management, can also provide positive results.
The soil texture is the cause of important aspects such as porosity, tenacity, adhesivity and plasticity.

Tab. 7.

CROP	SOIL CONTENT	ADVISED DOSES (kg/ha)		
		N	P_2O_5	K_2O
Apple	very low	150	120	230
	low	130	90	150
	medium	110	70	120
	medium-high	90	50	90
	high	80	40	60
	very high	70	20	40
Grape	very low	150	90	230
	low	120	70	180
	medium	100	60	150
	medium-high	90	40	120
	high	80	30	90
	very high	70	20	60
Peach	very low	200	120	230
	low	160	90	150
	medium	140	70	120
	medium-high	120	50	90
	high	100	40	60
	very high	80	20	40
Pear	very low	150	120	230
	low	130	90	150
	medium	110	70	120
	medium-high	90	50	90
	high	80	40	60
	very high	70	20	40

(data ESAV)

SOIL ANALYSIS

The soil analysis is very useful, in order to plan fertilization and to know the residues of fertilizers in relation to the crop, tillage and climate. An analysis can highlight shortages and help the understanding of the causes of an abnormal growth.
Testing the soil during the crop cycle and comparing the results with the plant growth can be an useful experiment for the next cultivation.

Sampling

1) Extracting Soil Sample
   – With a large field, take 1 or 2 samples per 1000 m2 (0.25 acre) of homogeneous areas.
   – Even for smaller areas, 2 samples are recommended (the more the samples, the better the end-results, because the sample is more representative)
   – For a small garden or plot, 1 sample is sufficient
2) Avoid extracting samples from soil presenting obvious anomalies
3) Sample quantity:
   Take the same quantity of soil for each sample. For example, use bags with similar dimensions (1 bag per sample)

Tab. 7.

CROP	SOIL CONTENT	ADVISED DOSES (kg/ha)		
		N	P_2O_5	K_2O
Asparagus	very low	160	120	180
	low	120	100	150
	medium	100	70	130
	medium-high	90	50	110
	high	80	40	90
	very high	70	20	80
Barley	very low	140	130	170
	low	110	90	120
	medium	90	70	80
	medium-high	80	50	60
	high	70	40	50
	very high	60	30	40
Corn silage	very low	340	200	230
	low	300	150	150
	medium	280	120	120
	medium-high	260	90	90
	high	240	60	60
	very high	220	40	46
Maize	very low	300	200	230
	low	270	150	150
	medium	240	120	120
	medium-high	230	90	90
	high	210	60	60
	very high	200	40	40
Soybean	very low	0	150	220
	low	0	130	170
	medium	0	100	130
	medium-high	0	80	100
	high	0	60	80
	very high	0	40	60
Sugar beet	very low	160	150	230
	low	120	130	180
	medium	100	100	150
	medium-high	90	80	120
	high	80	60	90
	very high	70	40	60
Tomato	very low	150	250	250
	low	130	180	200
	medium	110	150	150
	medium-high	90	120	120
	high	80	90	90
	very high	70	60	60
Wheat	very low	180	150	170
	low	160	100	120
	medium	150	80	80
	medium-high	140	60	60
	high	130	50	50
	very high	120	40	40

Porosity is important for the exchange of gases and liquids. Micro-porosity (porous $< 2 - 10\ \mu m$) permits water to be retained while macro-porosity (porous $> 10\ \mu m$) contributes to a fast circulation of air and water.
Plants therefore are in need of a correct relationship between micro and macro porosity. Clay soils have a greater micro-porosity than sandy soils and hence hold more water and remain wet for a longer period.
Because of the greater tenacity and adhesivity of clay soils, they are called heavy while sandy soils are referred to as light.
Organic matter, caused by animal and vegetable residues, is another important constituent of the solid part of the soil. Organic matter has a positive effect on the soil fertility by adding nutrients, stabilizing the pH reaction and permitting a good retainment of water. Organic matter is also important for the activity of microorganisms and, in general, contributes towards prevention of soil erosion.
The colloidal portion, composed of micro-particles (1-100 μm), is important for holding nutrients. Since most of these particles have a negative charge, the colloidal portion has a particularly large capacity to retain cations (NH_4^+, K^+, Na^+, Ca^{++}, Mg^{++}, etc.). The CEC (Cation Exchange Capacity) is higher in soils rich with clay and organic matter than in sandy soils.

CHEMICAL COMPOSITION

The chemical composition of soil includes pH and chemical elements. Their analysis is necessary for better management of fertilization, tillage and in order to choose the most suitable plants for best results.
By using the HANNA Soiltest, it is possible to measure pH and the most important elements for plant growth, that is, nitrogen (N), phosphorus (P) and potassium (K).

pH

pH is the measure of the hydrogen ion concentration [H^+]. A soil can be acid, neutral or alkaline, according to its pH value.
Fig. 3 shows the relationship between the scale of pH and kind of soil. The pH range from 5.5 to 7.5 include the most of plants; but some species prefer acid or alkaline soils.

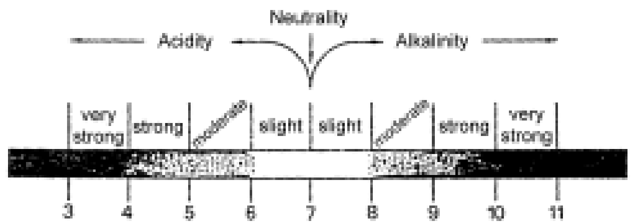
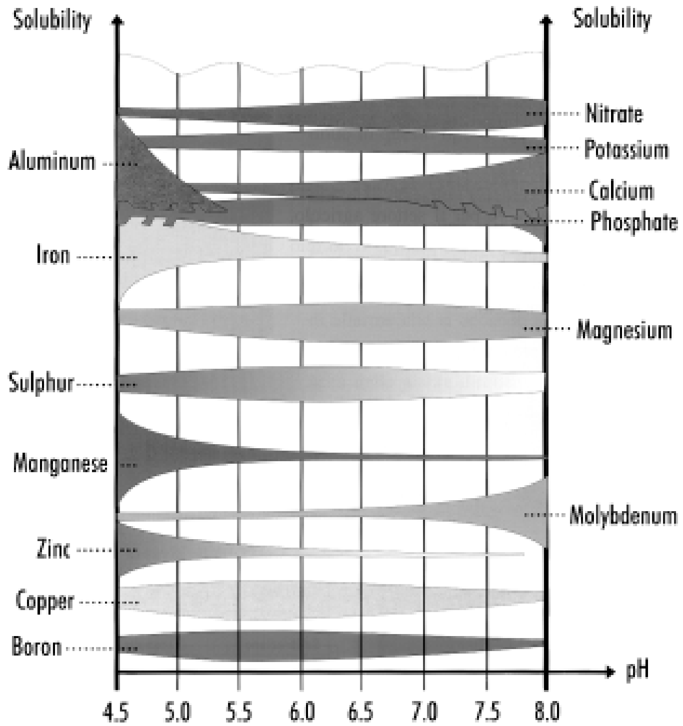


Fig. 3. Types of soil according to the pH value

Nevertheless, every plant need a particular range of pH, in which can better express its potentiality of growth.
pH strongly influences the availability of nutrients and the presence of microorganisms and plants in the soil.

For example, fungi prefer acidic conditions whereas most bacteria, especially those putting nutrients at the plants' disposition, have a preference for moderately acidic or slightly alkaline soils. In fact, in strongly acidic conditions, nitrogen fixing and the mineralization of vegetable residual is reduced.
Plants absorb the nutrients dissolved in the soil water and the nutrient solubility depends largely on the pH value. Hence, the availability of elements is different at different pH levels (Fig. 4).
Each plant needs elements in different quantities and this is the reason why each plant requires a particular range of pH to optimize its growth.
For example, iron, copper and manganese are not soluble in an alkaline environment. This means that plants needing these elements should theoretically be in an acidic type of soil. Nitrogen, phosphorus, potassium and sulfur, on the other hand, are readily available in a pH range close to neutrality.

Fig. 4. Solubility of the elements according to varying pH values



Furthermore, abnormal pH values, increase the concentration of toxic elements for plants. For example, in acid conditions, there can be an excess of aluminum ions in such quantities that the plant can not tolerate. Negative effects on chemical and physical structure are also present when pH values are too far from neutral conditions (break up of aggregates, a less permeable and more compact soil).

Tab.6.

CROP	YIELD (q/ha)	Nitrogen N (kg/ha)	Phosphorus P_2O_5 (kg/ha)	Potassium K_2O (kg/ha)
Garlic	100	80	30	60
Lettuce	200	60	35	100
Maize (grain)	120	160	65	80
Melon	350	180	65	260
Onion	350	150	60	160
Pea	50	190	55	170
Pepper	250	100	35	130
Potato	350	140	55	220
Rice (whole plant)	60	100	45	95
Soybean	40	300	70	35
Spinach	250	120	40	130
Strawberry	150	165	60	265
Sunflower	30	130	45	145
Sugar beet	600	170	75	250
Tobacco (leaves)	24	85	55	230
Tomato	500	150	60	290
Watermelon	600	110	45	190
Soft Wheat (whole plant)	60	170	25	100
Hard Wheat (whole plant)	45	130	20	80
Apple	350	90	33	130
Apricot	150	110	35	125
Cherry	75	50	20	75
Grapevine	150	70	35	115
Grapefruit	300	130	45	180
Lemon	200	45	20	70
Olive	50	50	20	65
Orange	250	70	25	100
Peach	200	130	30	130
Pear	250	70	15	80
Plum	180	100	20	90

The relationship between dosages of fertilizer elements and their presence in the soil is shown in Tab. 7. As above, the quantities reported are only indicative. Chemical analysis can be used as a basis for the evaluation, however other factors connected with the production also need to be considered.

Tab. 7. Relation between dosages of fertilizer elements and their presence in the soil

CROP	SOIL CONTENT	ADVISED DOSES (kg/ha)		
		N	P_2O_5	K_2O
Alfalfa	very low	0	150	230
	low	0	130	150
	medium	0	100	120
	medium-high	0	80	90
	high	0	60	60
	very high	0	40	40

It is important to note that whereas an insufficient dose of nutrients decreases the potential crop production, an excess can have a negative effect on the physiology of the plants and the crop quality. In addition, too much fertilization can be unnecessarily costly as well as being harmful to the environment.

Before sowing or transferring plants, use a slow-acting fertilizer to enrich the soil for long term. This is particularly important for Nitrogen which unlike Phosphorus and Potassium tends to become less present over time. Compound fertilizers which contain nitrogen (preferred in ammonium form), phosphorus and potassium can also be used.
Adding organic substances (such as manure and compost) help to increase the soil fertility (Tab. 5).

Tab.5. Composition of manure

ELEMENT	QUANTITY (%)
N	0.4-0.6
P_2O_5	0.2-0.3
K_2O	0.6-0.8
CaO	0.5-0.6
MgO	0.15-0.25
SO_3	0.1-0.2

Top dressing

If possible, add the fertilizer more than once. In case of lack of Nitrogen, use fertilizers containing Nitrate due to their faster absorption by the plants. It is important to add the necessary elements at particular phases in the plant's life cycle (for example, before sprouting or wheat raising).
Do not give nitrate to crops such as lettuce (in which the product is the vegetable part) at the end of the plant cycle, in order to avoid their accumulation in the leaves (nitrate is carcinogenic).

Tab. 6 below shows average quantity of element absorbed by the principal crops based on their yield (note that the relationship between absorption and fertilization is not exact).

Tab.6. Experimental average quantity of elements absorbed based on crop yield

CROP	YIELD (q/ha)	Nitrogen N (kg/ha)	Phosphorus P_2O_5 (kg/ha)	Potassium K_2O (kg/ha)
Alfalfa	120	280	75	300
Asparagus	50	125	40	110
Barley (whole plant)	60	110	25	95
Bean	100	130	40	100
Cabbage	200	110	60	150
Carrot	300	130	55	200
Colza	30	175	70	140

Management of the Soil in Relation with the pH Value

Once the pH value is known, it is advisable to choose crops that are indicated for this range (e.g. in an acid soil, cultivate rice, potato, strawberry).
Add fertilizers that at the same time do not increase acidity (for example urea, calcium nitrate, ammonium nitrate and superphosphate) or lower alkalinity (e.g. ammonium sulfate).
It is recommended that a cost evaluation is made prior to commencement of the modification of the soil pH. Corrective substances can be added in order to modify the soil pH, however, the effects are generally slow and not persistent. For example, by adding lime, the effects in clay soil can last for as long as 10 years, but only 2-3 years in a sandy soil.
For an acid soil, we can use substances such as lime, dolomitic, limestone and marl, according to the nature of the soil (Tab. 2).

Tab.2. Quantity (q/ha) of pure compound necessary to increase 1 unit of pH

SOIL AMELIORANTS	CLAY SOIL	SILTY SOIL	SANDY SOIL
CaO	30-50	20-30	10-20
$Ca(OH)_2$	39-66	26-39	13-26
$CaMg(CO_3)_2$	49-82	33-49	16-33
Ca CO_3	54-90	36-54	18-36

High pH levels can depend on different elements, hence, there are different methods for its correction.

– Soils rich with limestone:
  Add organic matter (this is due to the fact that non-organic ameliorants such as sulfur and sulfuric acid might not make economic sense due to the large quantities needed).
– Alkaline-saline soils:
  Alkalinity is due to the presence of salts (in particular a high concentration of sodium can be harmful).

Irrigation washes away salts hence an appropriate use of irrigation can provide positive results (drop-irrigation being the most recommended).
If alkalinity is caused by sodium, it is recommended to add substances such as gypsum (calcium sulfate), sulfur or other sulfuric compounds (Tab. 3). Also in this case, a cost evaluation is necessary.

Tab.3. Quantities provide the same result as 100 Kg of gypsum

Soil ameliorants (pure compounds)	Quantity (Kg)
Calcium chloride: $CaCl_2 \cdot 2H_2O$	85
Sulfuric acid: H_2SO_4	57
Sulfur: S	19
Iron sulfate: $Fe_2(SO_4)_3 \cdot 7H_2O$	162
Aluminum sulfate: $Al_2(SO_4)_3$	129

Tab.4. Range of preferred pH

PLANTS	pH
ORCHARD	
Apple	5-6.5
Apricot	6-7
Cherry	6-7.5
Grapefruit	6-7.5
Grapevine	6-7
Lemon	6-7
Nectarine	6-7.5
Orange	5-7
Peach	6-7.5
Pear	6-7.5
Plum	6-7.5
Pomegranate	5.5-6.5
Walnut	6-8
VEGETABLES AND HERBACEOUS CULTIVATIONS	
Artichoke	6.5-7.5
Asparagus	6-8
Barley	6-7
Bean	6-7.5
Brussels Sprout	6-7.5
Early carrot	5.5-7
Late carrot	5.5-7
Cucumber	5.5-7.5
Egg Plant	5.5-7
Lettuce	6-7
Maize	6-7.5
Melon	5.5-6.5
Oat	6-7
Onion	6-7
Pea	6-7.5
Pepper	6-7
Early Potato	4.5-6
Late Potato	4.5-6
Sweet Potato	5.5-6
Pumpkin	5.5-7.5
Rice	5-6.5
Soybean	5.5-6.5
Spinach	6-7.5
Strawberry	5-7.5
String	6-7.5
Sugar beet	6-7
Sunflower	6-7.5
Tomato	5.5-6.5
Watermelon	5.5-6.5
Wheat	6-7
LAWN	
Lawn	6-7.5

PLANTS	pH
GARDEN PLANTS AND FLOWERS	
Acacia	6-8
Acanthus	6-7
Amaranth	6-6.5
Bougainvillea	5.5-7.5
Dahlia	6-7.5
Erica	4.5-6
Euphorbia	6-7
Fuchsia	5.5-7.5
Gentian	5-7.5
Gladiolus	6-7
Hellebore	6-7.5
Hyacinth	6.5-7.5
Iris	5-6.5
Juniper	5-6.5
Ligustrum	5-7.5
Magnolia	5-6
Narcissus	6-8,5
Oleander	6-7.5
Peony	6-7.5
Paulownia	6-8
Portulaca	5.5-7.5
Primula	6-7.5
Rhododendron	4.5-6
Roses	5.5-7
Sedum	6-7.5
Sunflower	6-7.5
Tulip	6-7
Viola	5.5-6.5
HOUSEPLANTS	
Abutilon	5.5-6.5
African violet	6-7
Anthurium	5-6
Araucaria	5-6
Azalea	4.5-6
Begonia	5.5-7.5
Camellia	4.5-5.5
Croton	5-6
Cyclamen	6-7
Dieffenbachia	5-6
Dracaena	5-6
Freesia	6-7.5
Gardenia	5-6
Geranium	6-8
Hibiscus	6-8
Jasmine	5.5-7
Kalanchoe	6-7.5
Mimosa	5-7
Orchid	4.5-5.5
Palms	6-7.5
Peperomia	5-6
Philodendron	5-6
Yucca	6-7.5

Nutrients

The three elements that are most needed by plants are nitrogen (N), phosphorus (P) and potassium (K). This is the reason why they are called macronutrients and should be given to the plants. Other elements, the so-called microelements are generally present in sufficient quantities in the soil and the plants need them in smaller doses.

Nitrogen

Nitrogen is an indispensable element for the plant's life and is a key factor in fertilization. It is present in proteins, vitamins, hormones, chlorophyll, etc. Nitrogen allows the development of the vegetative activity of the plant, in particular, causes a lengthening of trunks and sprouts and increases the production of foliage and fruits (even though the quality depends by other elements). An excess of Nitrogen weakens the plants' structure creating an unbalanced relationship between the green parts and the wooden parts. In addition, the plant becomes less resistant to diseases.
The nitrogen adsorbed by the plants derives from the mineralization of organic matter and the application of fertilizers, but legumes (soybean, pea, clover, alfalfa, etc.) are able to take nitrogen by a symbiotic association with Rhizobium bacteria.
The fact that nitrate (the nitrogen chemical compound that the plants absorb mostly) is not durable in the soil and the large amount required for crop production, make it necessary to add this element, avoiding excesses.

Phosphorus

Phosphorus is an important element in the composition of DNA and RNA, the regulators of the energetic exchange (ATP, ADP), as well as the reserve substances in seeds and bulbs. It contributes to the formation of buds, roots and blooming as well as lignification. A lack of phosphorus results in: stifling of plant, slow growth, a reduction of production, smaller fruits and a lower expansion of the roots.
Most of the Phosphorus present in the soil is not available for plants and its release in the soil solution from which it is taken, is very slow.
Therefore, in order to avoid an impoverishment of the soil, and to give to the plants the appropriate quantity, a rational fertilization is needed.

Potassium

Even if potassium is not a constituent of important compounds, it plays a remarkable role in many physiological activities like the control of the cellular turgor and the accumulation of carbohydrates. In addition, it increases the size of fruits, their flavor as well as yielding a positive effect on the color and fragrance of flowers. Potassium also makes plants more resistant to diseases.
Generally speaking, potassium is normally retained by the soil and the losses are caused by plant absorption or erosion. In sandy soils however the level may be inadequate.

Fertilization

The quantity of substances to add to the soil, depends not only on the chemical state of the soil but also on factors such as local climate, the physical structure, previous and present cultivation, microbiological activities etc. Hence, only after a technical and economical evaluation, it is possible choose the proper quantity of fertilizer to add.