Nutritional recommendations for

POTATO

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Botanical name: *Solanum tuberosum L.*

Synonyms: Spuds; Pomme de terre; Patata; Kartoffel

Contents:

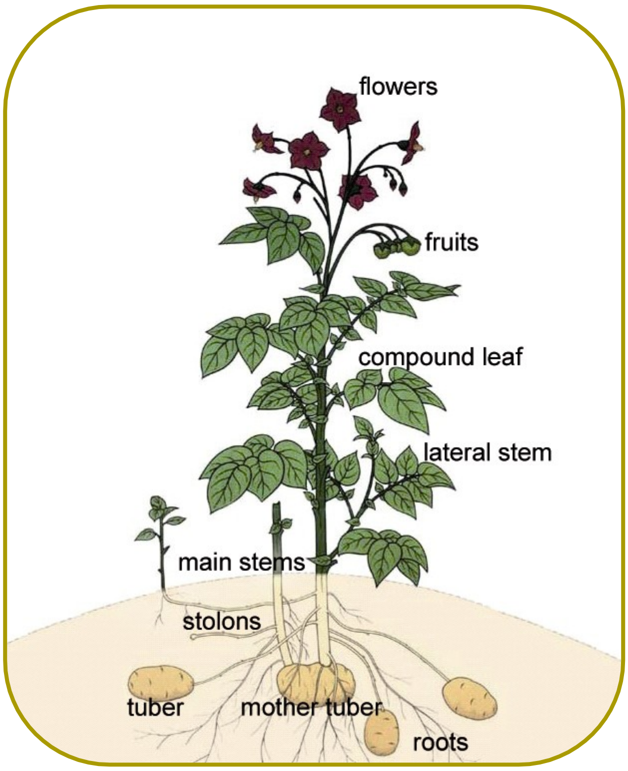
1. General growing conditions

1.1 The plant

The potato (*Solanum tuberosum*) is an herbaceous annual that grows up to 100 cm (40 inches) tall and produces tubers, which are botanically thickened stems that are so rich in starch that they rank as the world's fourth most important food crop, after maize, wheat and rice.

The potato belongs to the Solanaceae, and shares the genus *Solanum* with at least 1,000 other species, including tomato and eggplant. *S. tuberosum* is divided into two, only slightly different, subspecies: *andigena*, which is adapted to short day conditions and is mainly grown in the Andes, and *tuberosum*, the potato now cultivated around the world, which is believed to descend from a small introduction to Europe of *andigena* potatoes that later adapted to longer day conditions.

Figure 1: A scheme of the potato plant



1.2 Soil type and pH

Potatoes will grow on most soils, organic as well as mineral ones. But, light and medium texture soils are recommended where mechanical harvesting is practiced, to avoid difficulties in harvesting when weather conditions are adverse at harvest time. Lowest possible soil pH is 5.5. Soil pH below 4.8 generally results in impaired growth.

Too alkaline conditions can adversely affect skin quality and can induce micronutrients deficiencies.

1.3 Special sensitivities of the potato plant

1.3.1 Chloride

Potatoes are sensitive to the chloride anion. Chloride damage is manifested by scorching of the leaf tips and margins, and leaves yellowing and distortion. Fertilization with chloride-free fertilizers will, therefore, contribute to increased yields and to the improvement of their quality.

1.3.2 Boron deficiency

"Hollow Heart", by comparison, is characterized by formation of a cavity near the tuber centre, without any external indication of this syndrome. It is the result of soil boron deficiency. Rapid growth of the tuber, sometimes due to too low plant density, may cause this syndrome, too.

1.3.3 Storage conditions

"Black heart" symptom of potatoes is caused by a limited supply of oxygen to the tubers during their storage, and cannot be alleviated by improved growth conditions.

1.4 Irrigation

During the early growth phase, until tuber formation, it is essential to keep the soil constantly and uniformly wet to a depth of at least 10-15cm. The frequency of irrigation cycles during this period should be determined according to the specific soil type and climate conditions.

During the second growth phase, during tuber development, irrigation will be less frequent and applied once every 3-5 days. This allows efficient root respiration and intensifying growth rate. Potatoes can be irrigated almost until harvest.

Irrigation at tuber initiation can affect the skin quality of daughter tubers by influencing phytopathogens, either favorably or adversely, according to conditions, and moisture rate present. A monitored drip system equipped with a Nutrigation™ (fertigation) device is the preferable method of irrigation (Fig. 2)

Figure 2: Drip-irrigated potato field in southern Israel

1.5 Crop uses

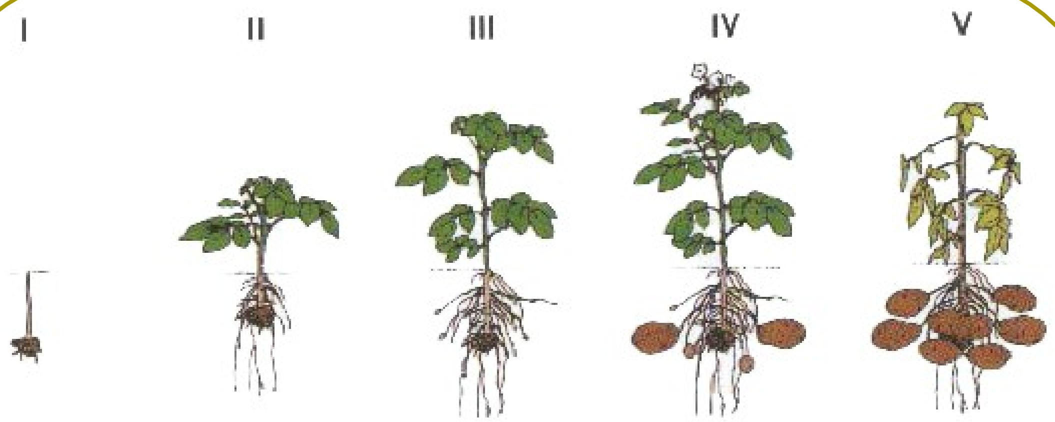
Potatoes are consumed fresh, and are being processed to chips and crisps. Potatoes are also used for the production of starch. Selected plots are grown for seed production.

Potatoes grown for processing are valued for yield, size, shape, and mainly for dry matter content (measured by specific gravity). As the specific gravity increases, the water content of the potato decreases, improving the frying properties and flavor. Management factors, including plant nutrition treatments, will influence potato yield, quality, and storage properties.

1.6 Crop growth stages

Potato growth is classified into five distinct growth phases (Fig. 3). The exact timing of these growth phases depends on many environmental and management factors that vary between locations and cultivars. However, these distinct stages of growth need to be considered when managing the crop.

Figure 3: Main stages of growth and development of potatoes. The nutritional requirements of the developing potato change during the growing season.



Stage I Sprout development
Sprout develops from eyes on seed tubers and grows upward to emerge from the soil. Roots begin to develop at the base of emerging sprouts.

Stage II Vegetative growth
Leaves and brunch stems develop from aboveground nodes along emerged sprouts. Roots and stolons develop at below-ground nodes. Photosynthesis begins.

Stage III Tuber initiation
Tubers form at stolon tips but are not yet appreciably enlarging. In most cultivars the end of this stage coincides with early flowering.

Stage IV Tuber bulking
Tuber cells expand with the accumulation of water, nutrients, and carbohydrates. Tubers become the dominant site for deposition of carbohydrates and mobile inorganic nutrients.

Stage V Maturation
Vines turn yellow and lose leaves, photo-synthesis decreases, tuber growth slows, and vines eventually die. Tuber dry matter content reaches a maximum and tuber skins set.

2. Nutritional requirements

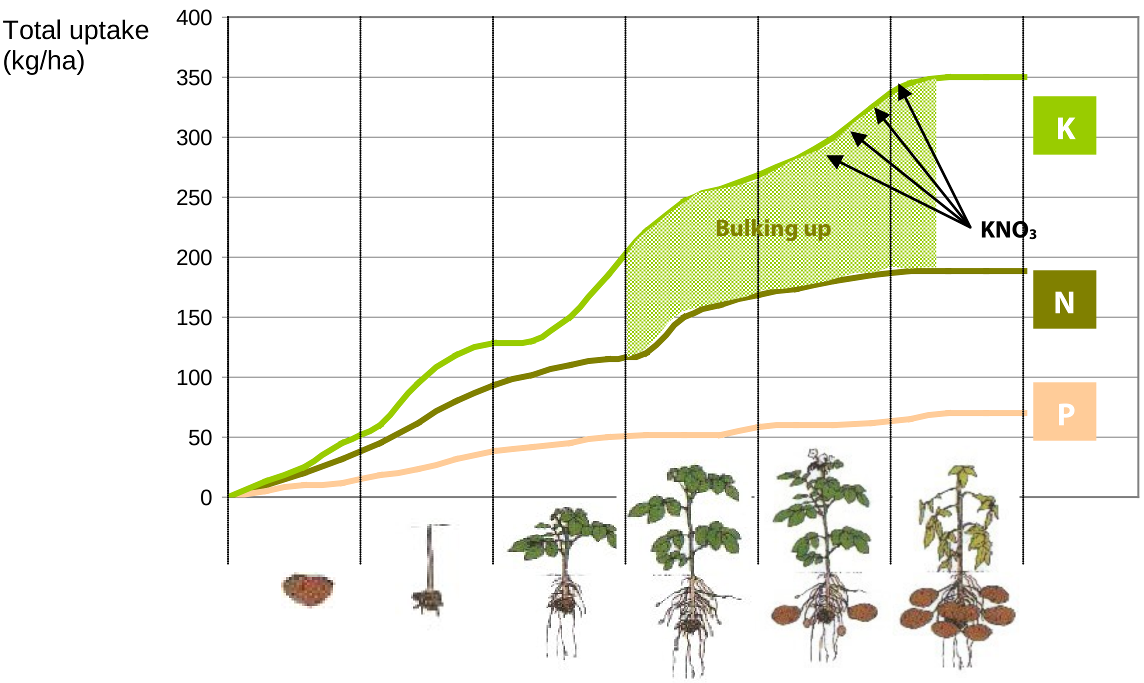
2.1 Nutrient uptake curves

Nutrients uptake is at its greatest during tuber bulking up (intensive volume increase process). The amount of nutrients removed by a potato crop is closely related to yield. Usually, twice the yield will result twice the removal of nutrients. Nutrients need to be applied as accurately as possible to the zone of uptake, slightly before, or at the time that the crop needs them. Failure to ensure that each plant gets the right balance of nutrients can spoil crop quality and reduce yield.

The highest requirement for potassium, as shown on Figure 4, is during the bulking up stage of the tubers. The flowering of potato plants is an indication when this morphological stage starts. Consequently, the ideal side-dressing period with Multi-K® would be during the tuber bulking stage.

Figure 4: Uptake of macronutrient uptake by a whole potato plant

Source: Harris (1978)



The daily requirements of potato tubers during the critical bulking stage are 4.5 kg/ha N, 0.3 kg/ha P and 6.0 kg/ha K. Potassium requirements of potato tubers during the bulking stage are very high as they are considered to be luxury consumers of potassium. Daily yield increase during the critical tuber bulking stage can reach 1000 - 1500 kg/ha/day. Therefore, it is important to supply the required plant nutrients during the tuber bulking stage in right N-P-K ratio and in ample quantities.

Figure 5: Uptake of macro and secondary nutrients by vines and tubers of potato plants yielding 55 ton/ha.
Source: Reiz, 1991

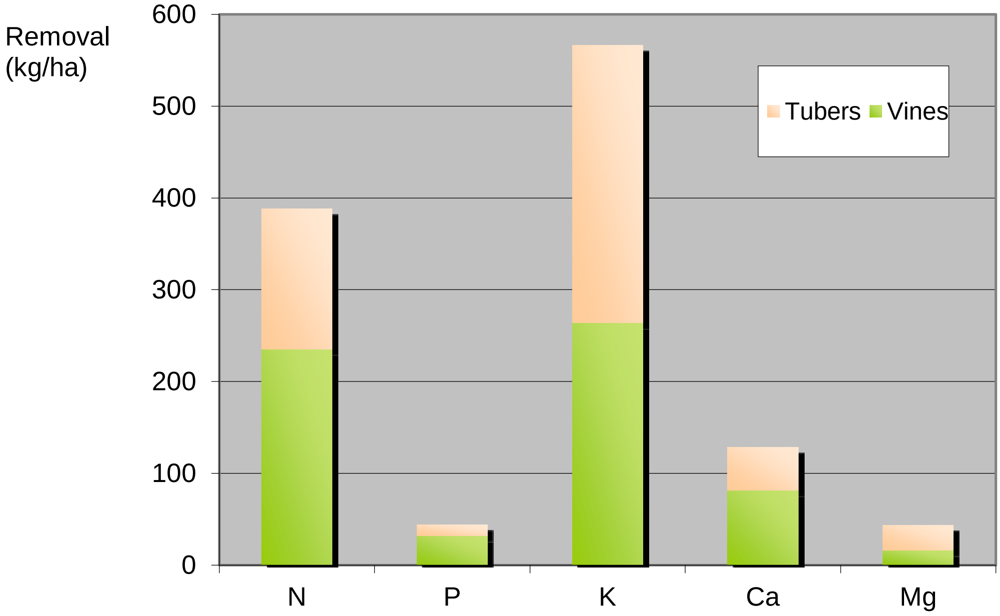
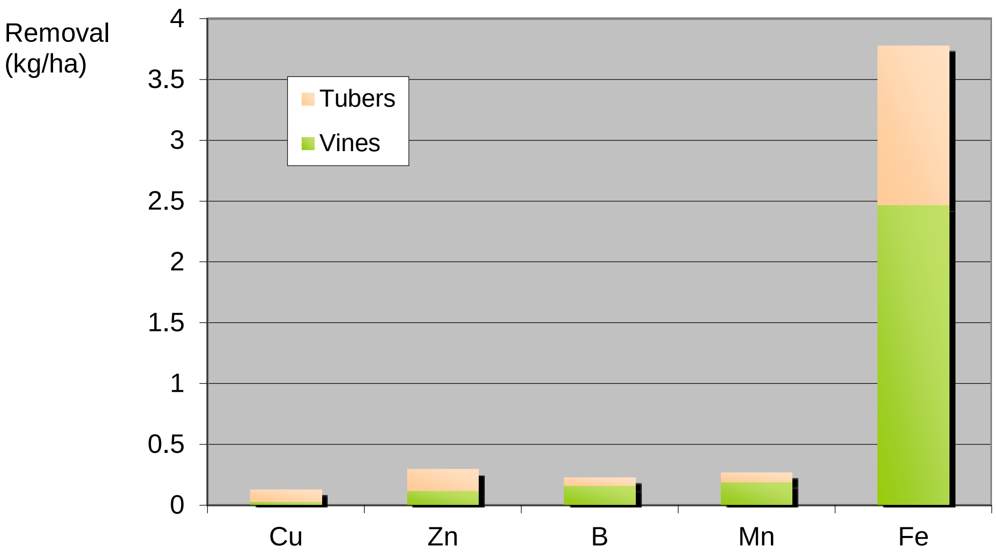


Figure 6: Uptake of micro-nutrients by vines and tubers of potato plants yielding 55 ton/ha.
Source: Reiz, 1991



2.2 Main functions of plant nutrients

Table 1: Summary of main functions of plant nutrients

Nutrient	Functions
Nitrogen (N)	Synthesis of proteins (growth and yield).
Phosphorus (P)	Cellular division and formation of energetic structures.
Potassium (K)	Transport of sugars, stomata control, cofactor of many enzymes, reduces susceptibility to plant diseases.
Calcium (Ca)	A major building block in cell walls, and reduces susceptibility to diseases.
Sulfur (S)	Synthesis of essential amino acids cystine and methionine.
Magnesium (Mg)	Central part of chlorophyll molecule.
Iron (Fe)	Chlorophyll synthesis.
Manganese (Mn)	Necessary in the photosynthesis process.
Boron (B)	Formation of cell wall. Germination and elongation of pollen tube. Participates in the metabolism and transport of sugars.
Zinc (Zn)	Auxins synthesis.
Copper (Cu)	Influences in the metabolism of nitrogen and carbohydrates.
Molybdenum (Mo)	Component of nitrate-reductase and nitrogenase enzymes.

Table 2: Effects of the nutrients and the potassium source on the yield quality.

Parameter	Increase in dosage of			Application of KCl in comparison to chloride-free K (-Cl)
	Nitrogen	Phosphorus	Potassium	
Tuber size	↑	No effect	↑	Chloride-free K helps increasing size
Sensitivity to mechanical damage	↑	↓	↓	No information
Tuber blackening [1]	↑	No effect	No effect	KCl is more effective than (-Cl)
% dry matter [2]	↓	↑ Slight effect	↓	Chloride-free K yields better results
% starch [3]	↓	↑	↓	Chloride-free K yields better results
% protein	↑	↓	Conflicting results	Chloride-free K helps increasing content
% reducing sugars	Inconsistent	↑	↓	No difference
Taste	↓	↑	No effect	Chloride-free K is better
Blackening after cooking	↑	No effect		

[1] Blackening is caused by oxidation of phenol compounds when skin is exposed.

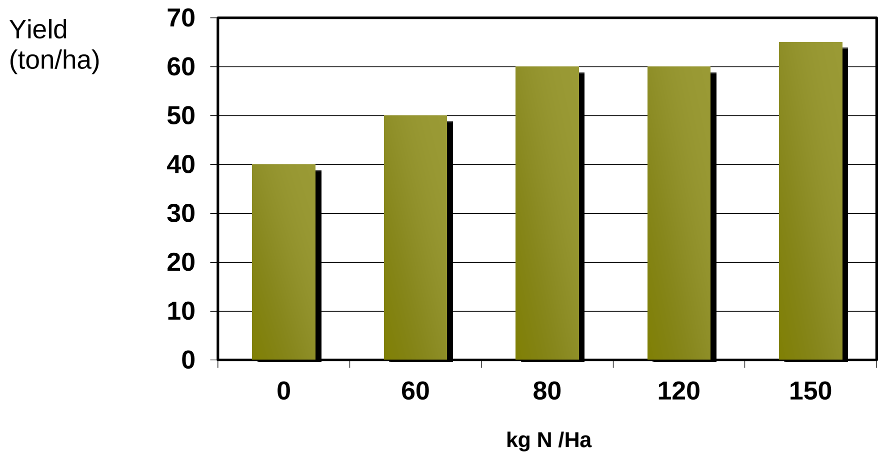
[2] A high percentage of dry matter is required in potatoes for industry.

[3] High concentrations are desirable. The characteristic is correlated to the specific gravity.

Nitrogen (N)

Adequate N management is one of the most important factors required to obtain high yields (Fig. 7) of excellent quality potatoes. An adequate early season N supply is important to support vegetative growth.

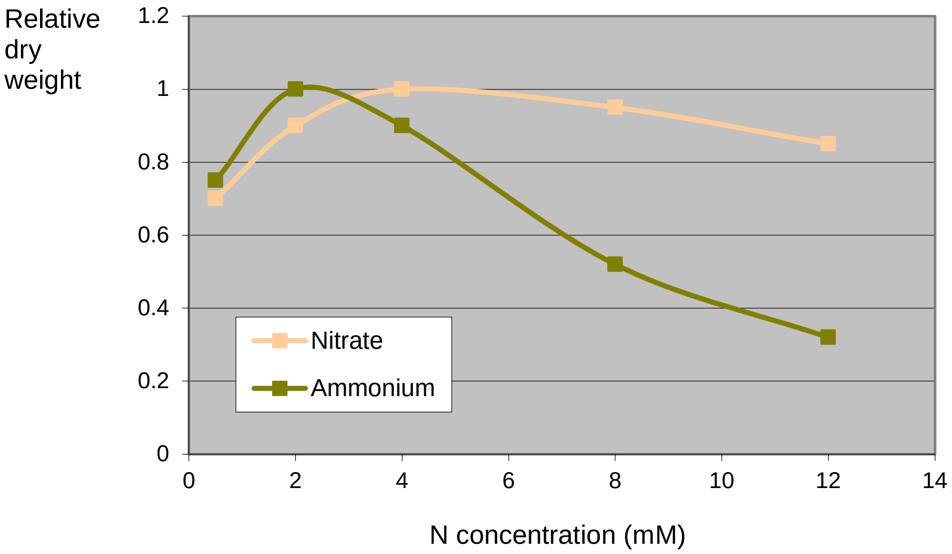
Figure 7: The effect of nitrogen (N) on potato yields



Excessive soil N, applied late in the season delays maturity of the tubers and result in poor skin set, which harms the tuber quality and storage properties. Potatoes are a shallow-rooted crop, generally growing on sandy, well-drained soils. These soil conditions frequently make water and N management difficult since nitrate is susceptible to leaching losses. On these sandy soils, it is recommended that potatoes receive split applications of N during the growing season. This involves applying some of the total N requirement prior to planting and applying the remainder during the season with side-dress applications or through the irrigation system by Nutrigation™ (fertigation). The period of highest N demand varies by potato variety and is related to cultivar characteristics, such as root density and time to maturity. Petiole analysis during the growing season is a useful tool, allowing growers to determine the N status of the crop and respond in a timely manner with appropriate nutrients.

A balanced ammonium / nitrate ratio is very important at planting time. Too much ammonium-nitrogen is a disadvantage as it reduces root-zone pH and thereby promotes Rhizoctonia disease. Nitrate-nitrogen enhances the uptake of cations such as calcium, potassium and magnesium, required for elevated specific gravity values.

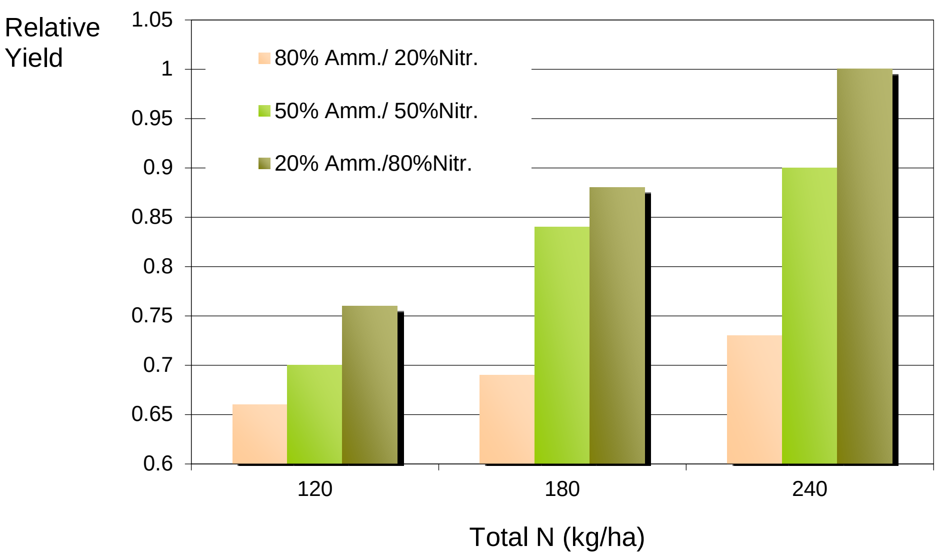
<u>Figure 8</u>: Relative response of potato growth to the nitrate-ammonium concentrations in the nutrient solution



At 12 mM of N, plants exhibited interveinal ammonium toxicity with NH_4^+ nutrition, but healthy growth with NO_3^- nutrition. Thus, a careful control of NH_4^+ concentrations is necessary to minimize ammonium toxicity to potato plants.

<u>Figure 9</u>: Effect of Nitrate/Ammonium ratio and N rate on total yield of U.T.D. tubers

Source: Vegetables & Fruits, Feb./March, 2000. South Africa



Nitrogen Assessment

Soil testing to a depth of 60 cm. in the spring is critical to planning an effective and efficient N management program. Post-harvest soil samples may help growers to select succeeding crops, which will make maximum use of the residual N after the potato crop.

The nitrogen demand by the crop during tuber bulking may be 2.2 to 3.0 kg/ha/day. Petiole nitrate sampling allows for in-season monitoring of the crop's nutrient status. Collecting the 4th petiole from 30 – 50 randomly selected plants throughout the field (Fig. 10) is recommended. Tissue samples are often collected weekly to track changes in nitrate levels, and to plan supplemental fertilizer applications, should levels drop below optimum.

Critical petiole nitrate-levels decline as the potato crop develops and matures. Generally, petiole nitrate-N levels at tuber bulking are <10,000 ppm = low, 10,000-15,000 ppm = medium, >15,000 ppm = sufficient. (Fig. 11)

Figure 10: The structure of the 4th leaf on a potato plant

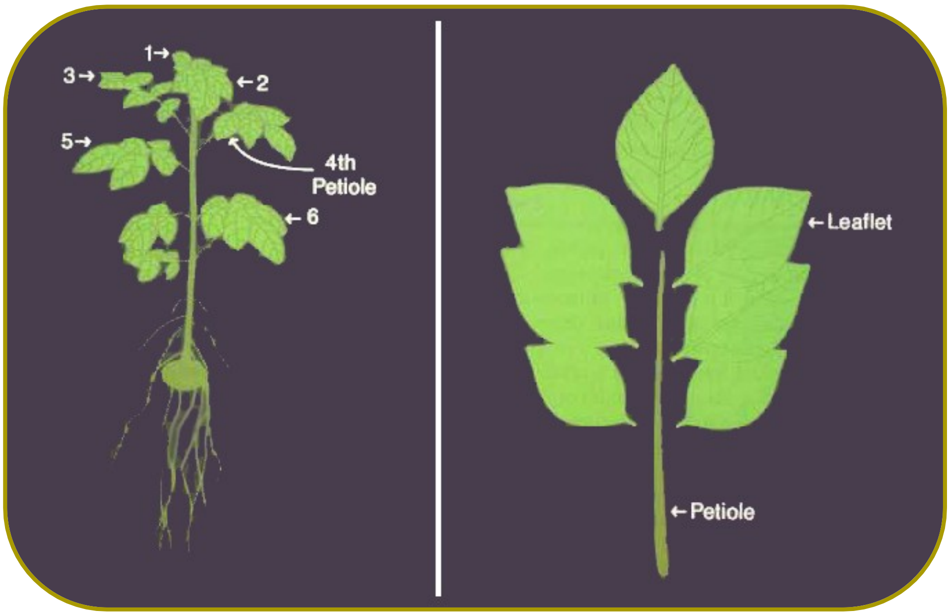
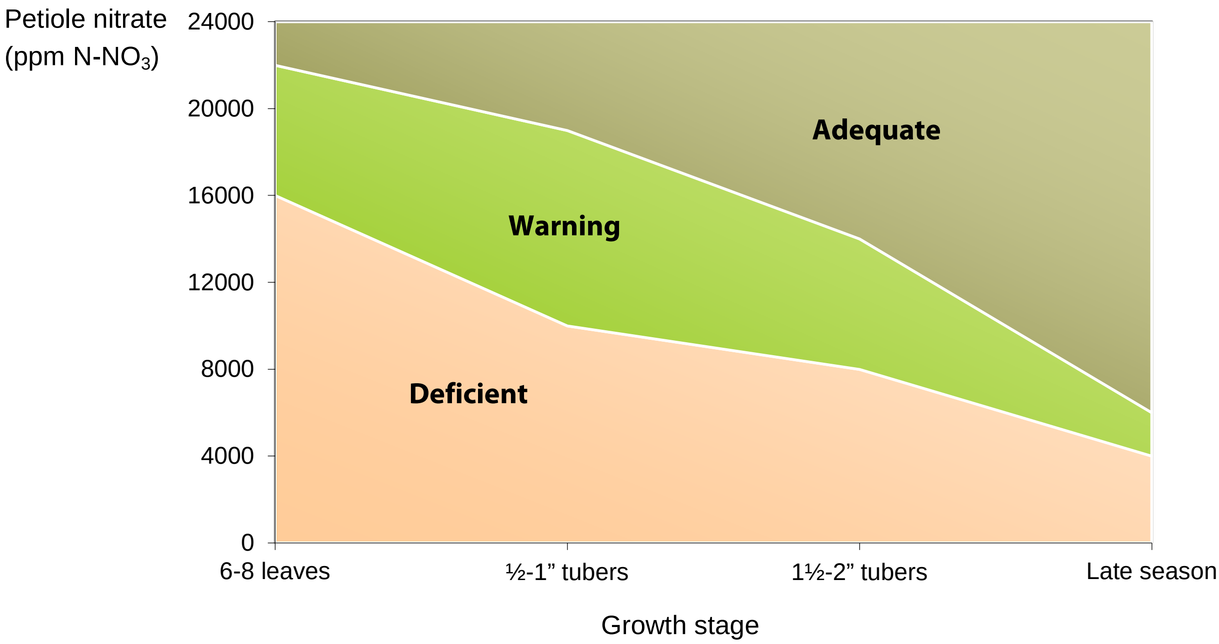


Figure 11: Interpretation of N-NO_3 levels in potato petioles at different stages of growth



Phosphorus (P)

Phosphorus is important for early root and shoot development, providing energy for plant processes such as ion uptake and transport. Roots absorb phosphate ions only when they are dissolved in the soil water. Phosphorus deficiencies can occur even in soils with abundant available P, if drought, low temperatures, or disease interfere with P diffusion to the root, through the soil solution. These deficiencies will result in stunt root development and inadequate function.
At the tuber initiation stage, an adequate supply of phosphorus ensures that optimum number of tubers is formed. Following the tuber initiation, phosphorus is an essential component for starch synthesis, transport and storage.

Recent research suggests that modifications to P fertilizer, such as polymer additives, humic substances, and coatings may be beneficial in improving P uptake and potato production.

Potassium (K)

Potato plants take up large quantities of potassium throughout the growing season. Potassium has an important role in the control of the plant water status and internal ionic concentration of the plant tissues, with a special focus on the stomatal functioning.

Potassium plays a major positive role in the process of nitrate reduction within the plant. Where large amounts (e.g. >400 kg/ha K_2O) are to be applied, in temperate conditions it is advisable to split the dressings 6-8 weeks apart.

Potatoes require large amounts of soil K, since this nutrient is crucial to metabolic functions such as the movement of sugars from the leaves to the tubers and the transformation of sugar into potato starch. Potassium deficiencies reduce the yield, size, and quality of the potato crop. A lack of adequate soil K is also associated with low specific gravity in potatoes.

Potassium deficiencies impair the crop's resistance to diseases and its ability to tolerate stresses such as drought and frost. Applying K fertilizer with a broadcast application prior to planting is most commonly recommended. If the K is band-applied, the rates should be kept below 45 kg K_2O/ha to avoid any salt injury to the developing sprouts.

Selection of the best K fertilizer

The source of potassium plays an important role on the quality and the yield of potato tubers. By comparing different sources of K, Multi-K® potassium nitrate was found to increase the dry matter ontent and the yield significantly higher than other sources of K (Fig. 12 & 13). This study was done on different cultivars and all of them responded with higher tuber yield to Multi-K® treatment (Fig 14).

Figure 12: The effect of different potassic fertilizers on the potato tuber yield

Source: Reiz, 1991

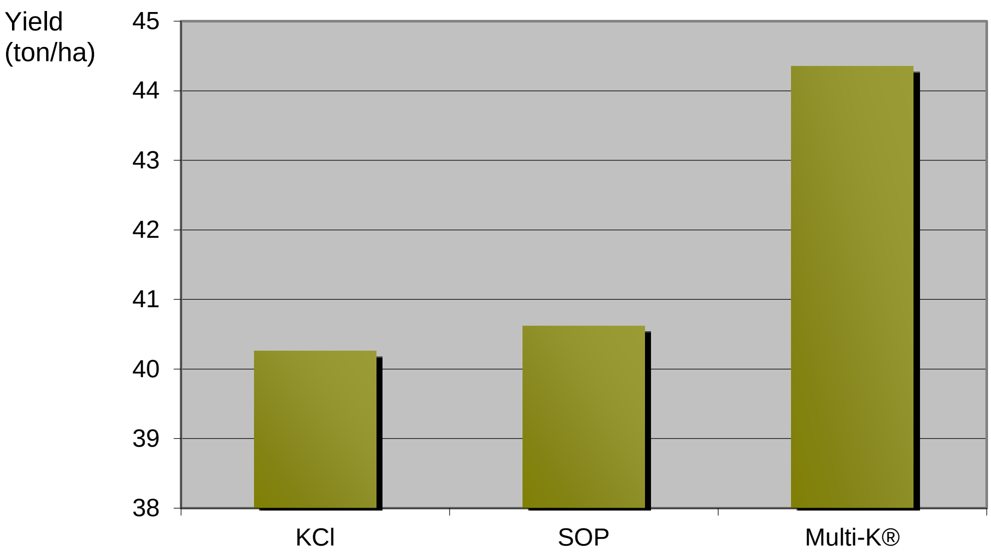


Figure 13: The effect of different potassic fertilizers on the dry matter content in potato tubers
Source: Reiz, 1991

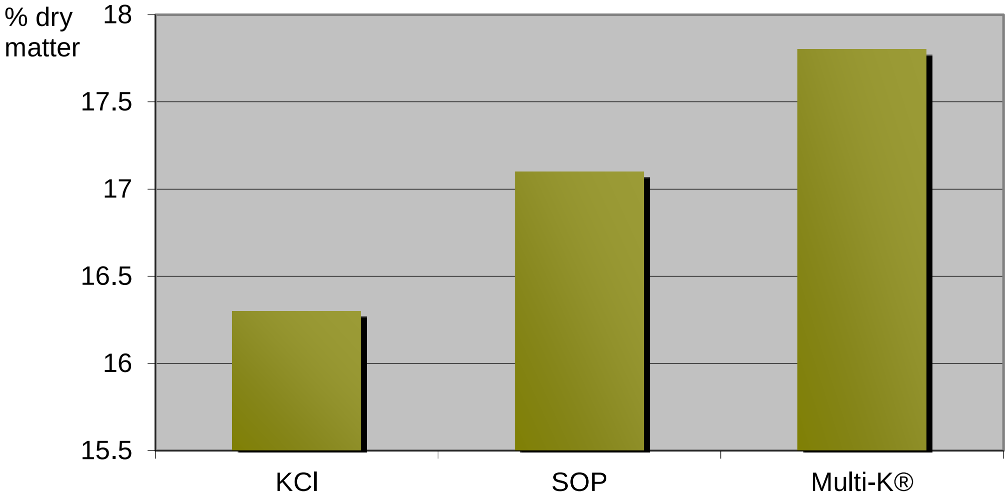
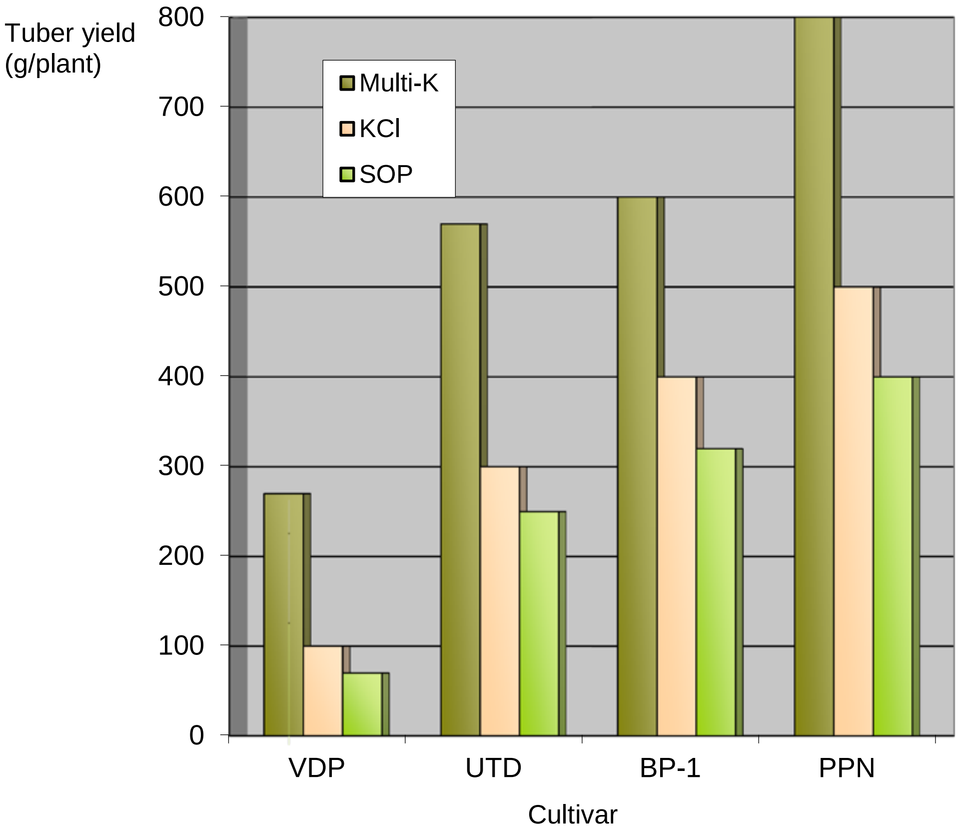


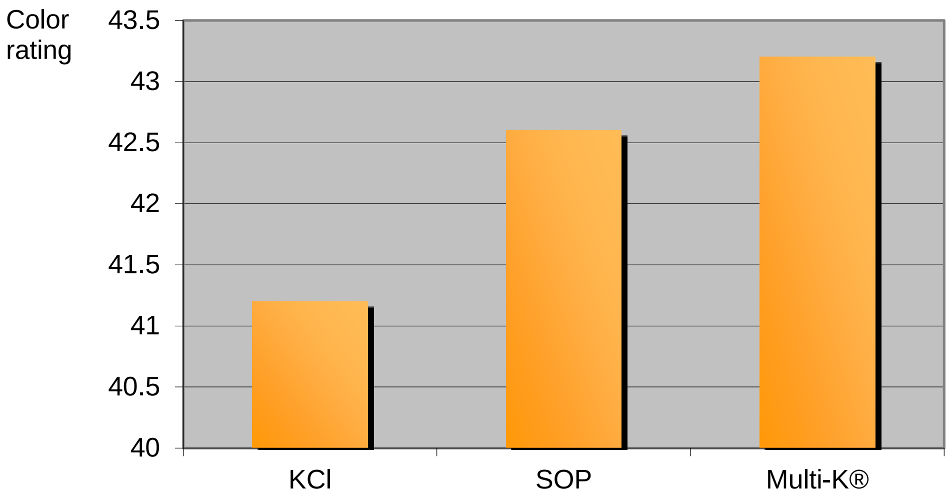
Figure 14: The effect of different potassic fertilizers on potato yield of various cultivars
Source: Bester, 1986



The potato's specific gravity and the chips color are important parameters for the processing potatoes industry. Both of these parameters are responding favourably to Multi-K® potassium nitrate treatments as compared to other sources of K fertilizers (Fig. 15, 16).

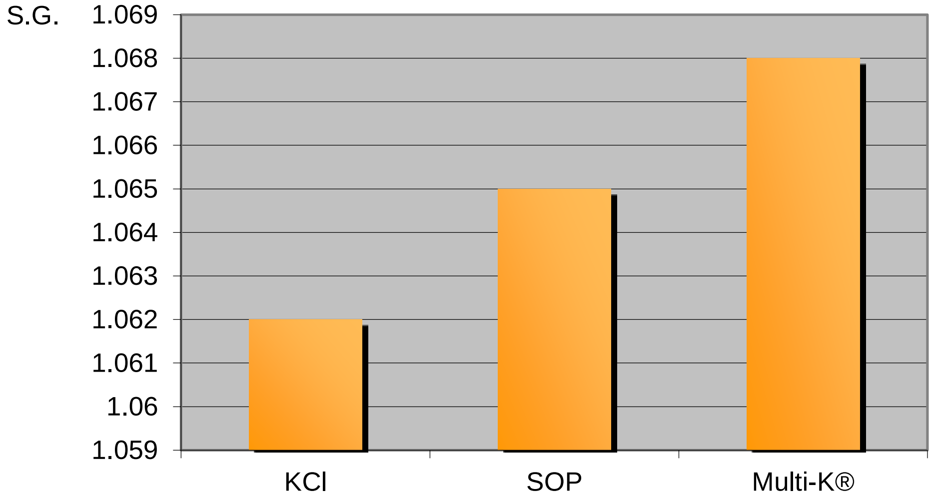
<u>Figure 15</u>: The effect of different potassic fertilizers on chips color rating

Source: Reiz, 1991



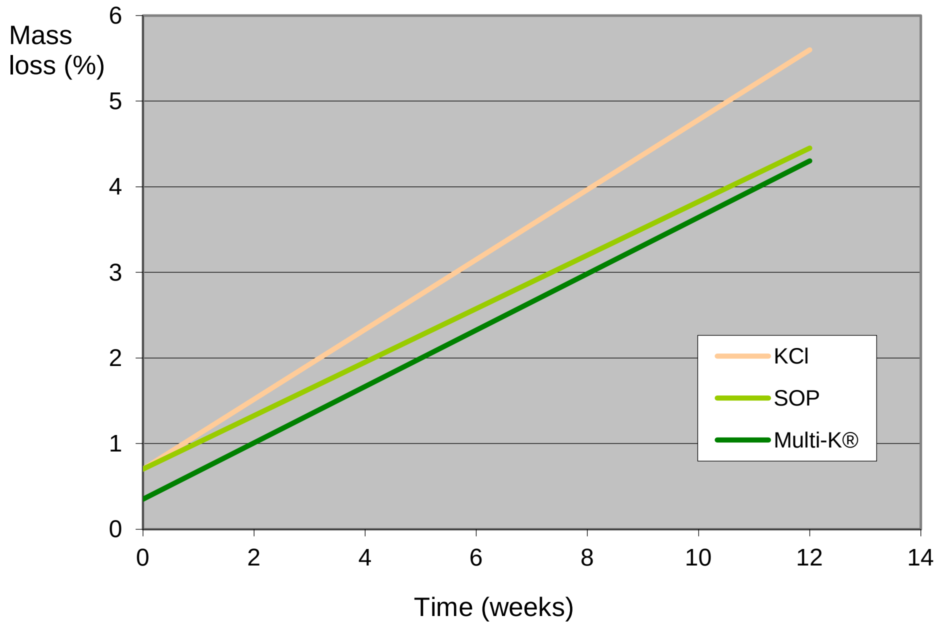
<u>Figure 16</u>: The effect of different potassic fertilizers on specific gravity of potato tubers

Source: Reiz, 1991



Beside the favourable effect of Multi-K® on the quality and yield of potato tubers, it also improves the shelf life of the tubers in storage (Fig. 17).

Figure 17: The effect of different K fertilizers loss of mass over time (@ 20°C, RH 66%)
Source: Bester (1986)



Calcium (Ca)
Calcium is a key component of cell walls, helping to build a strong structure and ensuring cell stability. Calcium-enriched cell walls are more resistant to bacterial or fungal attack. Calcium also helps the plant adapt to stress by influencing the signal chain reaction when stress occurs. It also has a key role in regulating the active transport of potassium for stomatal opening.

Magnesium (Mg)
Magnesium has a central role in photosynthesis, as its atom is present in the centre of each chlorophyll molecule. It is also involved in various key steps of sugar and protein production as well as the transport of sugars in the form of sucrose from the leaves to the tubers.

Yield increases of up to 10% were obtained in trials in which regular application of magnesium fertilizers has been practiced .

Sulphur (S)
Sulphur reduces the level of common and powdery scab. This effect is related to a reduction in the soil pH where sulphur is applied in its elemental form.

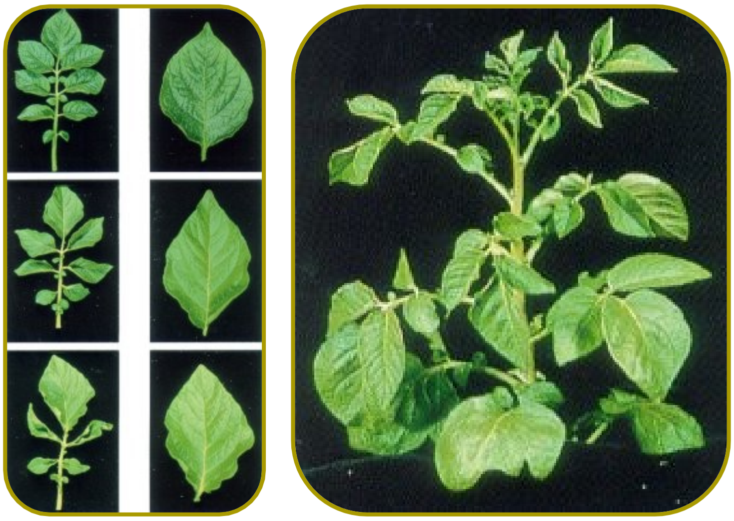
2.3 Nutritional disorders in potatoes

Nitrogen

Nitrogen deficiency is manifested by reduced growth pale leaves, and results in reduced tuber yield (size and number). The deficiency is made worse by extrenme soil pH (low or high), low organic matter, drought conditions or heavy irrigation (Fig. 18).

Nitrogen excess causes delayed maturity, excessive top growth, hollow heart & growth cracks, increased susceptibility to biotic diseases, reduced tuber specific gravity and difficulty in vine 'burning' before harvest.

Figure 18: Characteristic nitrogen (N) deficiency symptoms

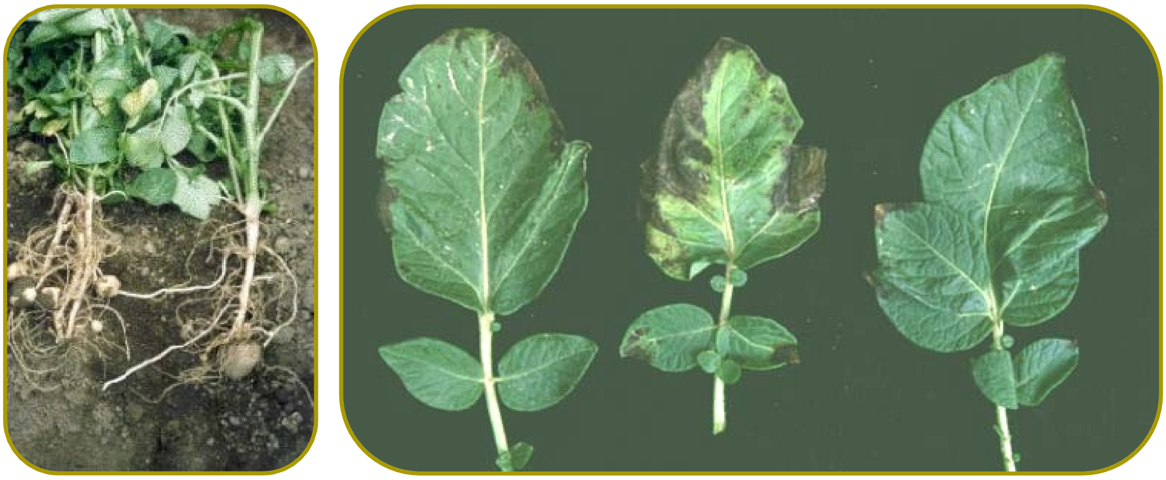


Phosphorus

Typical symptoms and syndroms related with phosphorus deficiency are: fewer tubers, smaller tubers, stunted plants, yellowing of older leaves, small dark green younger leaves (Fig. 19).
P deficiency leads to reduced early vigor, delayed maturity and reduced yields.

Excessive phosphorus, when present, ties up other elements such as calcium and zinc, inducing thereby their deficiencies

Figure 19: Characteristic phosphorus (P) deficiency symptoms



Potassium

Potassium deficiency retards nitrogen uptake, slows down plant growth and leads to reduced yields, inferior quality, and poor disease resistance. Typical symptoms of K deficiency are necrosis of leaf margins, premature leaf senescence (Fig. 20)

Excessive potassium causes reduced tuber specific gravity and reduced calcium and/or magnesium uptake. It also degrades soil structure.

Figure 20: Characteristic potassium (K) deficiency symptoms

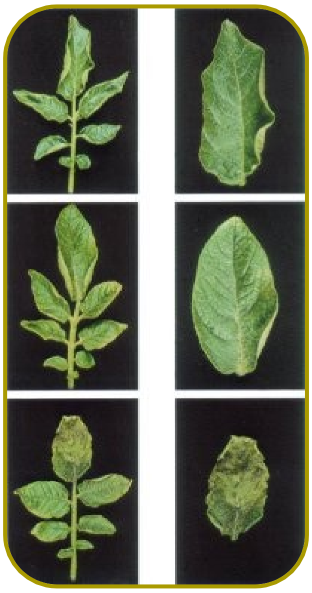
Calcium

Calcium deficiency interferes with root growth, causes deformation of foliage growth tips, and may result in reduced yields and poor quality. Calcium-deficient potato tubers have reduced storage capability. Low calcium levels in the soil result in poorer soil structure.

Typical symptoms of calcium deficiency are yellow curled leaves on upper leaves, tip burns, and small chlorotic new leaves. (Fig. 21)

Excessive calcium results in reduced magnesium uptake, with the symptoms related to magnesium deficiency.

Figure 21: Characteristic calcium (Ca) deficiency symptoms



Magnesium

As magnesium is a key element in photosynthesis, its rate slows down under conditions of magnesium deficiency, resulting in Reduced tuber formation and lower yields. Severe magnesium deficiency can reduce yields by up to 15%. Magnesium-deficient tubers are more easily damaged during lifting and storage.

Typical deficiency symptoms: Leaves get yellow and brown; The leaves wilt and die; Stunted plants, early crop maturation; Poor skin finish of the tubers. (Fig. 22)
Excessive magnesium results in reduced calcium uptake, with the symptoms related to calcium deficiency.

Figure 22: Characteristic magnesium (Mg) deficiency symptoms

Sulfur

Sulfur (S) deficiency causes reduced growth, and leaves become pale green or yellow. Number of leaves is reduced. (Fig. 23)

Figure 23: Characteristic sulfur (S) deficiency symptoms

Iron

Under Iron (Fe) deficiency, the interveinal areas get chlorotic while the veins remain green. In cases of severe deficiency, the entire leaf is chlorotic. (Fig. 24). Iron deficiency symptoms firstly appear on the youngest leaves.

Figure 24: Characteristic Iron (Fe) deficiency symptoms

Boron

Boron (B) regulates transport of sugars through membranes, and also plays a key role in cell division, cell development and auxin metabolism.

Under condition of boron deficiency growing buds die, and plants appear bushy, having shorter internodes. Leaves thicken and roll upward; leaf tissue darkens and collapses. Brown necrotic patches appear on tubers, and internal rust spot are formed. (Fig. 25)

Figure 25: Characteristic Boron (B) deficiency symptoms

Copper

Under copper (Cu) deficiency young leaves become flaccid and wilted, terminal buds drop at flower bud development, and leaf tips become necrotic (Fig. 26).

Figure 26: Characteristic Boron (B) deficiency symptoms

Zinc

Zinc deficiency symptoms: Young leaves become chlorotic (light green or yellow), narrow, upwardly-cupped and develop tip-burn. Other leaf symptoms are green veins, spotting with dead tissue, blotching, and erect appearance. (Fig. 27)

Figure 27: Characteristic Zinc (Zn) deficiency symptoms

Manganese

Manganese (Mn) deficiency symptoms: black or brown spots on younger leaves; leaves yellowing; poor skin finish of the tubers (Fig. 28). Tubers are more easily damaged during lifting and storage.

Figure 28: Characteristic manganese (Mn) deficiency symptoms

2.4 Leaf analysis standards

Table 8: Reference levels for each nutrient at foliar level:

Nutrient (%)	Deficient	Low	Normal	High	Excessive
Nitrogen (N)	< 4.2	4.2-4.9	5.0-6.5	>6.5	
Phosphorus (P)	<0.23	0.23-0.29	0.3-0.55	>0.6	
Potassium (K)	<3.3	3.3-3.9	4.0-6.5	6.5-7.0	>7.0
Calcium (Ca)	<0.6	0.6-0.8	0.8-2	>2.0	
Magnesium (Mg)	<0.22	0.22-0.24	0.25-0.5	>0.5	
Sulfur (S)			0.30-0.50		

Nutrient (ppm)	Deficient	Low	Normal	High	Excessive
Copper (Cu)	<3	3.0 -5.0	5.0 -20	30-100	
Zinc (Zn)	<15	15-19	20-50		
Manganese (Mn)	<20	20-30	50-300	700-800	>800
Iron (Fe)			50-150		
Boron (B)	<15	18-24	30-60		
Sodium (Na)			0-0.4	>0.4	
Chloride (Cl)			0-3.0	3.0-3.5	>3.5

2.5 Plant nutrient requirements

Table 9: Nutritional requirements of potatoes:

Expected yield (ton/ha)	Removal by yield (kg/ha)					Uptake by whole plant (kg/ha)				
	N	P_2O_5	K_2O	CaO	MgO	N	P_2O_5	K_2O	CaO	MgO
20	38	18	102	2	2	105	28	146	29	19
40	76	36	204	4	4	171	50	266	42	28
60	114	54	306	6	6	237	72	386	55	37
80	152	72	408	8	8	303	95	506	68	46
100	190	90	510	10	10	369	117	626	82	55
110	209	99	561	11	11	402	128	686	88	59

3. Fertilization recommendations

The recommendations appearing in this document should be regarded as a general guide only. The exact fertilization program should be determined according to the specific crop needs, soil and water conditions, and the grower's experience. For detailed recommendations, consult a local Haifa representative.

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3.1 General recommendations

3.1.1 Haifa NutriNet™ web software for Nutigation™ programs

Haifa fertilization recommendations are available in the online Knowledge Center on our website, www.haifa-group.com. Use the NutriNet™ web software, accessible through our website or directly at www.haifa-nutrinet.com to assist you in working out the recommended fertilizer rates at different growth stages according to the expected yield under your growing conditions.

The following is an example of recommendations, found on the NutriNet™, in accordance with the above-mentioned guideline to split the scheduled fertilization into:

a) Base-dressing (pre-plant) fertilizers, followed by:
b) Nutrigation™ (fertigation) at different growth stages, on sandy-loam soil, when the expected yield is 80 ton/ha:

a) Base dressing

Base dressing - potatoes

All nutrients in kg/ha

	N	P_2O_5	K_2O	CaO	MgO
Suggested base dressing	109	132	263	27	37
Actual base dressing					
% Surface covered	100%				
Ammonium nitrate (34%)	330				
Superphosphate (25%)	528				
Potassium sulfate (50%)	526				
Dolomite (26%)	104				
Magnesium sulfate (16%)	231				

b) Nutrigation™

Total amount of fertilizers applied by Nutrigation™

Nutrigation - potatoes

All nutrients in kg/ha

	N	P_2O_5	K_2O	CaO	MgO
Suggested nutrigation	255	88	395	7	9
Actual nutrigation					
Ammonium nitrate (33%)	351				
Multi M.A.P (12-61-0)	144				
Multi-K (13-0-46)	859				
Multi Cal (26%)	27				

Table 10: The total contribution of plant nutrients from each fertilizer as calculated by NutriNet™:

	kg	N	P_2O_5	K_2O	CaO	MgO
Ammonium nitrate (34%)	351	116				
Haifa MAP (12-61-0)	144	17	88			
Multi-K® (13-0-46)	859	112		395		
Haifa Cal (26% CaO)	27	4			7	
Magnesium sulphate (16% MgO)	58					9
Total	**1437**	**255**	**88**	**395**	**7**	**9**

Table 11: Recommended nutrient rates per ha per day and per growth stage as calculated by NutriNet™ :

Phase	Days from sowing / planting	kg/ha/day					kg/ha/phase				
		N	P_2O_5	K_2O	CaO	MgO	N	P_2O_5	K_2O	CaO	MgO
Planting	1	1	0	1	0	0	1	0	1	0	0
Vegetative growth	2-40	1.56	0.54	2.44	0.05	0.05	61	21	95	2	2
Tuber initiation & bulking	41-80	3.15	1.08	4.85	0.08	0.1	126	43	194	3	4
Maturation	81-130	2.36	0.82	3.64	0.06	0.08	118	41	182	3	4
						Total	306	105	472	8	10

Table 12: Recommended fertilizers rates per growth stage

Phase	Days from sowing / planting	kg/ha/phase				
		Ammonium nitrate 34-0-0	Haifa MAP* 12-61-0	Multi-K® * 13-0-46	Haifa Cal* (26% CaO)	Magnesium sulfate (16% MgO)
Planting	1	2	0	2	0	0
Vegetative growth	2-40	172	34	207	8	13
Tuber initiation & bulking	41-80	150	70	422	12	25
Maturation	81-130	72	67	396	12	25
	Total	**396**	**144**	**859**	**27**	**56**

*

Multi-K® = Potassium nitrate

Haifa MAP = Mono-ammonium phosphate

Haifa Cal = Calcium nitrate

3.1.2 Side dressing with Multi-K®

It is recommended to apply Multi-K® by side dressing in prilled form. It can be done by any surface fertilizer applicator. However, when the soil is too wet, especially in early spring, aerial application is recommended.

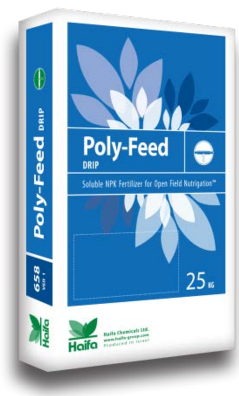
Table 12: Soil applied fertilization

Type of potatoes	When to apply	Rate kg/ha
Ware potatoes	5 - 8 weeks after planting	250 - 300 kg Multi-K® /ha
Early potatoes	After removing plastic cover	200 - 250 kg Multi-K® /ha
Comments	Split into 2 - 4 applications. First application 20-30 days after emergence	Fewer applications in heavier soils, more in light texture soils. 15 - 20 days interval.

3.1.3 Poly-Feed® water-soluble NPK fertilizers

Table 13: fertilization recommendations for potatoes. Expected yield: 60 ton/ha

Growth stage	Days	Poly-Feed® formula	kg/ha/day	Total kg/ha
Planting & Establishment	30	20-20-20	6	180
Tuber initiation	25	14-7-21+2MgO	18	450
Tuber growth	55	14-7-21+2MgO	18	990



3.1.4 Multicote® Agri controlled release fertilizer

An N:P_2O:K_2O ratio of 2:1:3* is recommended, as pre-plant application. This application will take care of the nutritional requirement of the plot for the entire growth season.

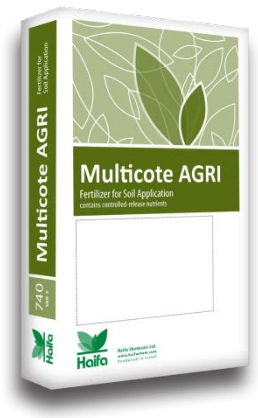
Multicote® Agri granules should be incorporated into the soil, 10cm deep and 10cm away from the planting row.

Consult a local Haifa representative for detailed explanations and instructions.

Table 14: Multicote® Agri application recommendations for potatoes*

	Application rate % of local practice*			% coated nutrients		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Light soil	60-70	100	70	70	-	Up to 50
Heavy soil	70-90	100	80	50-60	-	Up to 50

* These recommendations refer to areas where nitrogen application rates are not restricted by regulations. If nitrogen application is restricted, calculation of Multicote® Agri application rates should be based on the full optimum rates that would have been given with no restrictions.



3.1.5 Foliar nutrition

Foliar feeding is a fast and highly effective method of supplementing and enriching plant nutrients when needed. Foliar application of Haifa water soluble fertilizers provides needed plant nutrients for normal development of crops when absorption of nutrients from the soil is disturbed, precision-timed foliar sprays are also a fast-acting and effective method for treating nutrient deficiencies.

Foliar application of the correct nutrients in relatively low concentrations at critical stages in crop development contributes significantly to higher yields and improved quality.

Determine safe foliar applied rate:
To verify the safe rate under local conditions, it is advisable to spray recommended rate on a few plants. After 3-4 days check the tested plants for scorching symptoms.

Preparation of tank-mix:
Dissolve Haifa water-soluble fertilizes in about half of the tank volume, and add to the spray tank. When applying together with crop-protection agents, addition of wetting agents is not necessary. To ensure compatibility of tank-mix components, a small-scale test should be performed prior to actual application.

Table 15: Haifa water-soluble fertilizers for foliar application

Fertilizer	Curing Treatment	Recommended concentration
Haifa Bonus	Potassium deficiency	1% - 3%
Haifa MAP	Phosphorus deficiency	1% - 3%
Haifa MKP	Phosphorus and potassium deficiency	1% - 3%
Magnisal®	Magnesium deficiency	1% - 2%
Poly-Feed®	N-P-K and micronutrients deficiency	See table below
Haifa Micro	Micronutrients deficiencies	Consult Haifa agronomist

Table 16: Recommended foliar feeding with Poly-Feed® products for boosting crop performances

Stage	Poly-Feed® Foliar analysis	Concentration	Spray volume
Vegetative growth	"Vegetative Booster" 21-21-21	2% - 5%	50 – 80 L/ha
Tuber growth	"Poly-Potato" 12-5-40	Two applications at 2% - 4%	50 – 80 L/ha

3.2 Examples of potato fertilization with Multi-K® in various countries

3.2.1. South Africa

A. Cape region

Application Schedule	Product (N-P_2O_5-K_2O)		kg/ha	N	P	P_2O_5	K	K_2O
Before plant	Gypsum		2000					
Bended at planting	Granular 8-29-20		1130	55	110	252	95	114
Fertigation (Via Central Pivot)								
Weeks		Applications per week	Rate per application					
1 to 4	13-10-27*	2	75 kg/ha	80	27	61	133	160
	Calcium Nitrate	1	50 kg/ha	28	0	0	0	0
5 to 7	Multi-K®	2	60 kg/ha	55.2	0	0	110	132
	Calcium Nitrate	1	50 kg/ha	21	0	0	0	0
8 to 10	Multi-K®	3	60 kg/ha	54	0	0	158	189
Sub-total Nutrigation™				238	27	61	401	482
Total				293	137	313	496	596

* Water-soluble fertilizer made of Multi-K® MKP and AS

B. Free state

Fertilizers	Magnisal®	Haifa Cal	UAN	4-3-4 (18)	Multi-K®	KCl
S. G.	**1.3**	**1.48**	**1.3**	**1.3**	**0.2**	**0.2**
Week	**kg/ha**					
0 (Jan-10)						
1 - 5						
6	100	100	150	100		
7	100	100	150	100		
8	100	100	100	100		
9	7		90	100		
10				95	50	
11					50	
12					50	25
13					10	25
14						25
15						
Total	307	300	490	495	160	75

3.2.2. Australia

Soil type: Light (with low phosphorus and potassium)

Note: Nutrients supplied by a base dressing with strategic applications through the center pivot irrigators.

Recommended rates of nutrients

N	P	P_2O_5	K	K_2O
150-250 kg/ha	60-110 kg/ha	135-250 kg/ha	150-200 kg/ha	180-240 kg/ha

a) Base-dressing
On silt soils (medium soils) up to 50% of the N and K should be applied as pre-plant and up to 100 % of P applied as pre-plant dry fertilizer *.

N	P	P_2O_5	K	K_2O
50-80 kg/ha	60-110 kg/ha	135-250 kg/ha	50-60 kg/ha	60-70kg/ha

* On light (sandy) soils, up to 30% of the N and K should be applied as pre-plant and up to 100 % of the P applied as pre-plant dry fertilizer.

b) Nutrigation™
50%** of N and K are applied through the irrigation system (center pivot)

Time of application (weeks after emergence)	kg/ha/application					
	N	P	K	K_2O	Multi-K®	Ammonium Nitrate
1-5						
6	23	52	19	23	50	50
8	23	52	19	23	50	50
10	23	52	19	23	50	50
12	23	52	19	23	50	50
14	23	52	19	23	50	50

** When 70% of N and K are applied, increase Multi-K® rate to 55 - 60 kg/application an ammonium nitrate to 90 kg/application.

Nutrient applied kg/ha	N	P	P_2O_5	K	K_2O
(Approx)	195	70	160	185	225

Note: Nutrigation™ begins 6 weeks after emergence. If practical, applications can be split and applied on a weekly basis.

3.2.3. Poland

Soil type: Light /sandy
Plant density : 40,000-75,000 / ha
Expected yield: 35-45 T/ha, depending on variety

Average recommended rates of nutrients (kg/ha):

N	P_2O_5	K_2O	CaO	MgO
200-250	150	350-450	60-80	60-80

a) Base-dressing

Nutrient Requirements				Recommended Fertilizers			
N	P_2O_5	K_2O	MgO	AN	TSP	Haifa SOP	$MgSO_4$
30	100	130	53	90	220	260	160

AN - Ammonium nitrate (34%)
TSP - Triple Super phosphate (46% P_2O_5)
Haifa SOP - Potassium sulfate (50% K_2O)

b). Nutrigation™
Based on a weekly irrigation.

Growth stage	Weeks after emergence	Nutrition requirement (kg/ha/week)					Recommended fertilizer (kg/ha/week)			
		N	P_2O_5	K_2O	CaO	MgO	Multi-K® Mg	Haifa MAP	AN	CN
Vegetative growth	1-5	6	6					10	18	
Tuber initiation	6-7	5	5					8	15	
Tuber bulking	8-10	28		32	60	3.0	78		58	230*
Maturation	11-13	15		32		3.0	78		58	
	14-16			10		0.8	22			
Total		169	40	222	180	20	480	66	170	230

If fertilizers are applied by side-dressing, the entire weekly rate should be applied at once. Fertilizers should be placed besides the row.

Multi-K® Mg = Potassium nitrate enriched with magnesium (11-0-40+4MgO)
Haifa MAP= Mono-Ammonium Phosphate (12-61-0)
AN = Ammonium nitrate
CN = Calcium nitrate

3.2.4. Israel

Soil application:

Growth stage	N rate	Multi-K®*	P_2O_5 rate
From planting till tuber initiation	70-105 kg/ha	---	According to soil test or 150-200 kg /ha
At tuber initiation	-	300-500 kg/ha	
10 - 15 days later	-	300-500 kg/ha	

* Optional Multi-K® Mg

Foliar feeding:

Treatment	Fertilizer	Spray timing	Conc.	Spray volume	No. of applications
Improving growth	Poly-Feed® 20-20-20	One week after emergence	2% - 3%	Full coverage	2 - 3
Correcting K deficiency	Haifa Bonus 12-2-44	Two weeks after emergence	5% - 8%		
Higher yield	Haifa Bonus 12-2-44	From full canopy	5% - 8%		

Aerial application:
When there is a need for top-dressing and the soil is either too wet or the field is too large for timely ground application, an aerial application of prilled Multi-K® is a practical solution. This is especially effective when the soil temperature is still cold, (usually in early spring), so a nitrate application will enable the plant to take up nitrogen at this stage for quick response.

Appendix I: Haifa specialty fertilizers

Pioneering Solutions

Haifa develops and produces **Potassium Nitrate** products, **Soluble Fertilizers** for Nutrigation™ and foliar sprays, and **Controlled-Release Fertilizers**. Haifa's Agriculture Solutions maximize yields from given inputs of land, water and plant nutrients for diverse farming practices. With innovative plant nutrition schemes and highly efficient application methods, Haifa's solutions provide balanced plant nutrition at precise dosing, composition and placing. This ultimately delivers maximum efficiency, optimal plant development and minimized losses to the environment.

Potassium Nitrate

Haifa's Potassium Nitrate products represent a unique source of potassium due to their nutritional value and contribution to plant's health and yields. Potassium Nitrate has distinctive chemical and physical properties that are beneficial to the environment. Haifa offers a wide range of potassium nitrate products for Nutrigation™, foliar sprays, side-dressing and controlled-release fertilization. Haifa's potassium nitrate products are marketed under the Multi-K® brand.

Multi-K® Products

Pure Multi-K®	
Multi-K® Classic	Crystalline potassium nitrate (13-0-46)
Multi-K® Prills	Potassium nitrate prills (13-0-46)
Special Grades	
Multi-K® GG	Greenhouse-grade potassium nitrate (13.5-0-46.2)
Multi-K® pHast	Low-pH potassium nitrate (13.5-0-46.2)
Multi-K® Top	Hydroponics-grade potassium nitrate (13.8-0-46.5)
Enriched Products	
Multi-npK®	Enriched with phosphate; crystalline or prills
Multi-K® Mg	Enriched with magnesium; crystalline or prills
Multi-K® Zn	Enriched with zinc; crystalline
Multi-K® S	Enriched with sulfate; crystalline
Multi-K® B	Enriched with boron; crystalline or prills
Multi-K® ME	Enriched with magnesium and micronutrients; crystalline

Nutrigation™

Nutrigation™ (fertigation) delivers pure plant nutrients through the irrigation system, supplying essential nutrients precisely to the area of most intensive root activity. Haifa's well-balanced Nutrigation™ program provides the plant with their exact needs accordingly with seasonal changes. Decades of experience in production and application of specialty fertilizers for Nutrigation™ have made Haifa a leading company in this field. Haifa keeps constantly up to date with contemporary scientific and agricultural research, in order to continuously broaden its product line to better meet the requirements of crops and cropping environments.

Haifa offers a wide range of water-soluble fertilizers for Nutrigation™. All products contain only pure plant nutrients and are free of sodium and chloride

Multi-K®	Comprehensive range of plain and enriched potassium nitrate products
Poly-Feed®	Soluble NPK fertilizers enriched with secondary and micro-nutrients
Haifa MAP	Mono-ammonium phosphate
Haifa MKP	Mono-potassium phosphate
Haifa Cal	Calcium nitrate
Magnisal®	Our original magnesium nitrate fertilizer
Haifa Micro	Chelated micronutrients
Haifa VitaPhos-K™	Precipitation-proof poly-phosphate for soilless Nutrigation™
Haifa ProteK	Systemic PK fertilizer

Foliar Feeding

Foliar Feeding provides fast, on-the-spot supplementary nutrition to ensure high, top quality yields and is an ideal feeding method under certain growth conditions in which absorption of nutrients from the soil is inefficient, or for use on short–term crops. Precision-timed foliar sprays are also a fast-acting and effective method for treating nutrient deficiencies. Foliar application of the correct nutrients in relatively low concentrations at critical stages in crop development contributes significantly to higher yields and improved quality. Haifa offers a selection of premium fertilizers for foliar application. Haifa offers a selection of fertilizers for foliar application:

Haifa Bonus High-K foliar formulas enriched with special adjuvants for better absorption and prolonged action
Poly-Feed® Foliar NPK formulas enriched with micronutrients specially designed to enhance the crop performance during specific growth stages

Magnisal®, **Haifa MAP**, **Haifa MKP**, **Haifa Cal** and **Haifa Micro** are also suitable for foliar application.

Controlled Release Nutrition

Multicote®, Haifa's range of Controlled Release Fertilizers includes products for agriculture, horticulture, ornamentals and turf. Multicote® products provide plants with balanced nutrition according to their growth needs throughout the growth cycle. Multicote® products enhance plant growth, improve nutrients use efficiency, save on labor and minimize environmental impact.

Single, pre-plant application controlled-release fertilizer can take care of the crop's nutritional requirements throughout the growth season. Controlled release fertilizers are designed to feed plants continuously, with maximal efficiency of nutrients uptake. Controlled release fertilizers save labor and application costs. Their application is independent of the irrigation system, and does not require sophisticated equipment.

Taking advantage of MulticoTech™ polymer coating technology, Haifa produces Multicote® line of controlled release fertilizers.

Multicote® Products

Multicote® for nurseries and ornamentals; NPK formulae with release longevities of 4, 6, 8, 12 and 16 months
Multicote® Agri / Multigro® for agriculture and horticulture
CoteN™ controlled-release urea for arable crops
Multicote® Turf / Multigreen® for golf courses, sports fields, municipals and domestic lawns

Appendix II: Conversion tables

From	To	Multiply by	From	To	Multiply by
P	P_2O_5	2.29	P_2O_5	P	0.44
P	PO_4	3.06	PO_4	P	0.32
H_3PO_4	H_2PO_4	0.9898	H_2PO_4	H_3PO_4	1.01
K	K_2O	1.20	K_2O	K	0.83
Ca	CaO	1.40	CaO	Ca	0.71
Mg	MgO	1.66	MgO	Mg	0.60
S	SO_3	2.50	SO_3	S	0.40
S	SO_4	3.00	SO_4	S	0.33
N	NH_4	1.28	NH_4	N	0.82
N	NO_3	4.43	NO_3	N	0.22

From	To	Multiply by	From	To	Multiply by
Acre	Hectare	0.405	Hectare	Acre	2.471
Kilogram	Lbs	2.205	Lbs	Kilogram	0.453
Gram	Ounces	0.035	Ounces	Gram	28.35
Short Ton	MT	0.907	MT	Short Ton	1.1
Gallon (US)	Liters	3.785	Liters	Gallon (US)	0.26
Kg/Ha	Lbs/acre	0.892	Lbs/acre	Kg/Ha	1.12
MT/Ha	Lbs/acre	892	Lbs/acre	MT/Ha	0.001

1 meq	Correspondent element (mg)	1 mmol	Correspondent element (mg)	Weight of ion
NH_4^+	14 mg N	NH_4^+	14 mg N	18 mg NH_4^+
NO_3^-	14 mg N	NO_3^-	14 mg N	62 mg NO_3^-
$H_2PO_4^-$	31 mg P	$H_2PO_4^-$	31 mg P	71 mg P_2O_5
HPO_4^{2-}	31 mg P	HPO_4^{2-}	31 mg P	35,5 mg P_2O_5
HPO_4^{2-}	15.5 mg P	K^+	39 mg K	47 mg K_2O
K^+	39 mg K	Ca^{2+}	40 mg Ca	28 mg CaO
Ca^{2+}	20 mg Ca	Mg^{2+}	24 mg Mg	20 mg MgO
Mg^{2+}	12 mg Mg	SO_4^{2-}	32 mg S	48 mg SO_4
SO_4^{2-}	16 mg S	Na^+	23 mg Na	-
Na^+	23 mg Na	Cl^-	35.5 mg Cl	-