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Specialty Plant Nutrition **experts**

POTATO

+ Yield

- Number of tubers
- Storage
- Weight

+ Quality

- Size
- Dry matter
- Shape
- Skin quality

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SPECIALTY PLANT NUTRITION EXPERTS **POTATO**

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SPECIALTY PLANT NUTRITION EXPERTS ***POTATO***

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SQM,
experts in
Specialty Plant Nutrition

SQM, experts in Specialty Plant Nutrition, has developed this material to help producers, advisers and technicians in the potato industry to identify and obtain production improvements. Scientific information from field experiences in the Specialty Plant Nutrition area guided the creation of this material.

At SQM, we know that we must firstly understand a crop's production challenges in order to develop nutritional programs that offer effective solutions. Therefore, this booklet considers the role of plant nutrition in each key aspect of crop development and how to maximize production potential in specific conditions. Since potato crops in different areas of the world face varying production challenges, we recommend contacting local agronomy experts at SQM. These experts will assist you in identifying needs and building tailored nutritional programs that meet production objectives.

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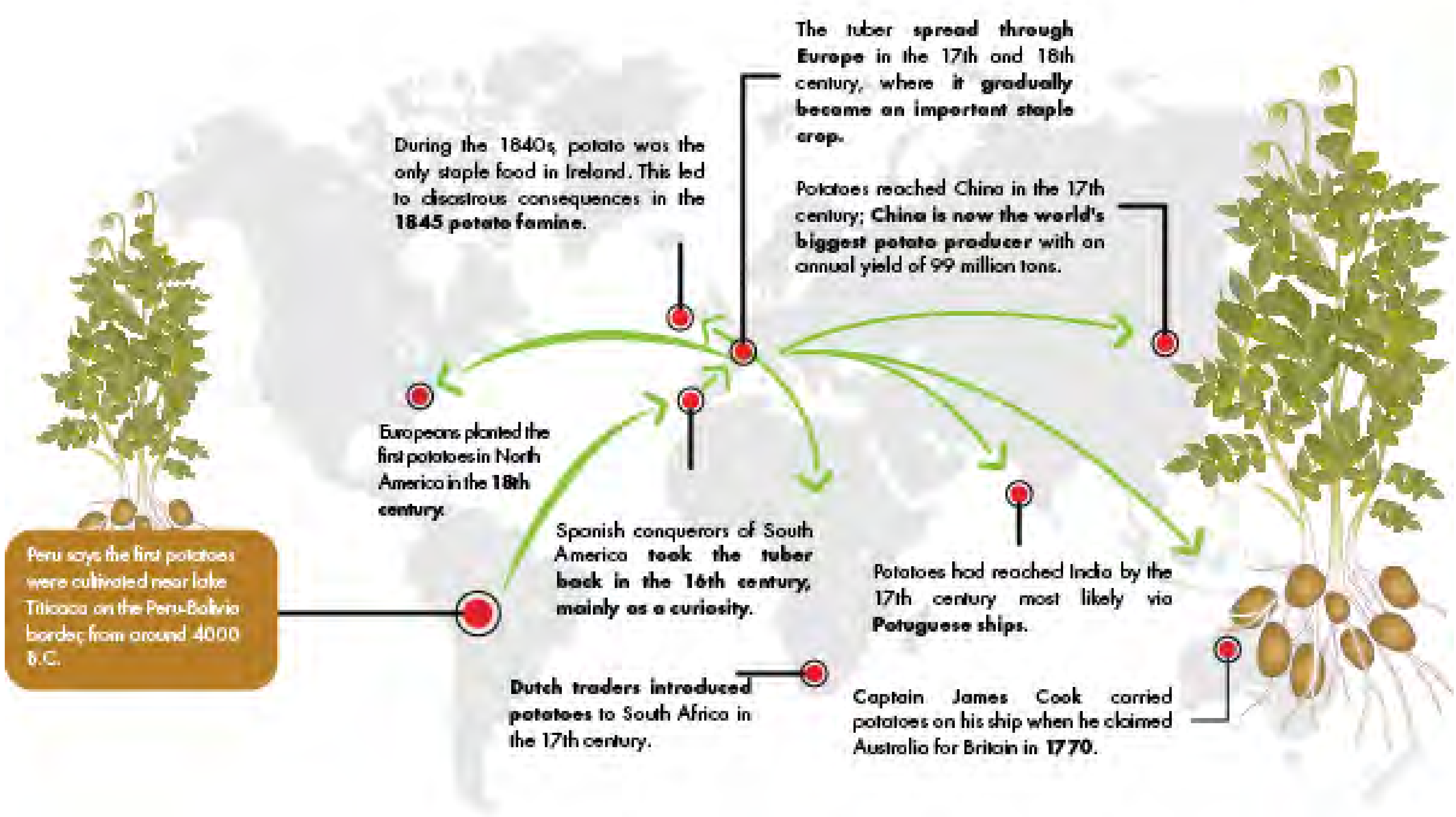
The information herein contained is given to the best of SQM's knowledge and is believed to be accurate. The conditions of your use and application of the suggested formulae and recommendations are beyond our control. No warranty is made as to the accuracy of any data or statements contained herein. SQM specifically disclaims any responsibility or liability relating to the use of the suggested formulae and recommendations and shall under no circumstances whatsoever be liable for any special, incidental or consequential damages arising from such use.

1.Origin

Potato (Solanum tuberosum, L.) is a cultivated plant that originates from the high plains of South America. The most ancient center of potato cultivation is probably the high plains of southern Peru and western Bolivia. Although potato cultivation appears to have originated exclusively in the Andean region, consumption of wild potato likely extended into the Southwestern United States (Burton, 1989).

The potato conquest of the world

Tuber conquering the world from the Andes



Peru says the first potatoes were cultivated near lake Titicaca on the Peru-Bolivia border, from around 4000 B.C.

Europeans planted the first potatoes in North America in the **18th century.**

During the 1840s, potato was the only staple food in Ireland. This led to disastrous consequences in the **1845 potato famine.**

The tuber **spread through Europe** in the 17th and 18th century, where **it gradually became an important staple crop.**

Potatoes reached China in the 17th century; **China is now the world's biggest potato producer** with an annual yield of 99 million tons.

Spanish conquerors of South America **took the tuber back in the 16th century, mainly as a curiosity.**

Potatoes had reached India by the 17th century most likely via **Potuguese ships.**

Dutch traders introduced potatoes to South Africa in the 17th century.

Captain James Cook carried potatoes on his ship when he claimed Australia for Britain in **1770.**

Source:
Food and Agriculture Organization of the United Nations, 2008.

2. Worldwide statistics (MT/ha)

MT/ha
19,58

Global potato yields

RANKING OF HARVESTED AREA	COUNTRY	AREA HARVESTED (ha)	PRODUCTION (MT = Metric ton)	YIELD MT/ha
1	China	5.815.140	99.122.420	17,05
2	India	2.130.000	43.770.000	20,55
3	Russia	2.030.858	31.107.797	15,32
4	Ukraine	1.311.600	21.750.290	16,58
5	Bangladesh	475.699	9.474.099	19,92
6	USA	407.810	19.990.950	49,02
7	Canada	342.409	4.324.110	12,63
8	Nigeria	333.100	1.246.380	3,74
9	Poland	311.620	8.872.445	28,47
10	Peru	310.698	4.400.295	14,16
11	Belarus	292.401	5.985.810	20,47
12	Germany	242.500	10.772.100	44,42
13	Nepal	199.971	2.805.582	14,03
14	Tanzanía	186.905	1.499.508	8,02
15	Kazakhstan	186.242	3.545.695	19,04
16	Romania	186.233	2.689.733	14,44
17	Egypt	184.592	5.029.022	27,24
18	Bolivia	181.708	1.073.744	5,91
19	Pakistan	178.223	4.000.361	22,45
	Others (20,46% of the world area)	3.938.756	95.366.624	19,83
	World total	19.246.465	376.826.965	19,58

Source: FAOSTAT, 2017

Countries with the greatest mean yield

48,99
New Zealand

49,02
USA

44,42
Germany

40,05
Jordan

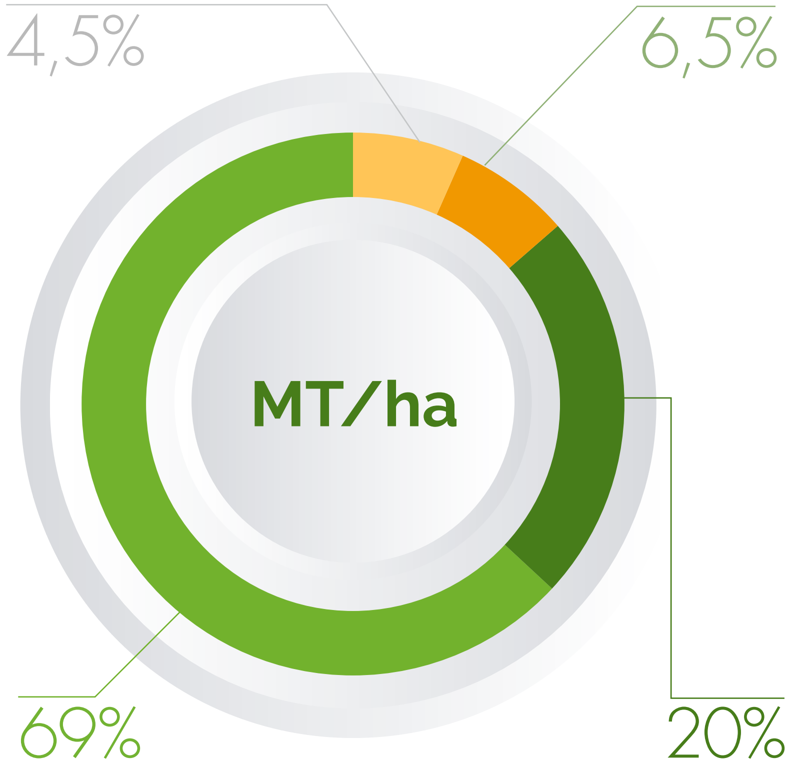
42,48
Denmark

42,00
The Netherlands

Source: FAOSTAT, 2017

Average yield

The world mean yield reached 19.58 MT/ha. A group of countries, including the United States, New Zealand, Germany, Denmark, the Netherlands, Australia and Jordan, have productions way above this average, with national average yields of more than 40 MT/ha. As shown in the figure, these countries represent only 4,5% of the global production area of potato.



Distribution of the mean yield in MT/ha of global potato production areas

- ● above 40 MT/ha
- ● from 30 to 40 MT/ha
- ● from 20 to 30 MT/ha
- ● less than 20 MT/ha

Source: FAOSTAT, 2017

> It is important to investigate the factors that contribute to these yield differences and the various approaches that can be taken to realize production potential

3. Production potential and yield components

Under ideal conditions, the production potential for the potato crop is more than 100 MT/ha. Variety, environmental and management factors affect the crop's ability to obtain this production potential.

All factors shown in the figure below directly influence potato yield components, including the number and weight of tubers.

YIELD (MT/ha) = Nº TUBERS X TUBER WEIGHT

Nº OF TUBERS

Nº of plants /ha | Nº of stems /plant

TUBER WEIGHT

Dry matter production | Dry matter translocation to the tubers

4. Key factors
in reaching production potentials

From a potato crop phenology viewpoint, six key factors can affect a plant's ability to reach production potential:

6 Key factors for realizing production potentials

- 4.1 Seed quality
- 4.2 Emergence and root development
- 4.3 Vegetative growth
- 4.4 Tuberization
- 4.5 Foliar area maintenance and optimization of light usage for the production of dry matter
- 4.6 Translocation of photoassimilates

4.1 Seed quality

The vigor, physiological age and health of seed tubers determine the number of tubers a potato plant will produce, in addition to the tuber weight and production potential. It is important to consider that the seed tubers feed the new plant until its root system is well developed.

Recently harvested tubers must undergo a dormant period or physiological rest in order for bud break to occur. Prematurely harvested potatoes tend to have longer rest periods than those harvested at full maturity.

Physiologically younger seed tubers generally present an accentuated apical dominance, which results in a lower number of bud breaks and stems.

Kramm (2017) showed that physiologically mature seed tubers generally have multiple bud breaks and generate a larger number of original stems from the potato seed. Along with other factors, this larger number of stems contributes to a larger number of tubers per plant.

Dormancy

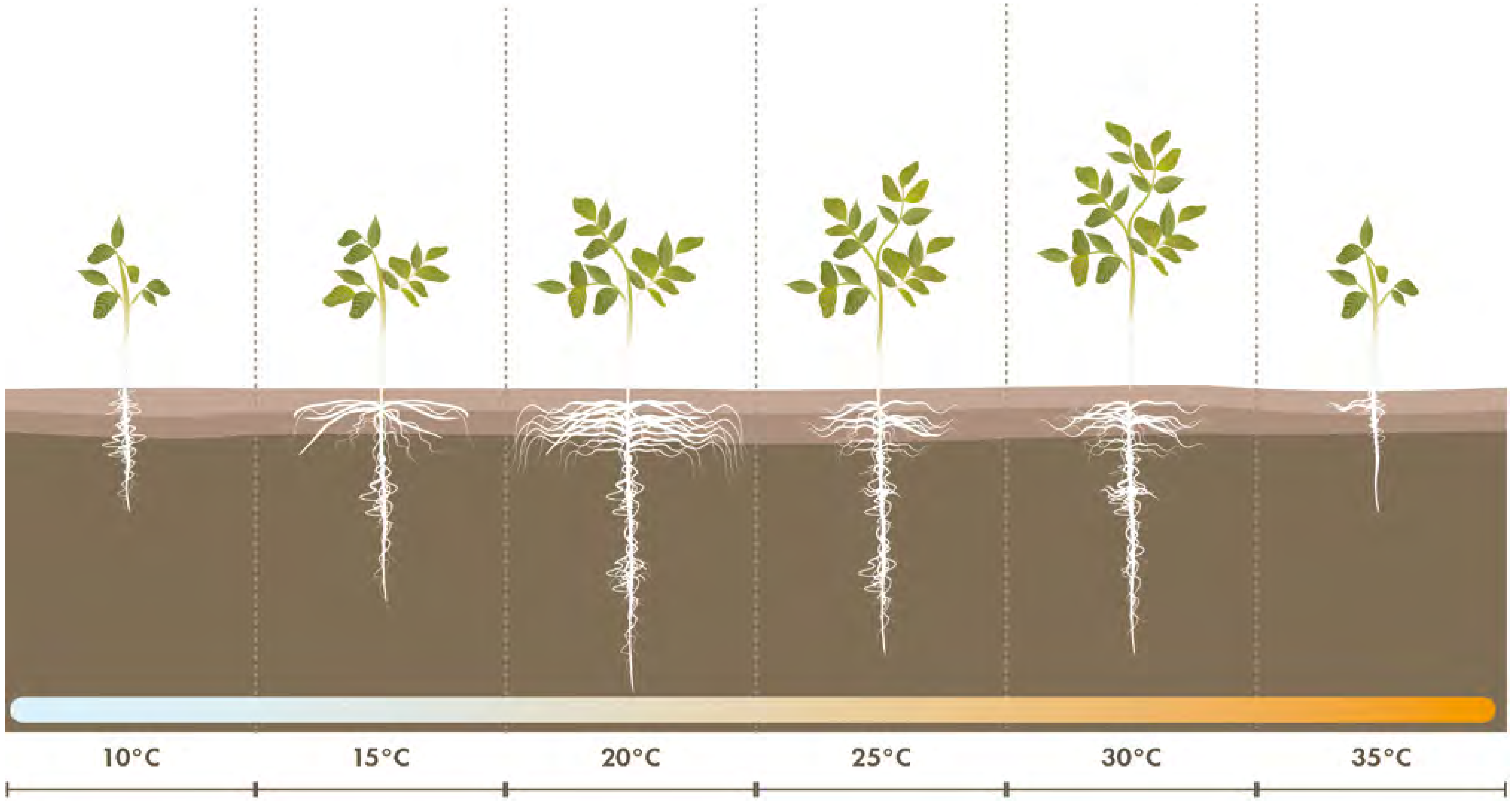
Apical dominance

Multiple bud breaks

4.2 Emergence and root development

Crop uniformity is determined by the homogeneity of emergence and the subsequent development of the plant (Kramm, 2017). Therefore, high productivity is directly related to a shorter period from planting to emergence, which helps to rapidly initiate the photosynthetic process.

Thus, factors such as adequate physiological age of the seed tuber, pre-bud break, superficial planting and adequate soil temperature (over 10° C) accelerate this process (Contreras, 2002). Temperature directly influences emergence and root development. After emergence, the roots and shoots of the plant are simultaneously developed.



SOURCE: Sattelmacher et al, 1990

Importance of **nitrogen** source in suboptimal temperature conditions

It is very important to select the optimal nitrogen source to be utilized on potato crops, especially at suboptimal temperature conditions (lower than 15° C and higher than 25° C). The majority of nitrogen absorbed by potato plants, 70 to 90 percent, is in the form of nitrate (Van Beusichem et al., 1988). In this form, nitrogen is transported to the leaves where it is reduced to NH_3. The NH_3 is immediately detoxified and combined with sugars produced during photosynthesis in order to generate an amino acid -glutamine- (Marschner, 1995).

When nitrogen is absorbed in the form of ammonium (NH_4), it is completely metabolized in the roots. The carbohydrates transported to the roots via the phloem are necessary for root development. This means that part of the carbohydrates, targeted to fuel root growth, now have to be used for the ammonium metabolism, which leaves less carbohydrates available for root growth. (Marschner, 1995).

Additionally, under stressful conditions, such as high or low temperatures, drought and salinity in the root zone, the plant's respiratory rate increases, which results in lower carbohydrates availability for the NH_4 metabolism. This could cause pH reduction and even toxicity by NH_3 (Kafkafi et al, 2012).

4.3 Vegetative growth

After emergence, a rapid phase of vegetative growth begins and continues until flowering before diminishing considerably, although it does not stop completely.

At this point, strong foliage and good root development are needed in order to start tuber growth. According to Harris (1992), there is a direct relationship between the growth rates of the roots and shoots. This means that varieties with large aerial growth have comparable root growth, and vice versa. The production of dry matter is fundamental to obtaining high yields, and for this the LAI (leaf area index) must reach 3 m^2 of leaf area/m^2 of crop surface as early as possible. This LAI should be maintained actively for as long as possible.

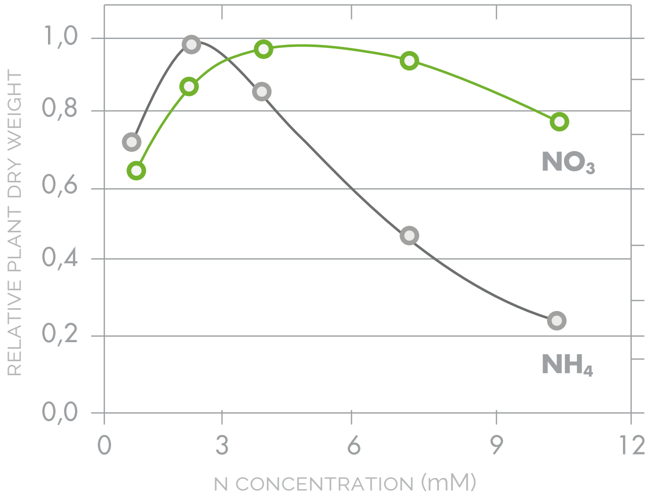
An early foliar cover is more important than a late senescence under scarce light conditions. Under conditions free of water stress, light interception is responsible for 92 percent of the yield variation.

Maximum root and vegetative growth is needed in the shortest timeframe prior to tuberization

Cytokinins stimulate growth of axillar and lateral buds (rupture of the apical dominance) and impede the onset of foliar senescence. Many researchers have demonstrated the influence of nitrate on cytokinin synthesis and accumulation, but these processes do not occur with ammonium sources (Hirose et al., 2008; Argueso et al., 2009; Peng et al., 2008). Nitrate nitrogen generates a rapid lateral vegetative growth since it encourages cytokinin synthesis, which allows an accelerated closure of the crop canopy (Römheld et al, 2005).

Nitrate nitrogen allows for greater plant development

Comparative response of potato plant growth to nitrate and ammonium solution concentrations (Cao and Tibbitts, 1998).



4.4 Tuberization

Tuberization starts when the stolons begin thickening. The tuberization process is very short, depending on the variety, temperature and soil moisture. Tuberization occurs five to seven weeks after planting, or between 15 and 40 days following emergence. Tuberization starts when the stolons begin thickening. During this stage, carbohydrates produced in the foliage are utilized for stolon growth and the initiation of the tuberization (Al Soboh et al, 2000).

The tuber initiation process depends on both the photoperiod and on certain plant hormones. Under high temperature conditions, gibberellins synthetized in the emerging stems are transported to the stolons. A high concentration of gibberellins in the stolons inhibits the tuberization process.

Several researchers (Guivarc'h et al., 2002; Rosin et al., 2003; Sergeeva et al., 2000) have demonstrated that potato tuberization is accelerated when the relation cytokinins/auxins is in favor of the cytokinins. In this way, a concentration increment of cytokinins favors the tuberization, especially in early species (García-Flores et al, 2009).

Temperatures above 20° C substantially impede the tuberization process, and it is totally inhibited if temperatures rise above 30° C (Al Soboh et al, 2000). Additionally, tuber initiation occurs three to four weeks earlier when it takes place on days with 10 to 14 hours of sunlight compared to days with more than 14 hours of sunlight (Dean, 1994). Contreras (2002) states that short days and low temperatures stimulate tuber initiation and that low night temperatures are more effective than low day temperatures. Short days with high temperatures cause short cycle varieties to initiate and develop tubers considerably earlier than long cycle varieties.

A concentrated tuberization period leads to greater homogeneity in the tuber size

Nutrition and tuberization

Applying **phosphorus** to the soil is fundamental for adequate **formation** of the root system and, in turn, achieving a greater number of tubers. Also, the application of nitrate nitrogen enhances cytokinin synthesis, while boron and zinc enhance intensive cell division. Additionally, an adequate **N:K balance** must exist, since excess nitrogen diminishes tuberization and elongates the process, resulting in a non-uniform tuber size.

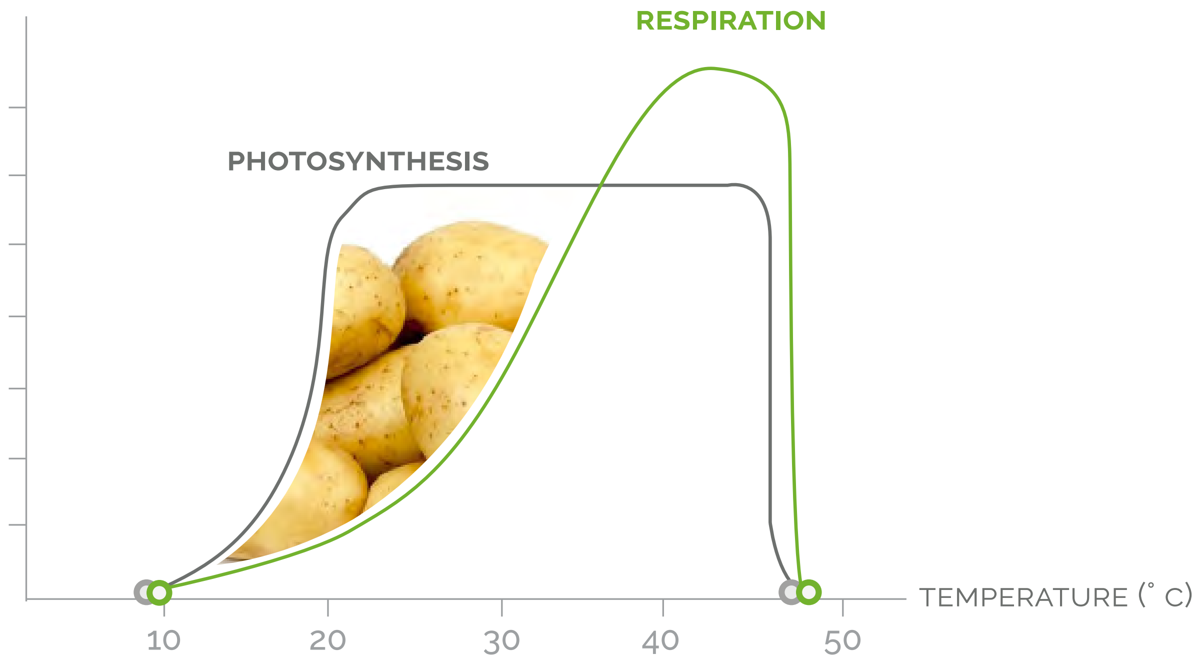
4.5 Foliar area maintenance and usage of light for the production of dry matter

One of the main functions of the photosynthetic system in potatoes is to capture light and harness it for the production of dry matter. As long as the foliar area is active, photosynthesis will occur, leading to greater yield and higher tuber quality.

Assimilation rates will reach 100 percent when the soil surface is completely covered by the foliage. The gross potato assimilation in a fully sunny day (50.000 lux) at 18 to 20° C is of 1,92 g CO_2 per m^2 of foliar area per hour, at a concentration of 0,03 percent of CO_2 in the air (Contreras, 2002).

Maximum yield is directly related to net daily photosynthesis, and obtaining maximum yield can take a prolonged time. The ideal situation is to have 3 m^2 of foliar area per each square meter of crop surface (Contreras, 2002).

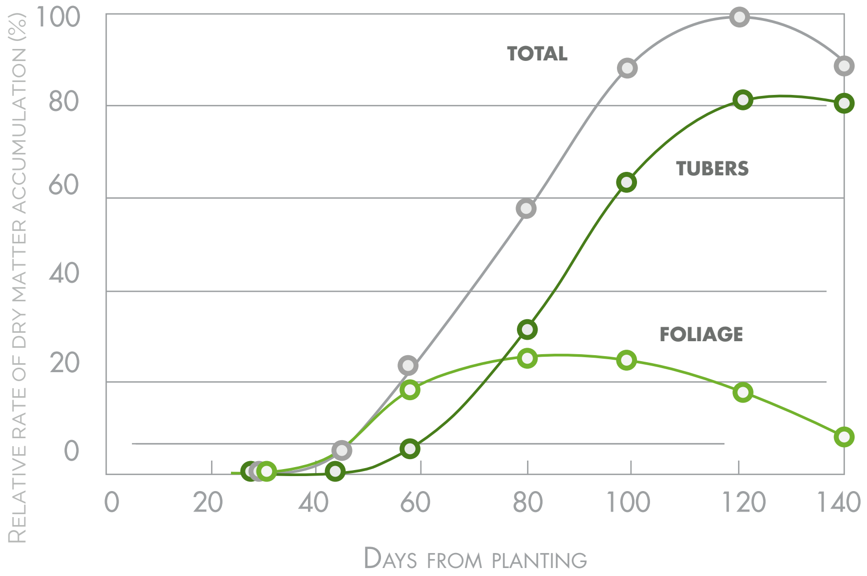
To determine net photosynthesis, the carbohydrates consumed in the respiration process have to be subtracted from the carbohydrates produced in the photosynthesis process. As shown in the figure below, increased temperatures cause respiration to increase, leaving less carbohydrates available for growing and accumulation in the tubers. Increased respiration also occurs under stressful conditions, such as drought and salinity.



Under stressful conditions, respiration increases leaving less carbohydrates for plant and tuber growth. Longer active foliar area duration results in a larger production potential

4.6 Photoassimilate translocation

The dynamics of photoassimilates distribution between foliage and tubers throughout potato's life-cycle.



Production and percent distribution of dry matter produced by a potato crop (cv. Russet Burbank)

Horneck and Rosen (2008)

During the bulking stage of tubers, potatoes require high day-time temperatures (18 to 20°C) and lower night-time temperatures (12 to 14°C) in order for carbohydrates to accumulate. This temperature regime helps the accumulation of dry matter, thanks to enhanced carbohydrate production, and minimized carbohydrate consumption by respiration.

Once the carbohydrates have been produced, they are transported to the different organs via phloem. **Magnesium** and **boron** play a central role in this process, but mainly potassium.

> Potassium is the main osmotic regulator of plants, and it directly participates in the stream of photoassimilates via phloem

Magnesium, boron and notably potassium are the principal elements that enable the translocation of carbohydrates from the leaves to the tubers

5. Plant nutrition

5.1 Nutrient demand

5.2 Effect of nutrients on yield parameters and tuber quality

5.3 Summary of main functions of nutrients

5.4 Absorption curve of nutrients

5.5 Vegetative/generative growth balance

5.1 Nutrient demand

Due to high production potential and the accumulation of starch in the tubers, potato crops require large amounts of nutrients, especially potassium.

Nutrient removal by potato tubers and foliage, per ton of tuber produced.

NUTRIENT	REMOVAL OF NUTRIENTS IN KG/MT OF FRESH TUBERS
N	3,0 - 5,3
P	0,6 - 1,1
K	7,4 - 9,8
Ca	0,10 - 1,5
Mg	0,25 - 0,45
Zn	0,002 - 0,003

NUTRIENT	REMOVAL OF NUTRIENTS IN KG/MT OF FRESH TUBERS
N	3,0 - 5,3
P_2O_5	1,4 - 2,6
K_2O	8,9 - 11,8
CaO	0,14 - 0,21
MgO	0,42 - 0,75

Dean, 1994

Potato crops remove **two to three** time more potassium than nitrogen

5.2 The specific contributions of the nutrients on potato yield and quality

CHARACTERISTICS	N	P	K	Ca	Mg	S	Mn	B	Zn
SIZE OF TUBERS	⊕	⊕	⊕		⊕		⊕	⊕	
NUMBER OF TUBERS		⊕	⊕						
STARCH			⊕		⊕			⊕	
SKIN QUALITY				⊕	⊕	⊕	⊕	⊕	⊕
STORAGE			⊕	⊕				⊕	

5.3 Summary of main nutrient functions

Each element has specific functions within the potato development.

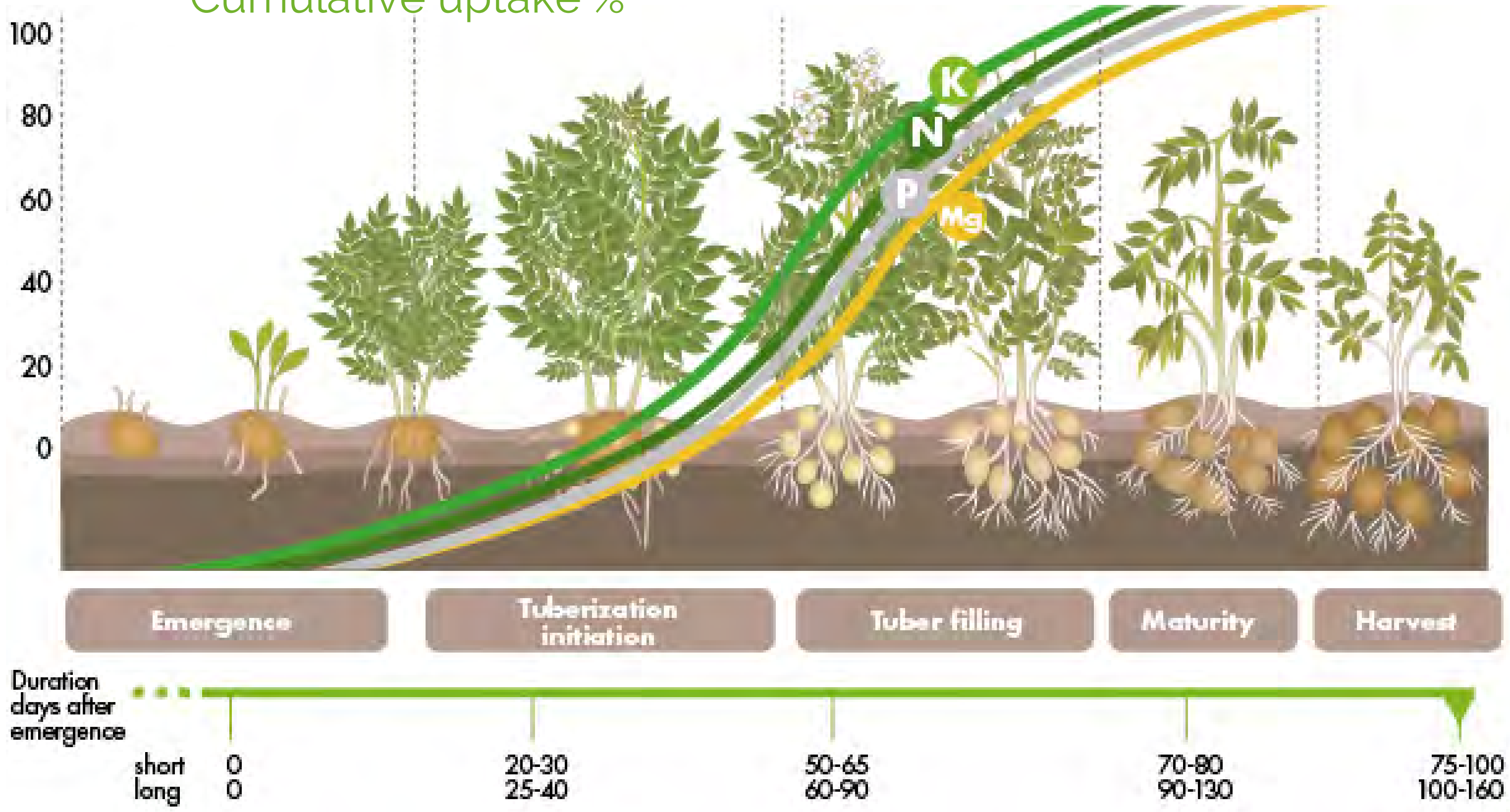
Nitrogen	Synthesis of proteins (growth and yield). Nitrate participates in the formation of cytokinins
Phosphorus	Helps to form and develop the root system and energetic compounds and aids in cellular division
Potassium	Transports carbohydrates, regulates osmosis, stomata control, photosynthesis enhancement, reduces susceptibility to diseases
Calcium	Improves tuber storage and skin quality and reduces susceptibility to diseases
Sulfur	Synthesis of essential amino acids, cysteine and methionine
Magnesium	Indispensable part of the chlorophyll molecule
Iron	Synthesis of chlorophyll
Manganese	Needed for the photosynthesis process
Boron	Formation of the cellular wall (pectins and lignins). Participates in the metabolism and transport of sugars
Zinc	Synthesis of auxins
Copper	Influences the metabolism of nitrogen and carbohydrates
Molybdenum	Part of the nitrate reductase enzyme and nitrogenase

5.4 Nutrient absorption curve

In the first growing stages, it is the seed tuber that provides the growth energy and the raw materials to the new plant. Once the plant has exhausted its internal reserves of nutrients, it must absorb nutrients from the soil in order to continue its rapid growth. The crop primarily develops foliage and roots for the first five to six weeks after emergence. At the end of this phase, the roots typically reach 72 percent of their exploration depth and more than 82 percent of foliage development.

Afterward, the tuber begins to grow faster, with most growth occurring between the seventh and fifteenth weeks. By this point, the tubers will have reached 95 percent of their final fresh weight. According to Contreras (2002), before flower initiation, 70 to 75 percent of the nutrients are absorbed, and most dry matter is produced. During this period of rapid tuber growth, highly soluble fertilizers are crucial for ensuring that a nutritional supply is available to the potato plant.

Cumulative uptake %



5.5 Vegetative/generative growth balance

Potato crops undergo four clearly identifiable phenological phases:

4 stages

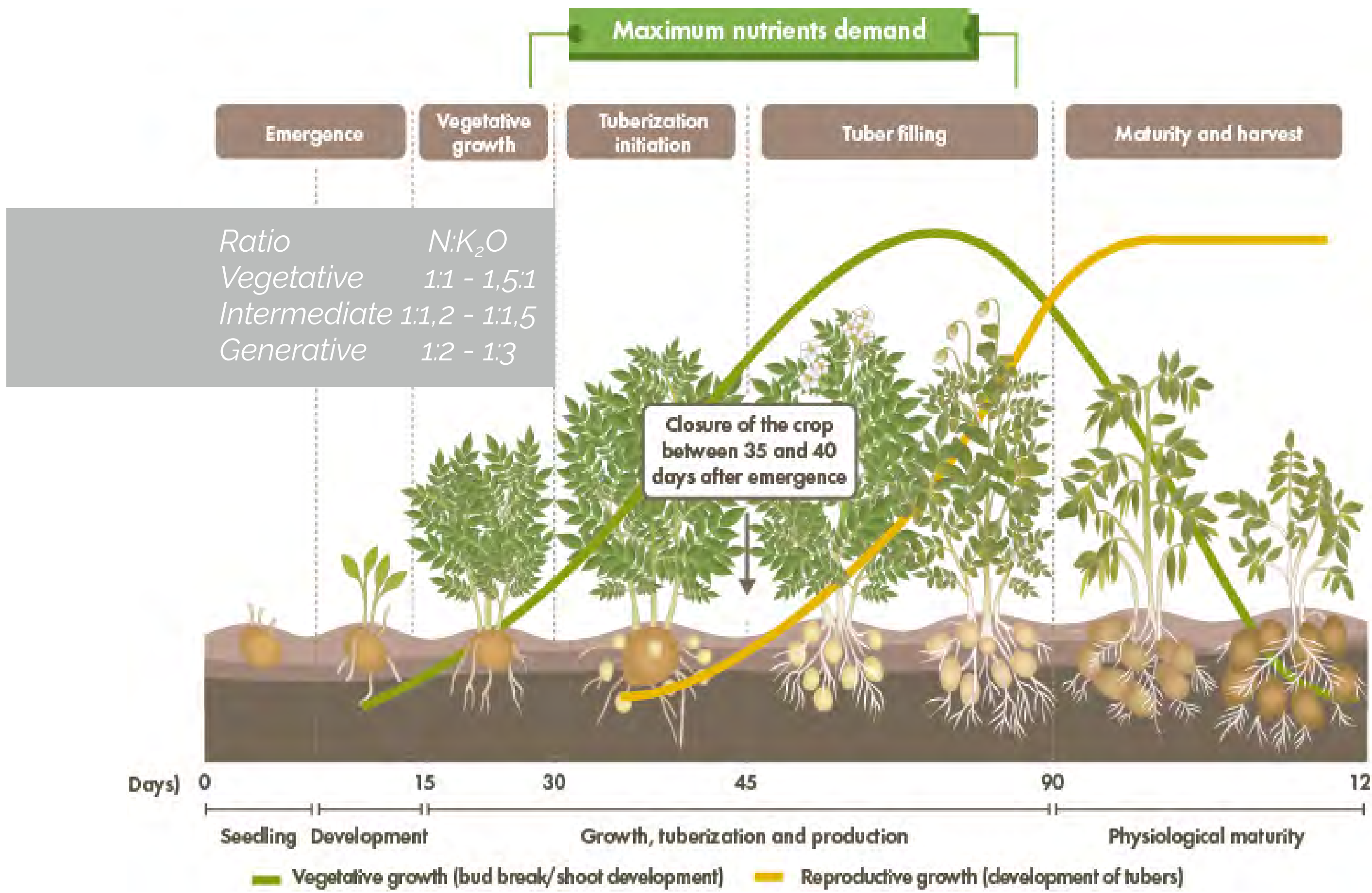
phenological **phases**

1. Planting to emergence
2. Emergence to tuberization initiation
3. Tuberization initiation to tuber filling
4. Tuber filling to maturity

Each of these phases has specific environmental and nutritional requirements to achieve the growth objectives of the different organs of the plant; taking into account that usually more than one organ is developing at the same time and competing for the photoassimilates produced by the plant.

This way, there is a balance between the vegetative and generative growth of the potato crop. A vegetative balance privileges the development of stems and the foliar area, while a generative balance favours the production and filling of tubers.

Nutritionally, the N: K ratio determines the vegetative and generative growth balances. A high N: K ratio promotes vegetative growth, while a low N: K ratio stimulates generative growth.



Ratio	$N:K_2O$
Vegetative	1:1 - 1,5:1
Intermediate	1:1,2 - 1:1,5
Generative	1:2 - 1:3

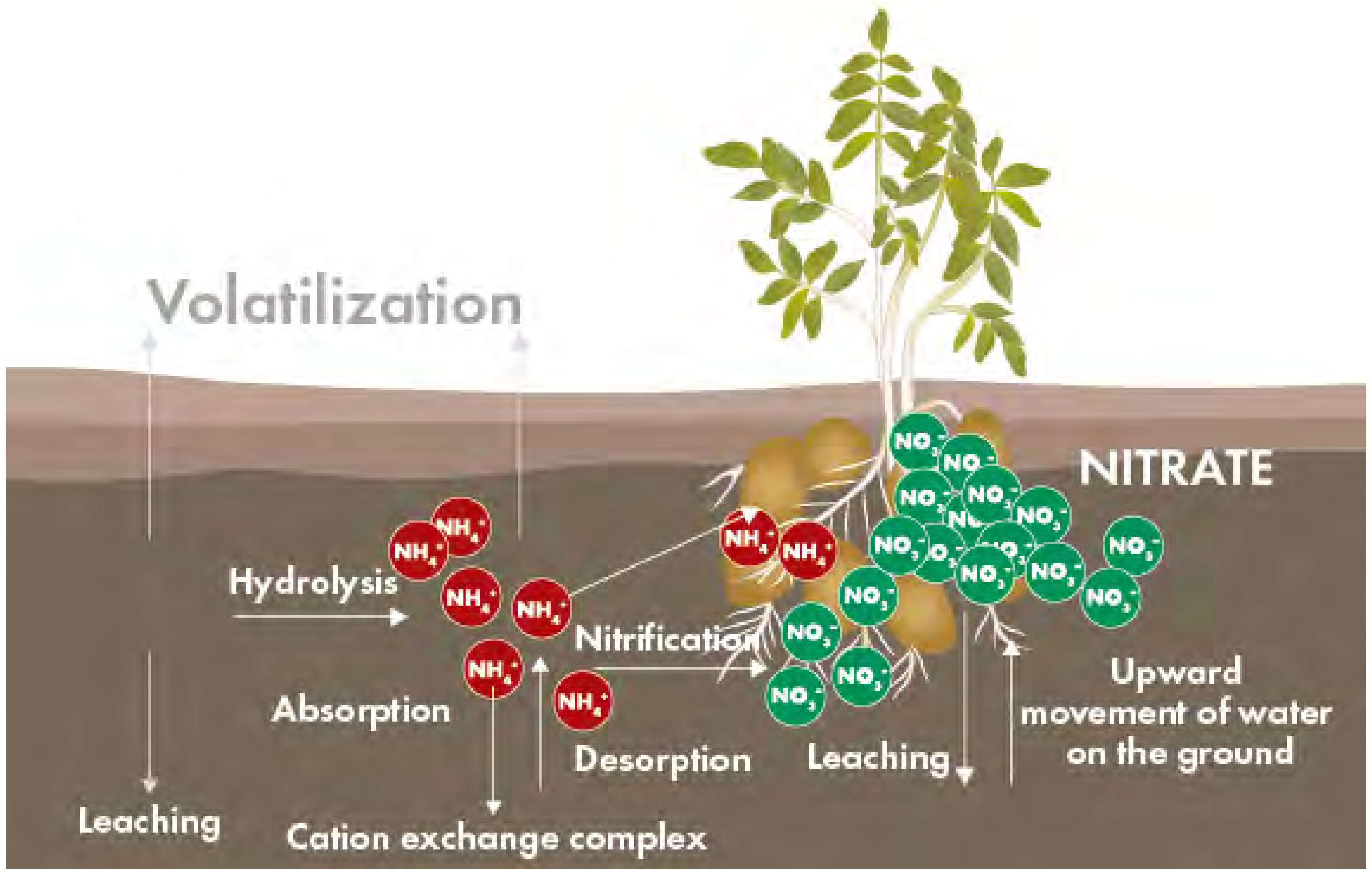
6. Nutrient sources

Previous chapters described the potato plant's requirement for nutrients, needed to obtain high yields and high quality of tubers. Additionally, the maximum nutrient demands and the importance of balancing vegetative and generative growth were reviewed. Now the benefits of different nutrient sources will be discussed in order to decide which fertilizers will best match the crop's needs in the most efficient way.

6.1 Nitrogen
    6.1.1 Summary of the benefits of nitrate sources
6.2 Phosphorus
6.3 Potassium
6.4 Results of trials and research
    6.4.1 Summary of the benefits of potassium nitrate
6.5 The importance of multiple fertilizer applications

6.1 Nitrogen

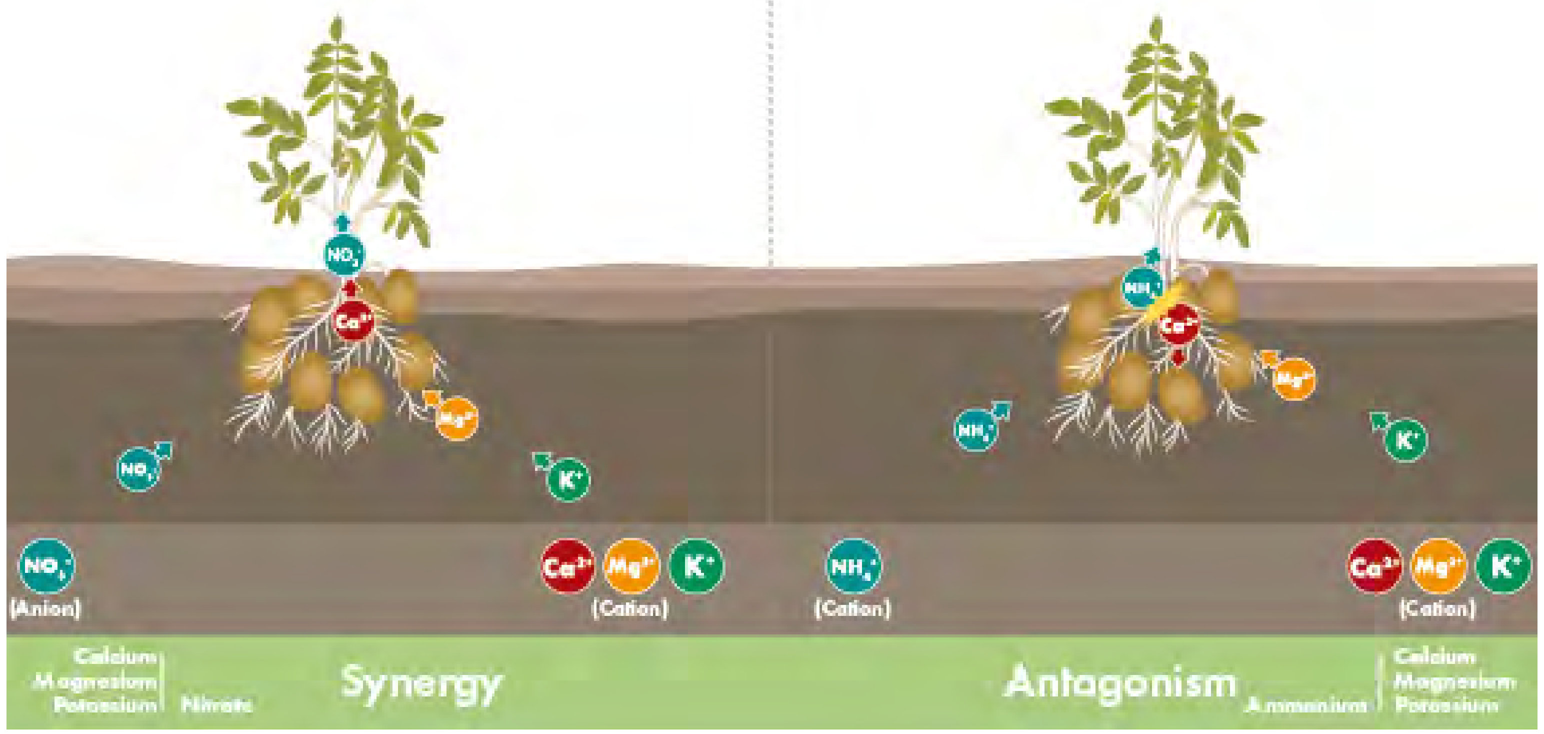
Plants in general, and particularly potatoes, benefit from taking up nitrogen, mainly in the nitrate form. More than 80 percent of nitrogen is absorbed as nitrate. In contrast to ureic and ammonium sources, nitrates does not require chemical processes prior to absorption, resulting in greater efficiency for the plant.



Although potatoes have the capacity to take up nitrogen through ammonium sources, ammonium must be metabolized, and this process requires carbohydrates.

This is particularly important in the early planting season and when soil temperature is low. In soils with low temperatures, ammonium will be slowly converted to nitrate, due to low microbial activity. Consequently, the roots will mainly absorb ammonium nitrogen. The ammonium metabolism in the roots requires carbohydrates, leaving less carbohydrates available for normal growth of roots and foliage.

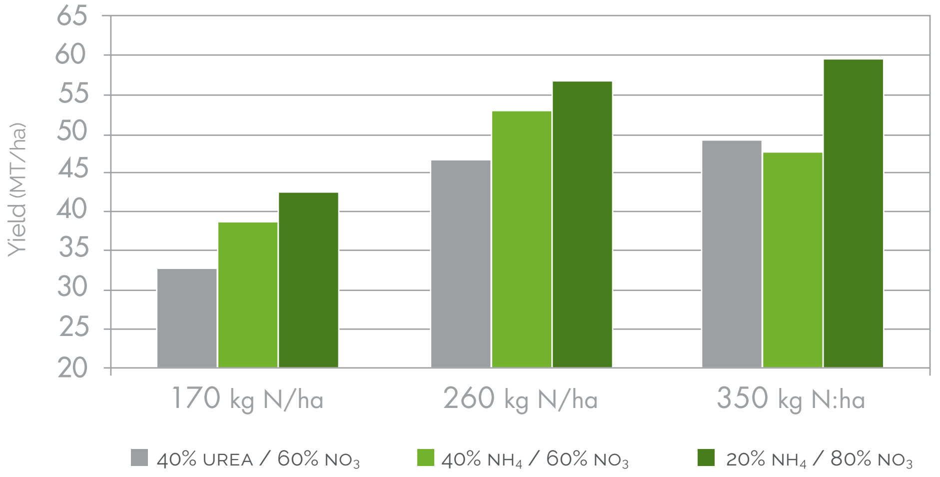
There are synergetic and antagonistic relationships between elements, and these play a very important role when balancing nutrition and high efficiency. Nitrate is an anion, meaning that it synergizes the synergize the uptake of of cations such as calcium, potassium and magnesium, and they synergize the uptake of have positive charges, while the ammonium ion has a positive charge, which means it competes with the absorption of calcium, potassium and magnesium. This means that increased absorption of ammonium limits absorption of potassium, calcium and magnesium and absorption of anions, such as chloride, which is favored, but which is also detrimental for crop yield and quality.



Increased absorption of nitrate leads to a reduction in chloride absorption, which diminishes possible problems like salinity stress.

Experiments conducted in South Africa demonstrated that applying 80% of the total nitrogen in the form of nitrate, produced a higher yield and dry matter of potato.

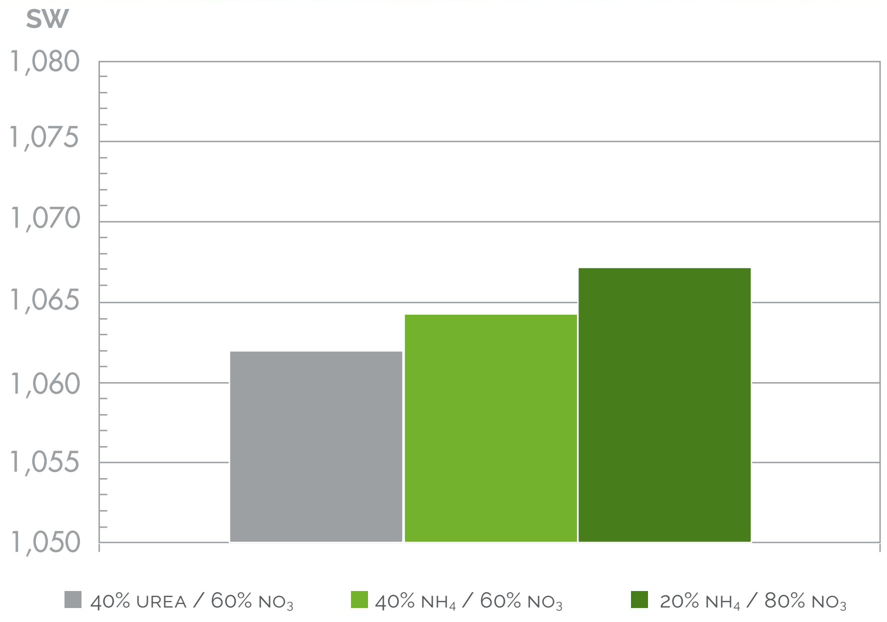
Higher yields by applying 20% of the nitrogen as NH_4, and 80% as NO_3, regardless of the total N rate.



Knight, F.H., P.P. Brink, N.J.J. Combrink and C.J. van der Walt, 2000

In the initial phase (from planting to tuber initiation), ratios such as NH_4:NO_3 50-50 can be used. From tuberization initiation, ratios such as 20-80 to 0-100 must be applied

Influence of the source and proportion of N on the specific weight (SW)



Knight, F.H., P.P. Brink, N.J.J. Combrink and C.J. van der Walt, 2000

6.1.1. Summary of the benefits of nitrate sources

Nitric sources can lead to higher production efficiency and crop yield

Summary
of nitric sources

No volatilization No loss of N

Mobility in the soil
makes contact with the roots rapidly

Direct uptake by the plant
higher uptake efficiency

Nitrates promote uptake of cations (K, Ca, Mg), synergism

No need to be converted (unlike ammoniacal and amide sources)
Nitrifying bacteria: depending on pH, temperature, texture, oxygen

Converted in amino acids in the leaves
energetic efficiency

Increased pH in acid soils
Increased availability of many nutrients for plant nutrition

Helps in prevention of chloride toxicity and salinity stress

Enhancement of cytokinin synthesis
Generates a higher number of stems and tubers

6.2 Phosphorus

Main sources

The main sources of phosphorus are diammonium phosphate, monoammonium phosphate, triple super phosphate, single superphosphate, urea phosphate, monoammonium phosphate technical grade, monopotassium phosphate and phosphoric acid.

> The most important variable to consider with phosphorus is soil pH. Super phosphates should be used as granular fertilizers on soil with an acidic pH, whereas soils with an alkaline pH, it is better utilize phosphate monoammonium or diammonium fertilizers

The pH level of the soil controls nutrient uptake. In acidic soils, phosphorus reacts with aluminum and iron to form insoluble compounds that cannot be absorbed by the plant. In alkaline soils, phosphorus also reacts with calcium to form insoluble compounds.

This means that if a granular fertilizer is applied to an acidic soil a single-, or a triple- superphosphate should be selected. Conversely, monoammonium and diammonium phosphates should be applied on soils with an alkaline pH.

> The soil pH determines nutrient uptake. In acidic soils, phosphorus reacts with aluminum and iron

Fertigation

Technical grade monoammonium phosphate, urea phosphate, phosphoric acid and monopotassium phosphate are suitable fertigation choices for soils or water with an alkaline pH. If the soil or water has an acidic pH, it is advisable to use monoammonium phosphate or monopotassium phosphate. Also, soluble NPKs can be applied as an alternative that works for any type of water.

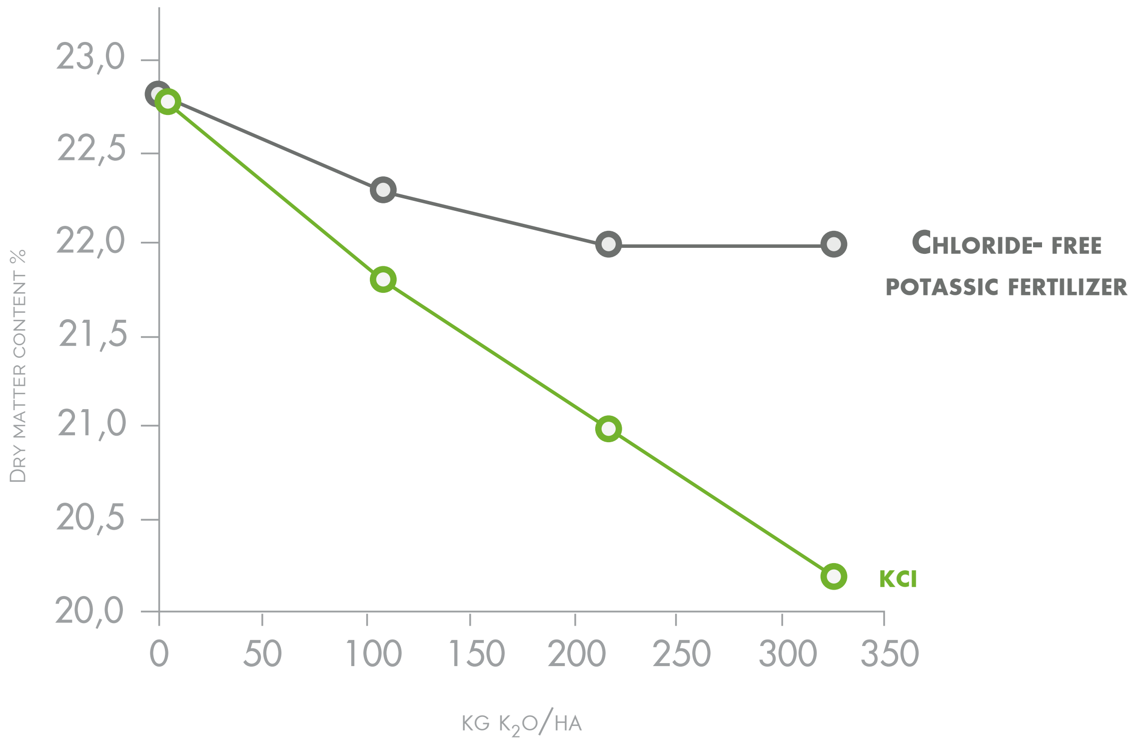
> Phosphate suffers from low mobility in soils, regardless the phosphate source applied

6.3 Potassium

Qrop® KS	Potassium Nitrate (KNO_3)
SOP	Potassium Sulphate (K_2SO_4)
MOP	Potassium Chloride (KCl)

In addition to supplying 60 percent of K_2O, potassium chloride also provides 47 percent of Cl, an element to which the potato plant is rather sensitive. A potato crop's performance is markedly hampered long before chloride toxicity symptoms show up.

Reduction of the dry matter content provoked by the use of KCl

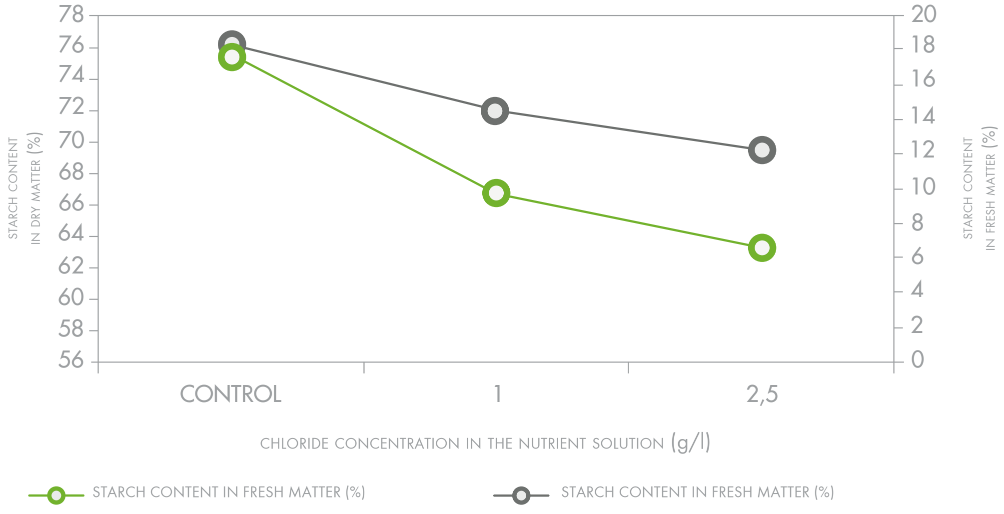


Source: Furunes, 1975.
Average of 46 experiments

Likewise, it has been observed that an increased concentration of chloride in the nutrient solution leads to a decrease in the starch content and increases reducing sugars in the potato tubers. This is highly detrimental, especially for potatoes grown for frying, since tubers must not contain more than 0.25% of reducing sugars, for the best post-frying color of potato chips. The presence of the reducing sugars fructose and glucose can generate darkening or "browning" in potatoes as they fry.

> Increased concentration of chloride in the nutrient solution decreases starch content and increases reducing sugars, affecting the frying quality of the potatoes

EFFECT OF CHLORIDE IN THE STARCH CONTENT



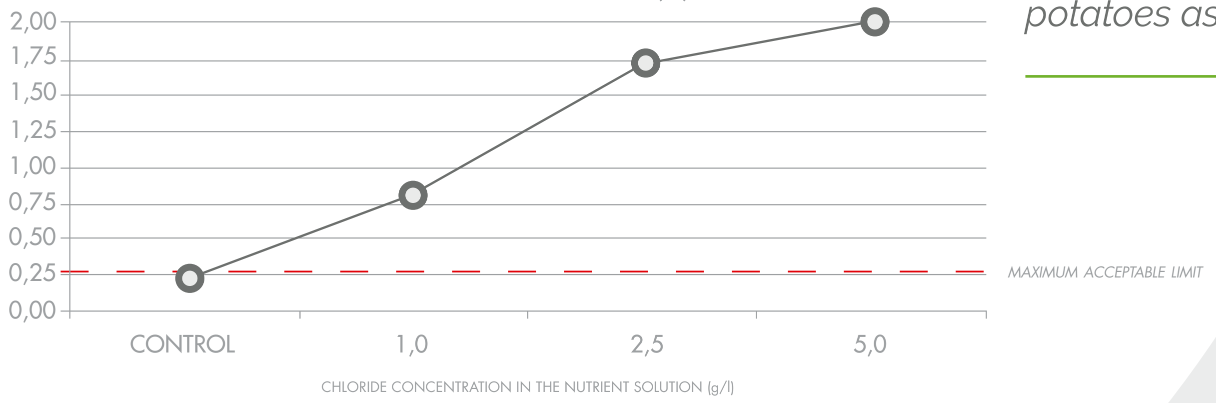
Contreras, 2002.

Darkening

Effect of increased chloride concentration

The presence of fructose and glucose causes browning in potatoes as they fry

CONTENT OF REDUCING SUGARS (%)



Contreras, 2002.

6.4 Results of trials and research

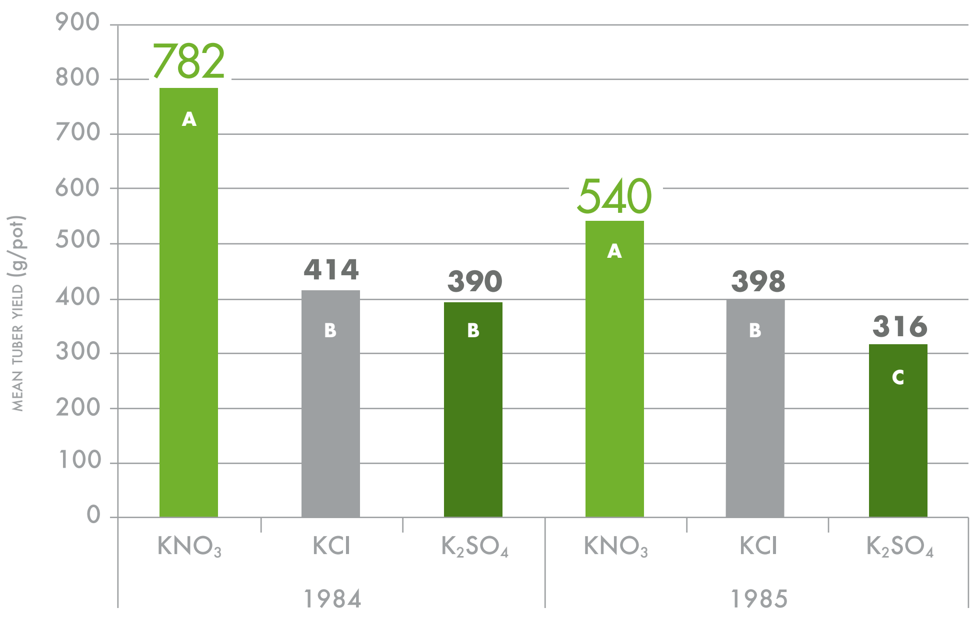
Pot experiments and open-field trials have demonstrated that potassium nitrate is the preferred source of potassium for potatoes, helping the plant produce a greater number of tubers, reach a higher yield and undergo lower loss during storage.

KNO$_3$

Is the preferred source of potassium for potatoes helping the plant produce a greater number of tubers, reach a higher yield and undergo lower loss during storage

Higher yield of tubers with **KNO$_3$**

Comparison of potassium nitrate with SOP and MOP.
Pot trials conducted in 1984 and 1985



Bester, G.G. and P.C.J Maree, 1990

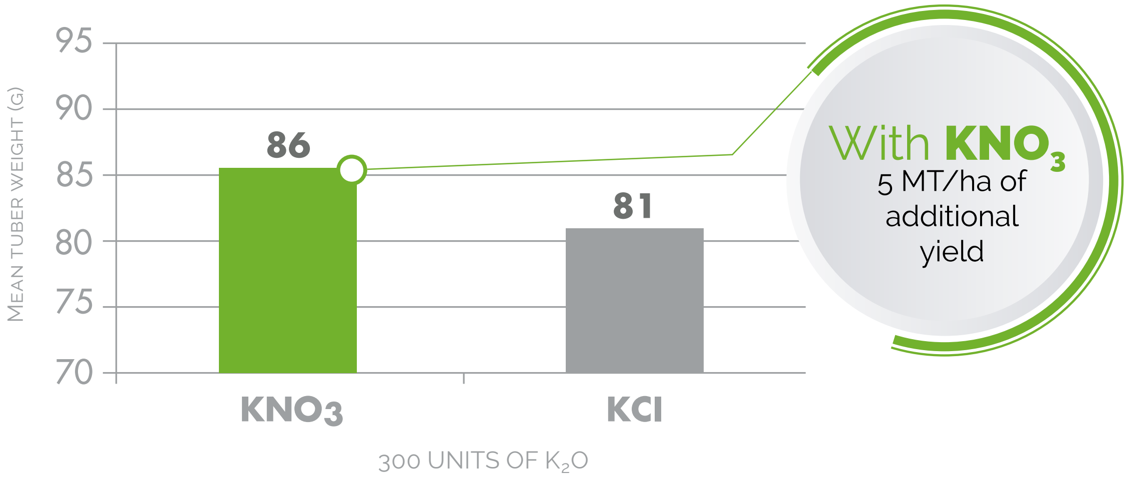
Higher number of tubers per plant with **KNO$_3$**

Comparison of potassium nitrate with SOP and MOP. Pot trials conducted in years 1984 and 1985

TREATMENT	**MEAN TUBER WEIGHT (G)**		**MEAN NUMBER OF TUBERS PER PLANT**	
	1984	1985	1984	1985
KNO$_3$	93 a	97 a	9,4 a	5,9 a
KCl	74 b	91 a	5,8 b	4,5 b
K$_2$SO$_4$	73 b	71 b	5,9 b	5,0 ab

Bester, G.G. and P.C.J Maree, 1990

KNO$_3$ increases yield by 5 MT/ha and reduces post harvest weight losses by 3 MT/ha



With **KNO$_3$**
5 MT/ha of additional yield

WEIGHT LOSS (MT/ha) AFTER 3 MONTHS OF STORAGE	
TREATMENT	WEIGHT LOSS
300u K$_2$O AS KCl	7 TON (9%)
300u K$_2$O AS KNO$_3$	4 TON (5%)
DIFFERENCE	3 TON (4%)

Soil with initial K content 215 ppm. Universidad de la Frontera, Temuco, Chile.2003-2004 trials in Maquehue, IX region

6.4.1 Summary of the benefits of potassium nitrate, obtained in various experiments

Increase of total yield

Increase of % commercial tubers
(desirable size)

Better external quality of tubers

I. Reduced: Darkening, scabies (Streptomyces scabies), and blight (Phytophthora infestans)
II. Improvement of skin quality

Better internal quality of tubers

I. Higher dry matter
II. Less internal darkening and incidence of "hollow heart"

6.5 The importance of multiple fertilizer applications

In order to improve plant nutrition management, the International Plant Nutrition Institute (IPNI) created the 4R concept:

4R

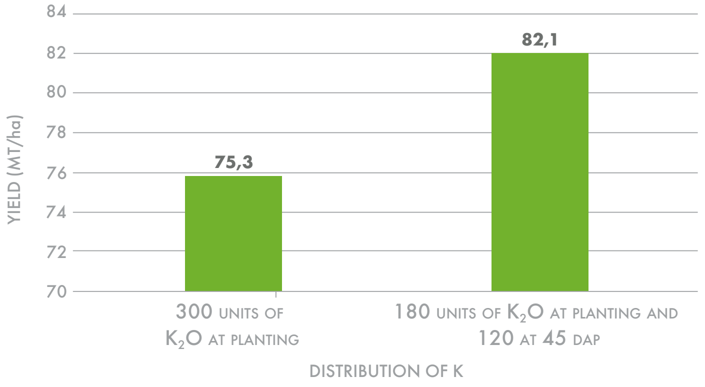
1. Right product/source
2. Right rate
3. Right time
4. Right placement

Split applications of K increased productivity by 9% (+7 MT/ha)

The 4R concept focuses on the need for choosing the right nutrient source and its application rate and optimal placement of the fertilizer to the crop based on characteristics of the crop variety, environmental conditions and management practices. Additionally, the right time to apply nutrients must be chosen so they coincide with the needs of the different phenological phases of the potato plant. Through the 4R concept, it is possible to produce a sustainable crop, increase efficiency and diminish losses through leaching or fixation of nutrients in the soil. Moreover, synergy of nutrients can lead to higher yield and improved tuber quality while utilizing the same or lower quantity of fertilizer. The graph shows the comparative results of nutrients' supply in only one application, versus multiple applications. Same total potassium rate, divided into to increases yield by nine percent in cv Desiree.

NUTRIENTS APPLIED (kg/ha)						
N	P_2O_5	K_2O	S	MgO	Zn	B
220	300	300	35	30	5	3

- N: 50% at planting in November and 50% with 45 DAP (days after planting)
- Source of N : 50% nitric (NO_3) and 50% ammonium (NH_4)
- Cv Desiree; Soil: 168 ppm K, 20 ppm P; pH (water) 5,5
- 4 replications; ANOVA, Test of Duncan



Universidad de la Frontera, Temuco, Chile.
2002-2003 trials in Hualpín, IX región.

7. Nutrition Proposals

SQM's Specialty Plant Nutrition line provides specific solutions for nutrient application via fertigation, soil and foliar. Combined with the expertise and knowledge of the agronomic team, SQM's Specialty Plant Nutrition solutions help clients increase their net income and obtain maximum yield of high quality crops.

7.1 **Ultrasol®**

7.2 **Qrop®**

7.3 Nutrition program with the **Qrop®** line

7.4 Recommendations for potato fertigation systems

7.1 Ultrasol®

Designed to offer an integral solution for fertigation, **Ultrasol®** has a range of complete nutritive, water-soluble solutions that meet plant needs by phenological phase. **Ultrasol®** formulas include macro and micronutrients and are completely water-soluble and chloride-free, which contributes to efficient nutrients uptake.

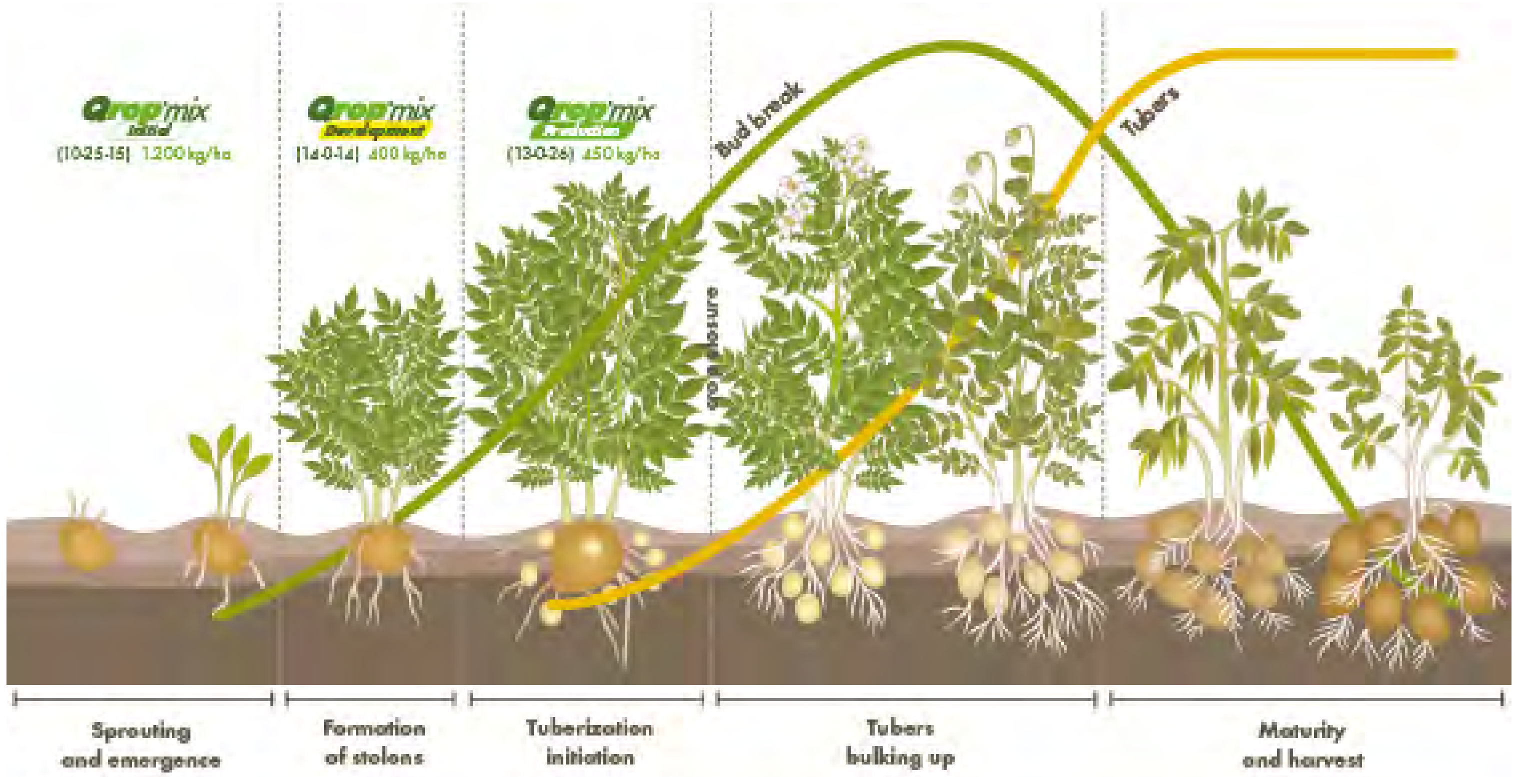
7.2 Qrop®

Qrop® is a complete line of nutrition solutions designed exclusively for direct soil application. Based on the main active ingredient of potassium nitrate, **Qrop®** is a complete line of nutrition solutions designed exclusively for direct soil application. With a great variety of specialized formulas and unique mixtures, **Qrop®** is highly precise and rapidly available for the plant.

All products of the **Qrop®** line address specific crop and soil conditions and help plants obtain maximum yield by providing the necessary nutrients.

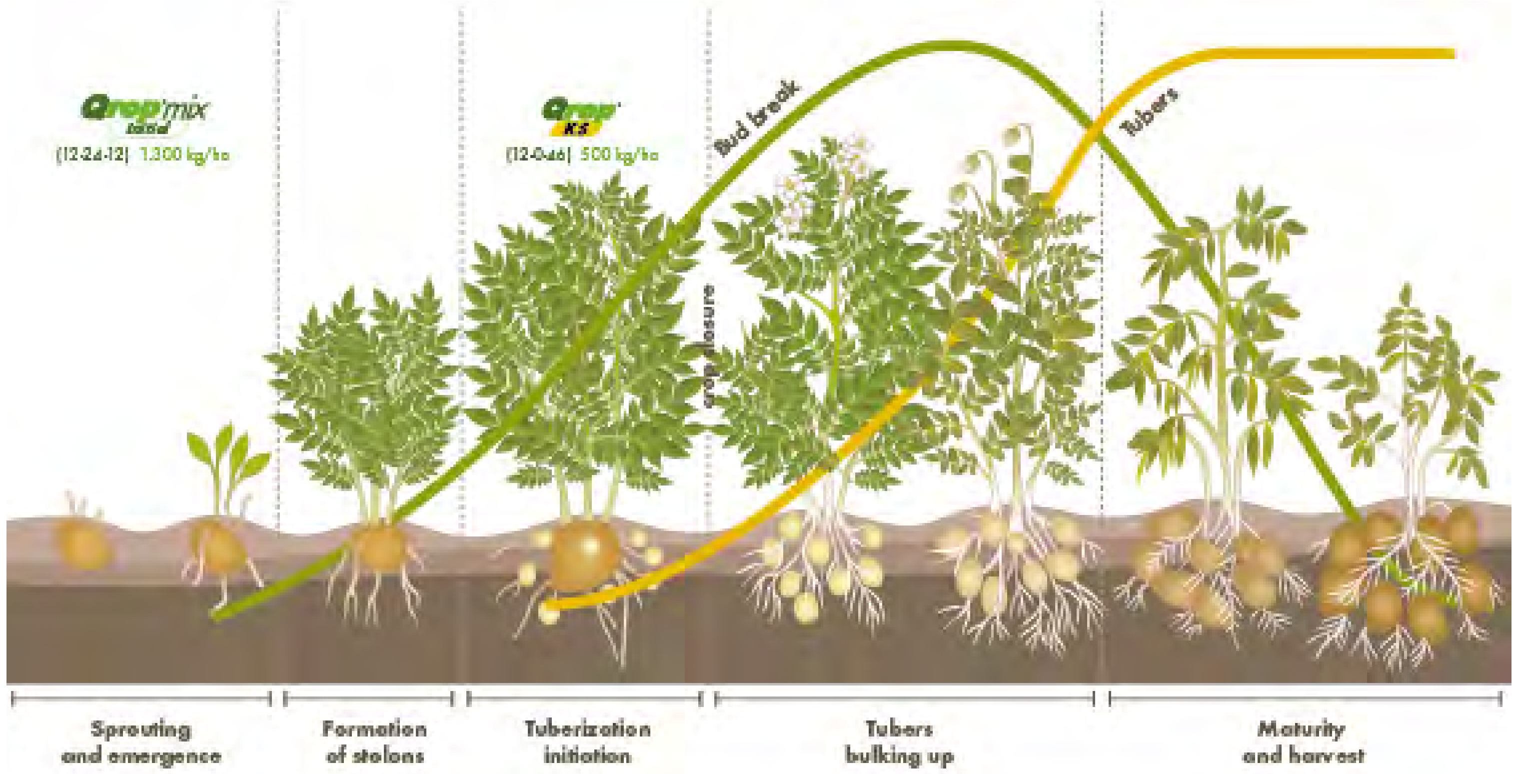
7.3 General nutrition proposals with the Qrop® line

Recommendation for fresh and processing market



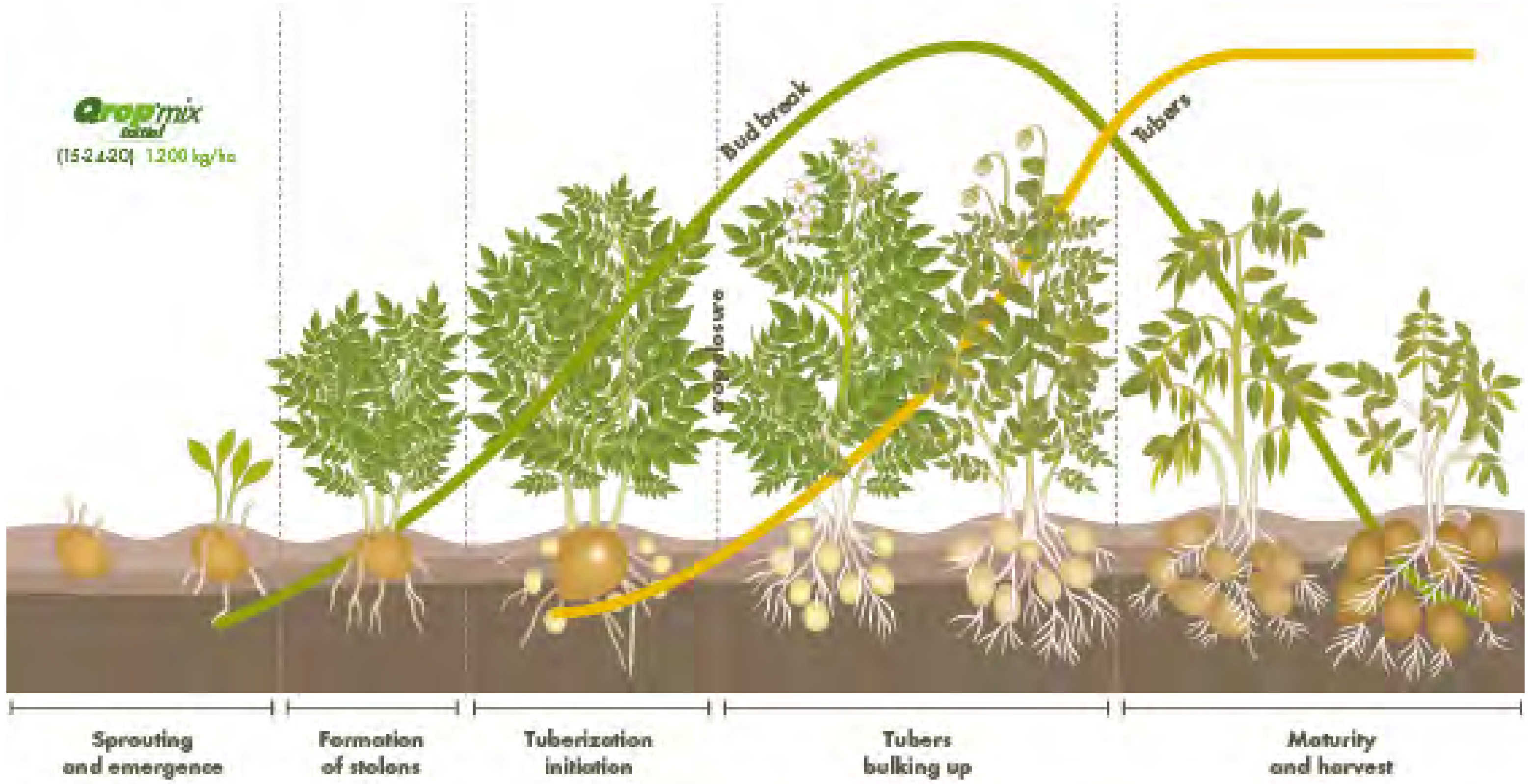
Product	Kg/ha										
	Dose	N total	N-NO_3	N-NH_4	P_2O_5	K_2O	S	Ca	MgO	B	Cl
Qrop® mix Initial 10 - 25 - 15	1.200	120	30	90	300	180	43	0	28	5	3,2
Qrop® mix Development 14 - 0 - 14	400	56	53	3	0	56	0	52	0	0	1,2
Qrop® mix Production 13 - 0 - 26	450	59	57	2	0	117	0	36	0	0	2,6
Total	**2.050**	**235**	**140**	**95**	**300**	**353**	**43**	**88**	**28**	**5**	**7**
			60%	40%							

Recommendation for fresh and processing market



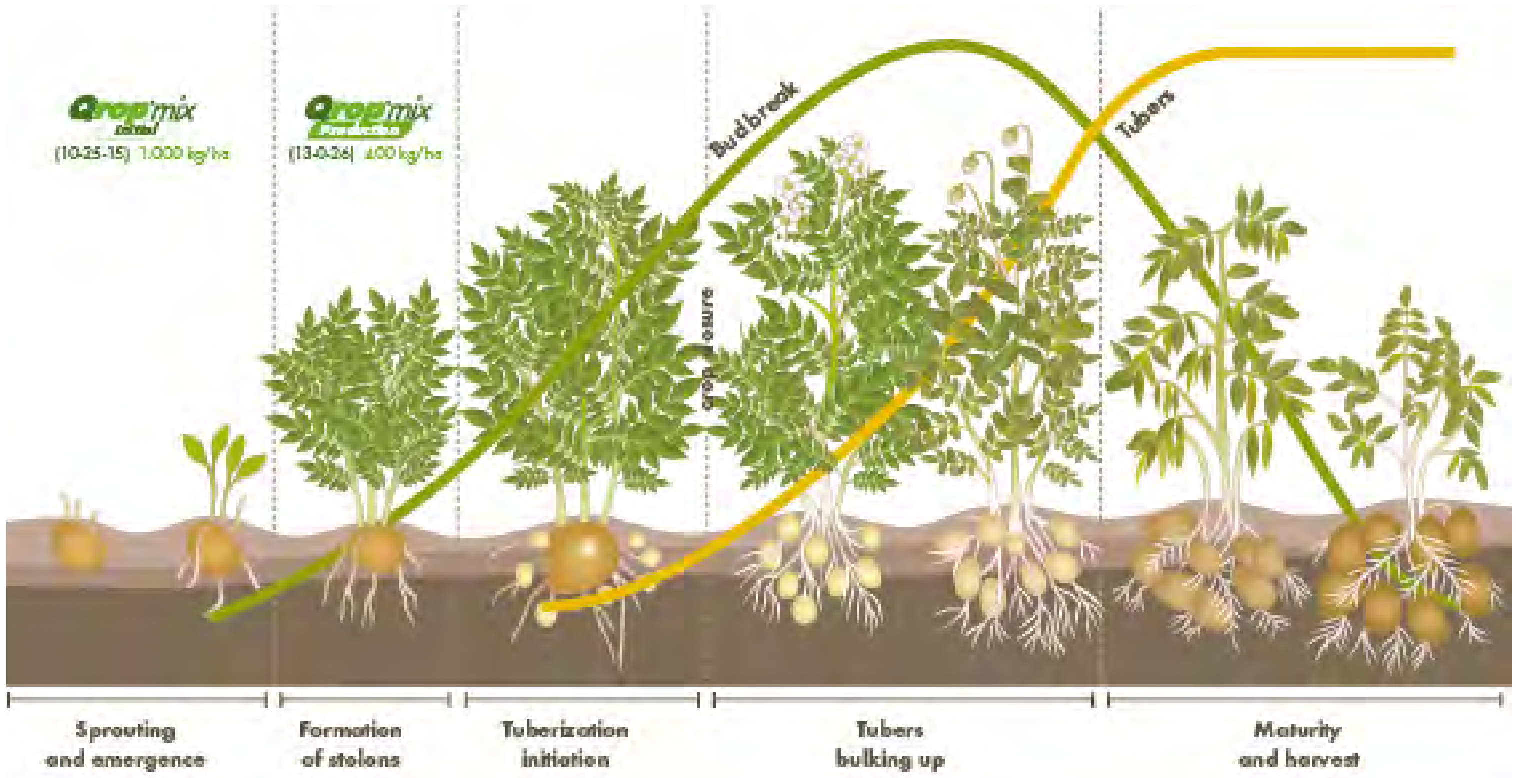
Product	Kg/ha										
	Dose	N total	N-NO_3	N-NH_4	P_2O_5	K_2O	S	Ca	MgO	B	Cl
Qrop® mix Initial 12 - 24 - 12	1.300	156	34	122	312	156	42	0	27	7	3
Qrop® KS 12 - 0 - 46	500	60	58	2	0	230	4	0	0	0	5
Total	**1.800**	**216**	**93**	**123**	**312**	**386**	**46**	**0**	**27**	**7**	**8**
			43%	57%							

Recommendation for seed production



Product	Kg/ha										
	Dose	N total	N-NO_3	N-NH_4	P_2O_5	K_2O	S	Ca	MgO	B	Cl
Qrop® mix Initial 15 - 24 - 20	1.200	180	63	117	288	240	0	0	0	5	5
Total	**1.200**	**180**	**63**	**117**	**288**	**240**	**0**	**0**	**0**	**5**	**5**
			35%	65%							

Recommendation for seed production



Product	Kg/ha										
	Dose	N total	N-NO_3	N-NH_4	P_2O_5	K_2O	S	Ca	MgO	B	Cl
Qrop® mix Initial 10 - 25 - 15	1.000	100	25	75	250	150	36	0	23	4	3
Qrop® Production 13 - 0 - 26	400	52	50	2	0	104	0	32	0	0	2
Total	**1.400**	**152**	**75**	**77**	**250**	**254**	**36**	**32**	**23**	**4**	**5**
			50%	50%							

7.4 Recommendations for potato fertigation systems

Fertigation systems

In addition to increasing water-use efficiency, fertigation systems provide a better way to meet the nutritional requirements of potatoes in a balanced way that can be applied periodically from the beginning to the end of the crop.

When preparing a fertigation program for potatoes, the characteristics and phenological cycle of the crop variety should be known and the soil ad climatic conditions should be well understood. This will help determining the correct fertigation program also considering the irrigation water quality.

> The tables show an example of a fertigation program via pivot in South Africa

Example of nutritional program in potatoes with pivot in South Africa, for yields of 60 MT/ha.

Sandy soil

Application of a granular mixture at planting and weekly fertigation via pivot.

Nutrients are expressed in kg/ha

Phase	DAP	N	P_2O_5	K_2O	MgO	CaO	N	P_2O_5	K_2O	MgO	CaO
		kg/ha					%				
Planting	0	43	207	52	14	238	14	64	10	21	68
Emergence, Vegetative Development	21 - 45	81	24	111	14	33	27	7	21	21	9
Tuberization	46 - 65	104	36	171	18	61	34	11	33	27	17
Tuber Growth	66 - 95	79	60	188	22	19	26	18	36	32	5
Total		**307**	**326**	**522**	**68**	**352**	**100**	**100**	**100**	**100**	**100**

Nutrients are expressed in kg/ha

Phase	DAP*	Product	Dose kg/ha	N	P_2O_5	K_2O	MgO	CaO
Planting	0	Basal dressing, soil applied		43	207	52	14	238
Emergence, Vegetative Development	21 - 45	Ultrasol® K	240	31	0	110	0	0
		Ultrasol® Calcium	127	19	0	0	0	33
		Ultrasol® MAP	40	5	24	0	0	0
		Magnesium sulphate	85	0	0	0	14	0
		Ammonium nitrate	75	26	0	0	0	0
Tuberization	46 - 65	Ultrasol® K	375	49	0	173	0	0
		Ultrasol® Calcium	235	35	0	0	0	61
		Ultrasol® Magnit	120	13	0	0	18	0
		Ultrasol® MAP	60	7	37	0	0	0
Tuber Growth	66 - 95	Ultrasol® K	410	53	0	189	0	0
		Ultrasol® Calcium	75	11	0	0	0	20
		Ultrasol® MAP	100	12	61	0	0	0
		Magnesium sulphate	140	0	0	0	22	0
Total				**305**	**329**	**524**	**68**	**352**

* = Days after planting

> *Do not mix in the same stock solution of Ultrasol® Calcium with Ultrasol® MAP, nor with magnesium sulphate

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