Research Findings

Redwin winter wheat; photos taken after flowering at a field site near Fort Smith Montana. The entire field was seeded to this cultivar and leaf spot symptoms were apparent across the entire field. The soil test very low in Cl.
Photo: Courtesy Dr. Richard Engel, Montana State University, USA.

The Value of KCl as a Fertilizer with Particular Reference to Chloride: A Mini Review

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Abstract

Potassium chloride (KCl), muriate of potash, is the most commonly used K fertilizer in the world providing crops with two nutrients, K and Cl, essential for both plants and animals. On application to most soils, both these nutrients are readily available to crops. In arable cropping, KCl is applied with other N and P containing fertilizers frequently increasing the efficiency of their utilization. The physiological and biochemical roles played by K in crop plants are mostly well understood and have been extensively investigated. Potassium is known to activate more than 60 enzymes, has a direct function in the synthesis of protein, exerts a major influence on plant water relations, cell turgor and is essential in the process of growth and development of cells. Potassium also plays a key role in photosynthesis and the

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transport of resulting sugars together with amino N compound to developing fruits and roots. During recent years it has become increasingly clear that K has a major function in crop production in mitigating effects of abiotic and biotic stresses including salinity, cold, frost, waterlogging, and drought as well as insects, pests and various diseases. The detailed molecular and biochemical controlling mechanisms involved still require further elucidation. Potassium and nitrogen are the two nutrients that are taken up in the largest amounts by crops. There is an extensive literature showing these two nutrients act in partnership to have an enormous impact in determining crop yield and quality. When K supply is inadequate (i.e. the ratio of K/N supplied to crops is too low), low molecular weight sugars and amino acids accumulate rather than the formation of high molecular weight compounds including proteins, starch, polysaccharides and cellulose present in high quality crops. Crop yields and quality are correspondingly affected. The role of chlorine as an essential nutrient in various aspects of crop nutrition is also becoming increasingly evident. The chlorine content of the lithosphere is about 500 mg kg^{-1} and occurs almost exclusively as the anion chloride (Cl^-). In general, irrigation water contains less than 150 Cl^- mg L^{-1}, which makes it suitable, for most crops providing that leaching can take place. Recommended amounts of KCl fertilizer applied to crops in field practice are in the range of 75-150 kg ha^{-1} for field crops and 300-500 kg ha^{-1} for horticultural crops. KCl is the only suitable form of Cl supply for irrigation and fertigation because of its high solubility. Chlorine is an unusual micronutrient in that Cl concentration in plants can vary enormously. It is required in the water splitting reaction of photosynthesis in the evolution of oxygen, charge compensation, and osmoregulation of the whole plant, as well as regulating movement of the stomatal guard cells of some crop species. Deficiency in crops usually only occurs in areas at great distance from the sea where the input from the atmosphere does not meet the demand, which for dryland wheat production is 4-8 kg ha^{-1}. It can also be a problem in crops such as kiwi fruit and palm trees that have a particularly high demand for Cl. Chloride toxicity occurs worldwide and is a general stress factor limiting crop growth in arid and semi arid areas. Crops differ markedly in sensitivity to Cl. Sensitive crops include: pepper, cabbage, lettuce, rape, tobacco, potato and sweet potato whereas a number of the major staple world crops are insensitive: rice, wheat, corn, sorghum, cotton, tomato, eggplant, banana and peach. It is well recognized that Cl can suppress a wide variety of plant pathogens in different crops. These include rust disease of barley (*Puccinia hordei*), stem blight disease of corn (*Aspergillus niger*), brown heart disease of potato (*Cephalotrichum stemonitis*), barley root rot (*Cochliobolus sativus, Fusarium culmorum*), and corn stalk rot (*Fusarium spp*). The soil borne fungus take-all in cereal crops (*Gaeumannomyces graminis*) is particularly sensitive to Cl. The reason for this appears to relate to its enhancing effect on Mn uptake and in increasing cellular osmotic pressure. In the context of human nutrition, the benefits of a balanced diet supplied with adequate amounts of K and Cl is discussed as well as the detrimental effects of excess NaCl.

Introduction

The fertilizer potassium chloride (KCl) (muriate of potash, MOP) provides two essential elements, the macronutrient potassium, as a cation (K^+) and the micronutrient chlorine, as an anion (Cl^-) and is the source of 90% of mineral K applied to crops throughout the world (IFA, 2013). Of all the mineral K fertilizers, KCl has the highest content of K (over 50%). It is readily soluble in water and on application to the soil, K^+ enters the soil solution and exchange complex and can then be rapidly taken up by plant roots. It also mixes well with N and P fertilizers and is rarely applied alone. Indeed KCl application offers an important means of raising the efficiency of utilization of these fertilizers. In the case of grassland, KCl is the only form of mineral K fertilizer applied. K removed in hay and silage in nutrient cycling is easily replaced by top dressing with KCl. Nearly all crops respond to KCl under conditions of K deficiency or inadequate supply. For only a very few crop plant species sensitive to Cl^- should application of KCl be restricted, as for example tobacco in which Cl at normal rates of application is detrimental to leaf quality and smoke flavour. The great overall advantage of KCl is that in comparison with other fertilizer forms (K_2SO_4 and KNO_3) it is relatively low in cost and easily accessible.

Most of the essential physiological functions of potassium in crop plants have been well researched. Potassium is taken up by the plant in similar very large quantities as nitrogen and plays a fundamental role in plant physiology and biochemistry especially in relation to N metabolism (see Marschner, 2012; Mengel and Kirkby, 2001; and Roemheld and Kirkby, 2010). It is known to activate more than 60 enzymes, have a direct function in the synthesis of protein, exert a major influence on plant water relations, cell turgor and be essential in the process of growth and development of cells. Potassium also plays a key role in photosynthesis in both the light and dark reactions culminating in the formation of sugar via the reduction of CO_2. Potassium is an exceptional macronutrient in that it is not to any extent incorporated into organic molecules so that it is present within the plant almost exclusively as a univalent cation. In this form it is highly mobile, is the dominant cation both in xylem and phloem pathways and is associated with the transport of inorganic anions and organic metabolites. In the xylem, K at concentrations in the range of 10-20 mmol L^{-1} are responsible for nutrient transport from root to shoot in many crop species whereas in the phloem much higher concentrations (100-200 mmol L^{-1}) occur. Here K controls loading of sucrose and amino acids produced during photosynthesis and their transport to developing fruits and roots. Within recent years it has become increasingly clear that K is the most important mineral nutrient acting to mitigate abiotic and biotic stresses affecting crop production including salinity, cold, frost, waterlogging, and drought as well as insects, pests and various diseases (Cakmak, 2005; Wang *et al.*, 2013). In this area much research is still needed to elucidate underlying physiological and molecular interacting and controlling mechanisms but there is no doubt that K ions protect cells against reactive oxygen species (ROS) induced under stress conditions (Cakmak, 2005).

Potassium chloride applied to the soil releases equal amounts of Cl and K ions into the soil solution. Chloride is very mobile in the soil and easily removed by leaching, whereas K entering the soil solution becomes relatively immobile and is held mainly in the soil solution and exchangeable K pools which are accessible for uptake by the roots (Roemheld and Kirkby, 2010). Although much less Cl is usually required for growth and development, chlorine, is an unusual micronutrient in that it is required for some essential functions in minute amounts but its uptake can vary greatly depending on the accessibility of Cl and plant species (Epstein and Bloom, 2004; Chen *et al.*, 2010).

The purpose of this mini review is to consider KCl as a crop fertilizer particularly in its relationship to N fertilization to explain the important interaction between these nutrients and to update information on the chlorine component in relation to soil and irrigation, deficiency and toxicity, effects of fertilization on crop yields and environment, effects on crop diseases, and the role played by chloride and K in human health.

Uptake and assimilation of N in relation to KCl application to crops

In crops fertilized with KCl, K exerts a very strong influence on N uptake and metabolism. Nitrate is the principal form of N uptake in most arable soils during the growing season when nitrifying bacteria are active. In many crop plant species both K and nitrate ions are rapidly taken up by roots and transported together from root to the shoot and leaves which are often the main sites of nitrate reduction and assimilation. Both nutrients can be cycled and recycled between shoots and roots which serve several well defined functions. These include supplying the roots with nutrients assimilated in the shoots (nitrate and sulphate reduction), maintenance of cation/anion balance providing additional driving force for solute flow in the xylem and phloem and acting as a shoot signal to convey nutrient demand to the roots. Cycling of mineral nutrients like K is also required to cover the demand for growth of apical root zones and to smooth out fluctuations that occur spatially and with time in the external nutrient supply of soil grown plants (Marschner *et al.*, 1997). These two nutrients K and N acting in partnership have an enormous impact on plant biochemistry and physiology including: induction of cell division and extension in shoots and roots i.e. growth; maintenance of cell turgor; control of plant water relations, enzyme activation; photosynthesis; and protein synthesis (Mengel and Kirkby, 2001). Additionally the ratio of K/N considerably affects metabolism. A low ratio induces the accumulation of low molecular weight compounds i.e. amides, amino acids and sugars, whereas a high K/N ratio favours the accumulation of high molecular weight compounds including proteins, starch, polysaccharides and cellulose (Marschner, 2012). An example illustrating the practical implication of this close interaction between K and N on crop yield is shown in Fig. 1 from an experiment on an Illinois soil, low in soil available K. Increasing rates of K fertilization to corn plants adequately supplied with N stimulated rates of nitrogen uptake, thereby increasing corn grain yield and efficiency of N utilization (Better Crops, 1998). A similar response of palm oil yield to the beneficial interactive effect between N and K in can be seen in Fig. 2 (Webb, 2009). There are many other similar examples in the agronomic literature showing the beneficial influence of KCl fertilization on N uptake and utilization increasing yield and quality in various crops as reported by Gething (1993) and Mengel and Kirkby (2001). This influence of K is also beneficial to the environment in restricting nitrate leaching and possible denitrification of nitrate unused by the crop.

In the older literature in particular, attention was given to the possible depressing effects of chloride on nitrate uptake by crops

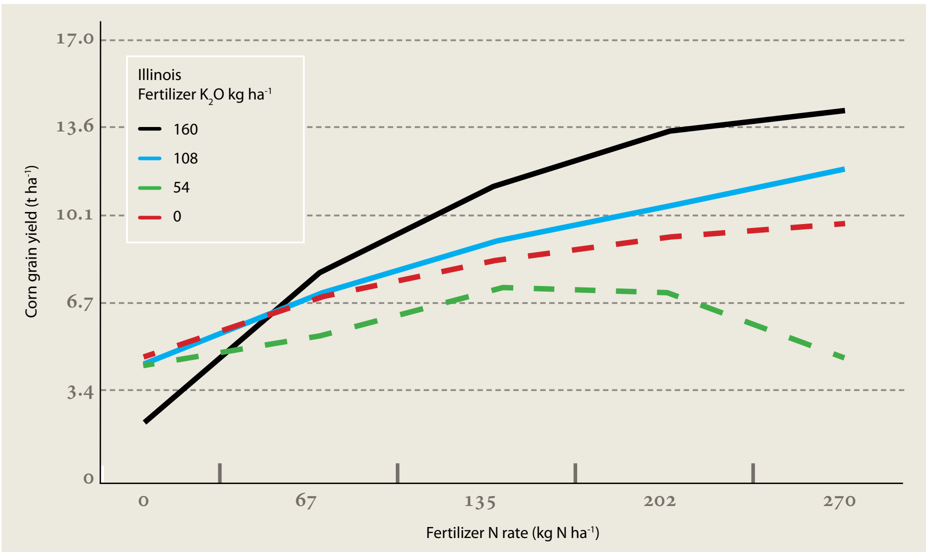

Fig. 1. Corn (*Zea mays* L.) yield in response to increasing rates of soil applied N and K. Adapted from Better Crops, 1998.

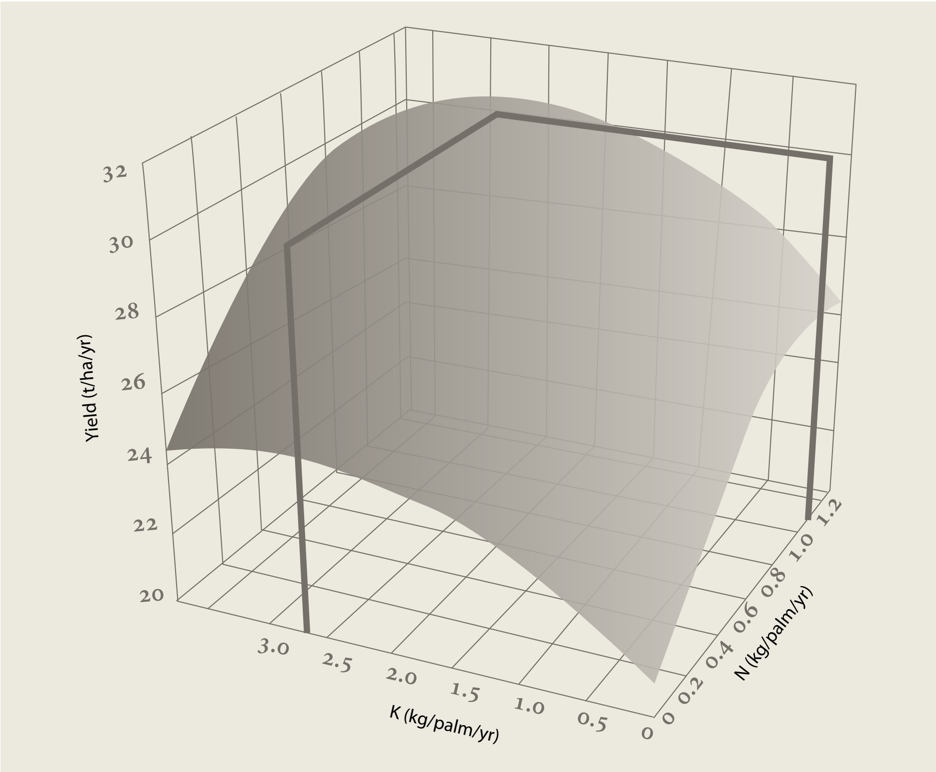

Fig. 2. Oil palm yield in response to increasing rates of soil applied N and K. Adapted from Webb, 2009.

equivalent to the application of about 500-1000 kg Cl ha^{-1} (Maas *et al.*, 1982). Recommended amounts of KCl fertilizer applied to crops in field practice are in the range of 75-150 kg ha^{-1} for field crops and 300-500 kg ha^{-1} for horticultural crops (Fan *et al.*, 2007; Shen *et al.*, 2011; Liu *et al.*, 2012), and are thus much lower than the amount of Cl supplied by irrigation. Moreover, the movement of Cl^- in soil solution is largely determined by water flow (White and Broadley, 2001) and thus Cl^- is easily leached through the soil profile. The addition of Cl^- by KCl fertilizer is therefore safe for most agricultural crops. Potassium chloride is the only suitable source of K that can be used in irrigation and fertigation systems; K_2SO_4 is unsuitable because of the low solubility of $CaSO_4$ while KNO_3 is not easy to handle and is much more expensive.

and hence N utilization. There is no doubt that Cl does compete with nitrate during uptake (Xu *et al.*, 2000; see also references in Khan *et al.*, 2014), but it has to be borne in mind that for most crops the demand for N is very much higher than that of Cl. Usually crop vegetative tissue has a concentration of between 2-5% N in the dry matter which is considerably greater than Cl which usually reaches only about 1% Cl and is often much lower (Heckman, 2006). Moreover, plants not only take up chloride but they release it back into the soil (White and Broadley, 2001). Additionally some plant species and cultivars can and do exclude Cl uptake (Abel, 1969 and Xu *et al.*, 2000). In comparison with the intense physiological and biochemical interactions between N and K any effect of Cl is thus normally of much lesser importance.

Cl^- in soil and irrigation

The chlorine content of the lithosphere is about 500 mg kg^{-1} and occurs almost exclusively as chloride. Hence, most of the water resources in the world contain significant amounts of Cl. In irrigated soils, the Cl^- concentration of topsoil depends closely on the amount and salt concentration of the irrigation water (Xu *et al.*, 2000). In the same review the authors reported that in general, irrigation water contains less than 150 Cl^- mg L^{-1}, which makes it suitable, for most crops providing that leaching can take place. For example, irrigation of 500 mm of water per growth season with a Cl^- concentration of 100-200 mg L^{-1} is

Cl^- in crops, deficiency and toxicity

Chloride is an essential nutrient for plants. It is required in the water splitting reaction of photosynthesis in the evolution of oxygen, charge compensation, and osmoregulation of the whole plant, as well as in the stomatal guard cells of some crop species (Xu *et al.*, 2000; Chen *et al.*, 2010; Marschner, 2012). Various reports of Cl deficiency symptoms have been published since those of Broyer *et al.* (1954) first established chloride as an essential plant nutrient. Whitehead (1985) reported that Cl deficient red clover grown in water culture showed symptoms of leaf wilt, shrivelling and necrosis and stem cracking. Heckman (2006), has drawn attention to a lack of data concerning critical concentrations for many crop species but in wheat at heading there are reports of values of about 1-1.5 mg Cl g^{-1} DM. Deficiency of Cl can occur in the field at sites at great distances from the sea as has been reported in the mid west US wheat belt (Fixen, 1993) where Cl content in the rainfall does not meet the demand of about 4-8 kg Cl ha^{-1} required for adequate crop yield as calculated from the Cl concentration value cited above. Deficiency symptoms in wheat occur as chlorotic and necrotic lesions in the leaves referred to as "Cl deficient leaf spot syndrome" and were reported by Engel *et al.* (1997), see Photo 1. From extensive work from chloride fertilization based on soil testing Mengel *et al.* (2009) report the high probability of beneficial effects of chloride fertilization in dryland wheat and sorghum production in central Kansas. Chloride deficiency can

Photo 1. Chloride deficiency in WB881 durum wheat plants grown in hydroponics in a controlled growth room. The plants were grown in the absence of chloride. Photo: Courtesy Dr. Richard Engel, Montana State University, USA.

also occur in crops with high Cl requirements such as kiwi fruit and palm trees (see Marschner, 2012).

Chlorine toxicity is much more common as a limiting factor in growth worldwide particularly in arid and semi arid environments. According to Marschner (2012) an external concentration of 20 mmol L^{-1} can lead to Cl toxicity in sensitive crop species whereas in tolerant species the value can be 4 to 5 times higher without reducing growth. In most arable soils, the concentration of Cl^- is much lower at about 2-3 mmol L^{-1} in soil solution which is not toxic to most crops (Xu *et al.*, 2000). Corn (*Zea mays* L.; cultivar of Trojan 114) for example tolerated an application of 728 mg Cl^- kg^{-1} in the greenhouse without showing any detrimental effects. The same was true for yield and growth at 340 kg ha^{-1} Cl^- in field experiments (Parker *et al.*, 1985). Cotton yield and quality were unaffected by Cl^- concentrations below 1,600 mg kg^{-1} (Tan and Shen, 1993). Sugar beet requires large amounts of chloride. Its yield increased with increasing Cl^- applications up to 1,600 mg kg^{-1} (Jing *et al.*, 1992). The same authors observed that yield of this crop was not reduced even with applications of Cl^- as high as 3,200 mg kg^{-1} in a clay soil.

Effect of Cl^- fertilization on crop yield and environment

The beneficial effect of Cl on crop yield and quality has been reported in experiments comparing forms of K application Parker *et al.* (1985) determined greater yields in corn (*Zea mays* L.) with equivalent rates of KCl fertilizer as compared to K_2SO_4 fertilizer. A similar beneficial effect of Cl^- fertilizer over sulphate on corn grain yield in field experiments was also reported by Heckman (1995). On a sandy loam soil, with chloride applications of up to 400 kg ha^{-1} over a three year period, yields of 500-1,500 kg ha^{-1} more grain were obtained over the control. Yields were positively correlated with increases in ear leaf Cl concentration. It was concluded that the reasons for enhanced levels of Cl nutrition included a favourable influence on corn production by enhancing retention of water in plant tissues and extending the period of grain fill as well as partitioning more photosynthate into the grain.

From the field experiments of Wen (2006) the rates of application of Cl^--containing fertilizers should be carefully managed in relation to crop species. Crops insensitive to Cl^- such as rice, wheat, corn, sorghum, cotton, tomato, eggplant, banana and peach can tolerate Cl^- fertilizer at rates of 1,350-1,800 kg ha^{-1} $season^{-1}$, whereas rates of application should be lower for moderate Cl^- tolerating crops such as soybean, pea, strawberry, peanut, apple, sugarcane where the range should lie between 675-1,350 kg ha^{-1} $season^{-1}$. For Cl^- sensitive crops such as pepper, cabbage, lettuce, rape, tobacco, potato and sweet potato the Cl^- application should not exceed 675 kg ha^{-1} $season^{-1}$.

Environmental effects of the continuous application of Cl^--containing chemical fertilizers to a paddy soil were studied over a 34 year period at a long-term field experiment site in Hunan Province, China. It was shown that the effect of this Cl treatment in comparison to the application of SO_4^{2-}-containing fertilizer was to enhance biodiversity as measured by an increasing number of weed species and higher biomass of water surface weeds and submerged weeds (Shen *et al.*, 2011). Compared with applied SO_4^{2-}-containing fertilizers, the authors reported that weed biomass was increased by 24.2% and 17.6% by managed Cl^--containing fertilizer in the late rice season and early rice season, respectively, indicating that Cl^- was not harmful to plant growth or development.

Effect of Cl^- fertilization on crop diseases

The Cl^- component in fertilizers has been reported to control a number of diseases in different crop species (Fixen, 1993). According to Elmer (2007) Cl^- application suppresses 23 pathogens on 12 crop species. These include rust disease of barley (*Puccinia hordei*), stem blight disease of corn (*Aspergillus niger*) and brown heart disease of potato (*Cephalotrichum stemonitis*) (Mao and Li, 1999; Zhang *et al.*, 2010). Barley root rot (*Cochliobolus sativus, Fusarium culmorum*) has also been shown to be suppressed by KCl fertilization (Timm *et al.*, 1986). Heckman (1998) demonstrated the beneficial effect of Cl^- fertilizer on corn stalk rot (*Fusarium spp*) in field experiments in which the concentration of Cl^- in the ear-leaf was inreased by raised levels of applied Cl^-. Zhe incidence of stalk rot (*Gibberella zeae*) was also found to be controlled to a greater extent with KCl than K_2SO_4 (Huber, slide 27 on http://brasil.ipni.net/ipniweb/region/brasil.nsf/e0f085ed5f091b1b852579000057902e/98de35edd4f507f483257afe005d60e6/$FILE/Palestra%20Don%20Huber.pdf). According to Huber, farmers in the USA have to face a cost as much as 8-10 billion dollars per year for corn stalk rot damage caused by *Gibberella zeae* and other fungi . The severity of stripe rust in wheat (*Puccinia striiformis* f. sp. *tritici*) was also shown to be significantly reduced in an experiment involving 381 cultivars spring top dressed with NH_4Cl as compared to $(NH_4)_2SO_4$ again indicating a specific effect of Cl^- (Christensen *et al.*, 1982).

The soil borne fungus take-all (*Gaeumannomyces graminis*) in wheat and barley seriously limits grain production in various regions in the world (Huber *et al.*, 2012). This fungal pathogen has a growth optimum at pH 7 and is highly sensitive to low pH as observed by Taylor *et al.* (1983). Both NH_4Cl and $(NH_4)_2$ SO_4 applications depress soil pH. However, the additional presence of Cl appears to be more effective in suppressing pathogen activity. Application of NH_4Cl supplying chloride at approximately 350 kg ha^{-1} to winter wheat, was shown to increase grain yield by 11 to 40% over that obtained with equivalent supply of $(NH_4)_2$ SO_4 in plots where the presence of take-all disease was confirmed (Christensen *et al.*, 1981), (see also Christensen *et al.*, 1993). This beneficial effect appears to relate specifically to the Cl and is not dependent on the accompanying fertilizer cation. The same authors reported similar benefits of Cl application supplied as KCl with N in the form of NH_4N in increasing yield of winter wheat and depressing the incidence of take-all in the roots (Table 1). The most effective treatment was to apply the KCl both in autumn and spring.

Table 1. Effect of chloride as KCl on the "Incidence of Take-All in Winter Wheat" in a field experiment supplied with NH_4N.

Chloride treatment		Infected roots	Grain yield
--------------*kg ha⁻¹*--------------		-------*%*-------	------*t ha⁻¹*------
Autumn	Spring		
0	0	45	5.3
56	0	34	5.7
56	185	11	6.5

Source: Christensen, N.J. *et al.* 1981. Agron. J. 73:1053-1058.

A most detailed and thought provoking account of chlorine and plant disease has been produced by Elmer (2007). He suggests that the major influence of chloride fertilization on plant disease appears to be a reduction of cell osmotic potential (increased turgor pressure) together with an increase in manganese uptake and an enhancement of beneficial microbes through changes in root exudation. Manganese increases host resistance by inducing deposition of ligneous defence barriers (Huber and Wilhelm, 1988). The increase in osmotic pressure can be accounted for as a result of the Cl uptake. There are both chemical and microbiological means to achieve a chloride-mediated Mn uptake in which soil pH has a controlling influence. In acid soils (pH lower than 6.6) adequately supplied with Mn, chloride suppresses nitrification and a chemical reduction occurs to produce Mn^{2+} whereas in neutral and alkaline soils, Cl may enhance Mn by altering the nutritional composition of the root exudates which in turn favours microbes that are able to induce Mn reduction. The beneficial effect of suppressing the incidence of take-all by use of a nitrification inhibitor is shown by Huber (slide 25 at http://brasil.ipni.net/ipniweb/region/brasil.nsf/e0f085ed5f091b1b852579000057902e/25dd770a7fa6689c83257b090060759d/$FILE/Palestra%20Don%20Huber.pdf). It also appears likely that Cl^- enhances the activity of relevant plant resistant enzymes. For example cucumber downy mildew (*Pseudoperonospora cubensis*) was suppressed by Cl^- application which was associated with an increase in β-1,3-glucanase activity (Jia *et al.*, 2004). A detailed account of the beneficial effect of Cl^- in restricting various plant diseases is given in Heckman (2006) and also referred to in Huber *et al.* (2012).

The effect of Cl^- and K^+ on human health

Chlorine is an essential mineral nutrient for humans (animals) as well as plants and similarly to plants is ingested as Cl^-. The body of an average adult human contains about 115g chloride making up about 0.15 % of the total body weight and the Cl anion represents about 70% of the total anion charge within the blood (Meletis, 2014). By far the greatest intake of Cl by humans is from table salt NaCl. The World Health Organization, 2012 recommends that human adult consumption should be limited to 5 g salt (NaCl) per day. This represents 3,035 mg Cl^-, an amount which is at least 5 fold greater than that which can be supplied in the diet by plant material assuming a daily intake of 30 g dry plant material (approx 300 g fresh plant material) with a Cl concentration in the range of 2-20 mg g^{-1} in the dry matter (Xu *et al.*, 2000). The 5 g NaCl figure for human intake is often greatly exceeded, as in the US, so that the contribution of Cl from plant material can be even lower than the value cited above. Excessive intake of NaCl is extremely damaging to health causing hypertension and is associated with cardiovascular disease. Indeed a current problem in the human diet is the low intake of K relative to the high Na intake (see Roemheld and Kirkby, 2010); this is one of the reasons for the benefit of a high intake of fruit and vegetables as a source of K in the human diet. Amongst the functions of K in human nutrition are its essential roles in protein synthesis, carbohydrate metabolism, electrical activity of the heart and the acid base balance together with its functions as an anti oxidant in both plants and animals. Chloride obtained from crops is thus not harmful to human health and KCl application to crops is without influence on the intake of Cl by humans, and is of benefit in providing a source of K.

Khan *et al.* (2014) suggest that KCl fertilization of crops can be detrimental to human health by depressing crop quality but convincing evidence of any direct effect on the human diet is lacking. What is certain is that worldwide, KCl is the predominant form of K fertilization for nearly all commercially produced nutritional crops and it has been extensively demonstrated that both the yield and quality of crops adequately supplied with KCl is far superior than when supply is inadequate or deficient (Kafkafi *et al.*, 2001). As an example of a supposedly harmful effect of KCl fertilization, Khan and his colleagues cite literature relating to potato production arguing that chloride fertilization lowers starch concentration which in turn reduces specific gravity "with adverse consequences for health such as obesity and cardiovascular diseases arising from greater oil retention in processed products such as potato chips and French fries". Here the authors appear to lose sight of the major causes of the increasing rates of obesity and cardiovascular diseases now established as: a high calorie poor diet increasingly being made up of sugar and junk foods low in fibre, an excess Na intake, and a lack of the macro and micronutrients and vitamins as a regular major components of the daily intake. In relation to the dangers of consuming French fries, heating these above 120° C gives rise to the potential carcinogen acrylamide. Tubers of potato varieties with high concentrations of reducing sugars and asparagine are particularly prone to acrylamide formation (Amrein *et al.*, 2003). In this respect the work of Gerandas *et al.*, 2007 provides clear evidence of the benefit of increasing K/N ratio of fertilizer treatment during tuber growth in depressing the accumulation of reducing sugars, asparagine as well as the levels of acrylamide in the French fries from the processed tubers.

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The paper "The Value of KCl as a Fertilizer with Particular Reference to Chloride: A Mini Review" also appears on the IPI website at:

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