FERTILISER NEWS, Vol. 49 (11), November 2004, pp.51-55 (5 pages)

Use of MOP as Fertiliser – Some Myths and Reality

Worldwide, more than 90% of the total K_2O as fertiliser is used through MOP, which contains about 46% chloride. Some myths are associated with the use of MOP, as fears have been expressed about deleterious effect of Cl on soil and plant health. Another point of concern is the use of MOP for top dressing and also in foliar spray. This review is an attempt to provide an insight into all these myths and reality associated with the use of chloride through MOP.

Generally, chloride is not harmful to plant, animal or microbiological life in normal quantities but it is undesirable in excess. Chloride has many vital roles in a number of biochemical functions in plants, like enzyme activation, photosynthesis and cell division, regulation of opening and closing of leaf pores (stomata). The optimal concentration range in most crops is reported between 0.3 to 1 g Cl/kg dry matter. Chloride deficiency symptoms in crops have not been well described because few have been observed under field conditions. Plants suffering from severe deficiency of Cl show symptoms of chlorosis and wilting. Chloride deficiency mainly has been reported in areas far from the sea where airborne Cl is very small. Chloride deficiency has not been reported anywhere in India. Responses to Cl fertilisers in wheat, corn and grain sorghum have been widely documented in the Great Plains and the Pacific Northwest in USA. Chloride application has also been associated with suppression of foliar or root diseases in some crops. Foliar application of 1-2% MOP has been reported to be quite safe and beneficial in a host of crops like tea, coffee, guava, litchi, sugarcane, sunflower, soybean, rice, tomato, chilli, groundnut, etc. in India.

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WORLDWIDE, out of total 28 million tonnes of K_2O used, more than 90% is used through MOP* (muriate of potash) (8) and the rest through SOP (sulphate of potash) and NOP (nitrate of potash), basically due to the lower fertiliser price, although SOP and NOP also contain important plant nutrient anions of SO_4^{2-} and NO_3^- besides K, respectively. MOP also contains accompanying anion of Cl^-, an essential plant micronutrient, deficiency of which has been a relatively recent phenomenon. Recent studies in America, Canada and elsewhere have reported Cl deficiency in soils away from coastline and have also established the useful role of Cl in management of some diseases in wheat and other crops (19). But many myths are associated with the use of Cl, as some fears are usually expressed about its deleterious effect on soil and plant health. Another point of importance is the use of MOP for top dressing and also in foliar spray. In this paper an attempt has been made to review some of the myths and realities associated with the use of MOP as a fertiliser, more particularly that of Cl.

Chloride (Cl) is an essential element for all plants, one of the 16 nutrient elements required for normal growth and for completion of plant life cycle (3). It is required in small quantities by plants, similar to other micronutrients like iron, manganese, zinc, copper, molybdenum and boron. Chloride is not harmful to plant, animal or microbiological life in normal quantities but is undesirable in excess. The definition of Cl as a plant essential micronutrient was completely described in the early 1950's. However, the functions of Cl in field crops became obvious only in the 1980's.

CHLORIDE IN PLANTS

CHLORIDE is an essential micronutrient that serves as a key osmotic regulator in the plant, responsible for the hydration and turgor of the plant cells. It aids the movement of water into cells and the ability of cells to retain water, which is especially important when plants are under moisture stress (11).

Chloride has a vital role to play in a number of biochemical functions in plants, like enzyme activation, photosynthesis and cell division. It operates as a counter ion for cation transport (potassium, calcium and magnesium) to maintain electrical charge balance. Chloride also plays a central role in the regulation of opening and closing of stomata; this is necessary for absorption of carbon dioxide (CO_2) for photosynthesis and avoidance of drought stress by minimising water loss from the plant (8, 11).

Chloride deficiency symptoms for crops are not well described because a few have been observed under field conditions. Plants suffering from severe deficiency of Cl show symptoms of chlorosis and wilting. Leaf tips wilt is followed by bronze coloration followed by necrosis. On first examination this can appear to be some sort of leaf disease. Chloride toxicity symptoms include burning

* Muriate of Potash (MOP) has an analysis of 0-0-60. Its nutrient composition is approximately: Potassium: 60% K_2O, Chloride:46%. Chemical formula is KCl (potassium chloride)

of leaf tips and margins, bronzing, premature yellowing and abscission of leaves. Seedlings and tubers exhibit root and shoot scorch (19).

Plant species differ considerably in their sensitivity to Cl excess with sugar beet, barley and rape, being highly tolerant; wheat, grasses and potatoes intermediate; while peas, beans, clover and other legumes and some fruit trees like mango are sensitive. Chloride additions are an important part of nutrient management in crops like coconut and oil palm (8,19).

The main positive effect of Cl in crops like oil palm, coconut and kiwi is through improvement of the water balance in the plant. Chloride deficient plants loose water more rapidly than plants that are well supplied with Cl. Similarly, Cl deficient plants that suffer from water stress require longer period to recover its internal water balance. Therefore, the positive effect of Cl application on growth rate, yield, resistance to diseases and physiological disorders such as apex cracking and breaking of leaves, are related to the regulation of the water balance in the plant (8,19).

The amount of Cl found in plants varies with habitat because both the external Cl concentration and the balance of other available anions influence its content. The optimal concentration range in most crops is between 0.3 to 1 g Cl/kg dry matter (11). Cereal crops need about 0.4% Cl in the whole plant at the boot to flowering stage to achieve their full yield potential (8).

CHLORIDE IN SOIL

Soils near continental margins receive Cl carried inland by rain and snow, but Cl content diminishes rapidly with distance from the sea. Therefore, soils in some parts of the world are deficient in Cl, and additions of this element are associated with yield responses and improved growth as for any other limiting nutrient. Chloride deficiency mainly occurs in areas far from the sea where airborne Cl is very small (for example, the Midwest of the USA), and in tropical areas where excessive rainfall produces drainage that leaches out the Cl (6). Soils in India are generally well supplied with Cl as its deficiency has not been reported anywhere, however, Cl toxicity could be a problem in heavy textured soils with impeded drainage and growing Cl sensitive crops like tobacco, tomato, mango, etc. in rainfed or receiving brackish irrigation water in arid or semiarid areas.

Chloride inputs to soil derive from rainfall, fertilisers (mainly MOP), manures, and irrigation water and with seawater flooding. The Cl from all these sources is the same, as Cl^- anion, and there is no difference between Cl added from manure or rain than from fertilisers. Indian soils which are generally well drained, light to medium textured and receive only on an average about 16 kg KCl/ha/year as fertiliser, don't face any Cl toxicity problem arising out of MOP application.

The Cl ion has a negative charge (Cl^-), similar to nitrate (NO_3^-) and sulphate (SO_4^{2-}), and cannot attach to the negatively charged clay particles or organic matter. It is only held weakly in soils and leaches in a similar manner to nitrate and this mechanism is the natural regulator of Cl in most soils. Chloride is highly mobile in the soil, and under good drainage conditions it is easily leached out from the root zone by either irrigation or rain (8, 19).

As Cl can move freely with the soil water, soil Cl levels can be highly variable and can increase or decrease from year to year, depending on the water table and the location in the landscape.

Soils under covered crops (greenhouses) can suffer Cl build-up because they are not subject to leaching through drainage and the normal natural regulation. Similarly, soils in arid and semi-arid climates with little rainfall are vulnerable to salt build up. Problems may also occur where crops are irrigated with water containing high levels of Cl (8, 19).

FERTILISERS WITH CHLORIDE

MOP is the most widely used potassium fertiliser for agricultural crops, accounting for more than 95% of K consumption. Other fertilisers containing Cl are compound NPK's based on MOP and ammonium chloride (NH_4Cl), which is mainly used in China as a N source.

When a grower applies MOP as K source, either alone or in a blend, Cl is also applied, as the fertiliser contains 46% Cl. An average application of 50 kg K_2O/ha (equivalent to 83 kg MOP fertiliser) supplies 38 kg Cl/ha, or 46 kg Cl for every 100 kg of MOP.

The majority of the field crops (wheat, maize, pastures, banana, coffee, sugarcane, rice, cotton, etc.) are not sensitive to high Cl concentrations. Some of these crops require K in high quantities, like banana, and the most economic way to supply K to the plant is by application of MOP fertiliser. Research has shown that Cl accumulation in banana leaves due to intensive use of MOP has no negative effect on the crop productivity (8, 19).

MOP is a perfectly safe fertiliser, and fears of Cl problems in rainfed agriculture are generally unfounded. In India, as the MOP fertiliser is subsidised, hence it is considered to be the most economic source of K for the vast majority of situations. Correct practice in terms of application rates and timing should be observed, as for all other fertilisers or manures.

Toxicity problems due to Cl excess may occur where crops are irrigated with water containing high levels of Cl and with crops that are sensitive to Cl. Under these conditions, the use of fertilisers containing Cl (like MOP) can exacerbate the damaging effects of salinity. Cl-free fertilisers like mono potassium phosphate (MKP), KNO_3 or SOP are more suitable fertilisers for these specific crops situations or where quality is a premium like Virginia tobacco.

RESPONSES TO CHLORIDE FERTILISATION

Historically, comparatively little attention was given to the Cl component in MOP fertiliser. For many years it was believed that field-grown crops would not benefit from Cl applications due to its ubiquitous presence in the environment. Although Cl deficiency symptoms can be induced readily in the laboratory, they are not often observed under field conditions because Cl concentrations in soils are generally adequate, and only small amounts of Cl are required by plants. Indeed, assuming a minimal requirement for crop growth of 1g/kg dry weight (11), only 4 to 8 kg Cl/ha is required for the average crop. Nevertheless, a substantial increase in yield has been reported for many crops in response to Cl fertilisation (19).

A role for Cl fertilisation in crop production was not given serious consideration until research in the Philippines, USA and Europe during the 1970's, demonstrated yield and/or disease control benefits from Cl. The probability of response to Cl fertilisation increases in plant species with a high Cl requirement, such as wheat, sugar beet, kiwi fruit, palm trees, and in highly leached soils with a low input of Cl from rain and other sources.

Responses to Cl fertilisers in wheat, corn and grain sorghum have been widely documented in the Great Plains and the Pacific Northwest in USA. Winter wheat, spring wheat and barley have responded to Cl fertilisation from Texas to the Canadian Prairies and into the Pacific Northwest. Increased yields have been attributed as a micronutrient response as well as to a reduced incidence of fungal disease associated with enhance Cl nutrition (6).

To demonstrate that yield responses to MOP fertilisation are due to the Cl component in this fertiliser, these studies were conducted using different sources of Cl, including potassium chloride (KCl), calcium chloride ($CaCl_2$), magnesium chloride ($MgCl_2$), and/or ammonium chloride (NH_4Cl), in order to isolate the effect of the accompanying cation in the Cl fertiliser.

Research across the Great Plains has shown that wheat responds consistently to Cl fertilisation, particularly when soil Cl levels are less than 22 kg/ha (0 to 60 cm depth). Cl sensitive cultivars often show 330 to 1000 kg/ha yield responses when Cl is applied. Great Plains research shows yield response occurs about half the time when plant Cl is between 0.12 and 0.4%, but it occurs 80% of the time when plant Cl concentrations are 0.12% or less (6).

Nowadays, soil and plant Cl analyses are used as diagnostic tool for Cl fertilisation, with calibrated critical concentrations of Cl in tissue and soil. At this time, researchers state that wheat will most likely respond to Cl if soil test levels are below 3 ppm and plant tissue levels, at the boot stage, are below 0.10%.

Also in the Pampean region in Argentina, response to MOP application in wheat has been attributed to Cl, as increased Cl application was correlated to grain yield. Foliar analysis indicated low Cl levels, close to the critical values given in USA and in some sites, leaves exhibited deficiency symptoms. Photosynthetic activity in affected leaves is reduced, resulting in poor grain fill, lighter grain weights, and lower yields.

CHLORIDE AND SUPPRESSION OF DISEASES

VAST RESEARCH has shown that the incidence and rate of development of plant diseases may be reduced by an adequate and balanced mineral nutrition. In particular, potassium and chloride fertility have been proven to be effective in reducing crop injury from diseases.

Yield increases from Cl supplied as MOP have been associated with suppression of foliar or root diseases such as stalk rot of corn; crown and root rot in asparagus; root rot in barley; fusarium yellows in celery; gray leaf spot in coconut; stem rot and sheath blight in rice; root and crown rot in sugar beet; yellow rust, take-all root rot and many other diseases in wheat (8, 19).

The main mechanisms suggested for this action are: (i) the osmotic effect of Cl which may affect the ability of the pathogens to infect and develop inside the host plant, and (ii) biological inhibition, as Cl may stimulate the growth of certain soil microorganisms that inhibit the growth of certain plant pathogens.

Suppression/inhibition of pathogen are associated with the following effects of Cl: lower tissue NO_3^- which decreases crop susceptibility, increased soil NH_4^+ and NH_4^+ uptake, resulting in rhizosphere acidification and nitrification inhibition. The mechanisms involved in these responses, i.e. direct effect on the plant pathogen or increased host tolerance, still need further study (8, 19).

Chloride affects progression of some diseases by suppressing or slowing infection; however, it does not eliminate diseases and it can't be used instead of fungicides. In many trials, it has been reported positive and significant interactions of Cl application with systemic foliar fungicides that are commonly used in cereals. Use of Cl resulted in lower disease incidence and significant yield increases when used either in combination with or in sequence with fungicides.

For that reason, MOP offers a cost-effective, environmentally sound tool that can be part of Integrated Pest Management (IPM). Multiple benefits of including MOP in IPM are: i) reduction of the quantities and costs of fungicides; ii) reduction of pesticides and hazardous residues in food crops and in the environment; iii) reduced risk of development of fungicide-resistant strains of the fungus; iv) stimulation of plant growth and enhancement of crop vigour.

CHLORIDE AND BIOLOGICAL ACTIVITY IN SOIL AND IN ORGANIC FARMING

IT HAS BEEN suggested that the biological activity of soil (microorganisms, earthworms) is adversely affected by Cl additions in fertilisers. Soil biology is immensely complex and moreover, there is no reliable scientific evidence to support this contention. On the contrary, MOP has been used worldwide as a potassium source for many decades without causing any adverse impact on soil fertility or productivity.

Generally, MOP has been prohibited in organic crop production and mostly believed to be because of its Cl content. However, this is totally contradicted by the allowable use of crude salts such as sylvinite and kainite within the organic rules, as these materials, respectively, contain 2.8 and 4.8 times as much Cl as MOP per unit of K.

CHLORINE, CHLORIDE ?

LATELY, there has been a misconception that Cl has a negative effect on plants and soil organisms which basically has arisen from the confusion regarding the Cl present in the fertilisers and in disinfectants, herbicides and other products. Let's clarify these points:

Chloride is an essential element for humans, animals and all plants. It is a component of common salt and found in seawater. This element exists in the plant-soil system as the chloride anion Cl^-, as well as in the most used potassium fertiliser (KCl).

This must not be confused with other forms of the element Cl (Chlorine, Cl_2) *such as chlorine gas (highly toxic* and unstable), chlorine in swimming pools, hypochlorite (a steriliser and bactericide), hydrochloric acid (corrosive and dangerous liquid), chlorates (herbicides), etc. In contrast with the chloride, these forms are not present in the nature and must be industrially produced. None of these forms can occur in soils as the result of the addition of Cl in fertilisers, manures or rainfall.

FOLIAR APPLICATION OF MOP

SOIL APPLICATION of MOP is the safest way of applying Cl, however, doubts have been raised over Cl toxicity on leaves when foliar applied. Foliar application involves the use of MOP in solution. It results in fast K absorption and *utilisation and has the advantage of* quickly correcting deficiencies diagnosed by observation or foliar analysis. Other advantages are low application rates and uniform distribution of fertiliser.

Because of its osmotic action, MOP applied on leaves is not well tolerated by plants and therefore it is not usually used for foliar application. Nevertheless, it can be beneficial in some crops. Many experiments have been conducted on foliar feeding of MOP in India.

Foliar application of 1-2% MOP was found to be quite safe and beneficial in a host of crops like tea, coffee, guava, litchi, sugarcane, sunflower, soybean, rice, tomato, chilli, groundnut, etc. (1,2,4,5,7,9, 10, 12, 13, 15,16, 17, 18). Spray of MOP was found to decrease the damage caused by water stress and sheath blight disease in rice (14).

Foliar fertilisation is supplementary to and cannot replace the basal fertilization with MOP to the soil. Foliar application should be done during periods of low temperature and relatively high humidity, such in the early morning or late evening. Recommended concentrations should be followed, otherwise the foliar spray may cause leaf burning and necrosis. Usual concentrations are in the range of 1 to 2% of MOP in the spray solution (8).

CONCLUSIONS

FROM THE FOREGOING review, it can be concluded that chloride deficiency symptoms in crops have not been well described because few have been observed under field conditions, however, plants suffering from severe deficiency of Cl show symptoms of chlorosis and wilting. Chloride deficiency mainly has been reported in areas far from the sea where airborne Cl is very small but it has not been reported anywhere in India. Toxicity problems due to Cl excess may occur where crops are irrigated with water containing high levels of Cl and with crops that are sensitive to Cl. Under those conditions, it will be advisable to use Cl free potash fertilisers like SOP, MKP, etc. *Chloride application has also* been associated with suppression of foliar or root diseases in some crops. Foliar application of 1-2% MOP has been reported to be quite safe and beneficial in many crops in India. Greater care needs to be exercised in distinguishing *Cl from fertilisers or from detergents/* disinfectants/herbicides, as Cl or chlorine gas from the latter can be a toxic hazard to soil micro-flora or other living beings.

FUTURE RESEARCH NEEDS

FUTURE RESEARCH should focus on identifying the areas deficient in chloride and elucidating its role in disease management under cropping situations where chloride fertilisation could be limiting. It will be worthwhile to identify the pathway of disease management so as to clarify the controversy whether it is K or Cl responsible for imparting disease resistance. Screening of field as well as horticultural crops for their sensitivity or tolerance to Cl toxicity could be helpful in identifying the crops *to be grown under* situations of Cl excess. Role of Cl application on quality of crops need to be further elucidated to clarify many myths associated with adverse effect of MOP application on quality.

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