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Responses of Crops to Foliar Application of Calcium and Potassium

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ABSTRACT: Nutrient availability in the soil has become a limiting factor in the production of crops under the optimum conditions of all other resources, as the soil's capacity to supply the required nutrients has been challenged by many factors. Reduced nutrient loss, direct availability of nutrients, lower fertilizer requirements and a high B:C ratio are advantages of foliar application of nutrients over soil application. Calcium is an essential macronutrient that maintains the structure of the plant cell wall, acts as an intracellular messenger in the cytoplasm, assists in other nutrient uptake and mediates enzymatic processes. Calcium foliar application increases the calcium content of the leaves and fruits, increases the growth and yield parameters and the quality of the fruit, slows down the senescence, slows down the development of the fungi in the fruit, reduces the incidence of final rot on the fruit and increases the shelf life of the harvested produce. Calcium foliar spray in combination with other nutrient solutions and growth regulators such as zinc, boron, humic acid and salicylic acid have more beneficial effects on the crop. Potassium is an essential macronutrient that regulates plant growth through enzyme activation, osmotic balance, stomatal activity, transport of photosynthesis, sugar and water, stress relief, starch and protein synthesis and determines the quality of production. Researches regarding the foliar spray of Ca salts on agronomic crops are limited as compared to horticultural crops. Since, Ca has a major role in the plant and animal body, it is necessary to supplement in all crops ensuring food security. This review paper analyzes the results of earlier research on foliar treatment of calcium and potassium at different concentrations which made impact on the quantitative and qualitative improvement of the crop.

Keywords: Abiotic stress, Blossom End Rot, Calcium, Drymatter, Estragole, Foliar application

INTRODUCTION

Crop production must exceed the demand of the growing population by integrating economically viable, environmentally sustainable and socially sustainable technologies. For better management, every aspect of crop production must be revised. External inputs such as irrigation and fertilizer application ensure high crop yields. The availability of nutrients, as well as soil fertility, plays an important role in determining crop yield under optimum atmospheric conditions and water availability. The soil capacity defined as inherent in the provision of essential plant nutrients required for normal plant growth is referred to as soil fertility. However, the requirement of plants exceeds this inherent ability and is met by the external application of plant nutrients in the form of fertilizers and manures.

Calcium (Ca) is an essential macronutrient required by plants as a divalent cation (Ca^{2+}) involved in normal plant growth, metabolism, structural framework and physiological mechanisms. Although Calcium deficiency is rarely reported, there is a high risk of acidic soils and low saturated soil base (McLaughlin and Wimmer, 1999). Calcium mobility within the plant (Chishaki *et al.,* 2007; Gilliham *et al.,* 2011) determines calcium-related disorders (White and Broadley, 2003; Hocking *et al.,* 2016; Yu *et al.,* 2020) and the relative concentration of Ca in different parts of the plant (Quintana *et al.,* 1999; White and Broadley, 2003). Calcium exhibits a one-way movement towards young tissues as well as meristematic zones, and recycling will not occur even under deficient calcium conditions after tissue deposition (Hanger, 1979; Clarkson, 1984). The immobility of Ca in plants and soil affects the growth and yield of crops. It is necessary to ensure the availability of Ca to the plant at different stages of growth with a high yield objective. Soil application of Ca can increase crop yield as well as improve soil conditions, while the foliar application has more advantages in correcting deficiency disorders of Ca (Cheour *et al.,* 1990; Cheour *et al.,* 1991; Wada *et al.,* 1996; Murillo-Amador *et al.,* 2006; Singh *et al.,* 2007; Dordas, 2009; Hosein-Beigi *et al.,* 2019; Correia *et al.,* 2020).

Potassium (K), an essential macronutrient, plays an important role in the regulation of plant growth through enzyme activation, osmotic balance, stomach activity, transport of photosynthesis, sugar and water, stress relief and synthesis of starch and protein that ultimately determines the quality of production (Prajapati and Modi, 2012). Root-soil interaction affects the availability of potassium to plants (Ashley *et al.,* 2005). Potassium, accounts for 2.6 percent of the lithosphere while the actual soil concentration is 0.04 – 3.0 percent (Sparks and Huang, 1985). Potassium is the most abundant cation in plants and the fourth most abundant element in the earth crust, but the concentration in soil solution is low and 1-4% of total potassium in soil is bioavailable (Hafsi *et al.,* 2014). Potassium deficiency causes many plant disorders at physiological, biochemical and transcriptional levels (Hartt, 1969; Pettigrew, 1999; Zhao *et al.,* 2001; Kanai *et al.,* 2007; Gerardeaux *et al.,* 2010; Ma *et al.,* 2012; Li *et al.,* 2019; Zhu *et al.,* 2019; Thornburg *et al.,* 2020). There is a wide scope for the foliar application of potassium to plants that ensure healthy growth and high yield (Thalooth *et al.,* 2006; Akram *et al.,* 2007; Aown *et al.,* 2012; Afzal *et al.,* 2015; Adhikari *et al.,* 2020).

This review paper focuses on the impact of foliar application of Ca and K through different sources on various crops at different concentrations.

A. Effect of Foliar Application of Calcium on crop growth and yield

In addition to promoting growth and yield, the external application of calcium has many advantages. The foliar application increases the calcium content of strawberry leaves and fruit tissues (Cheour *et al.,* 1990; Dordas, 2009). An increase of 26.8% in leaf potassium was also observed in plants sprayed with 1.5 g/l calcium nitrate (Heidari *et al.,* 2014). But the deposition of Ca varies with the plant's ability to distribute and accumulate calcium (Cheour *et al.,* 1991). Increases in plant height, number of stems per plant, the concentration of chlorophyll, the yield of dry matter and yield of essential oil were observed in oregano treated with 0.5% and 1% calcium chloride (Dordas, 2009). Foliar applied Ca, either through $CaCl_2$ or $Ca(NO_3)_2$ may increase the yield of essential oils but does not affect the content of essential oils (Heidari *et al.,* 2014; Dordas, 2009). Foliar chelated calcium spray at 60 ppm in Egyptian cotton produced high seed yield, high seed index, high content of cottonseed oil and oil yield, high protein yield per hectare, increased insatiability, high total unsaturated fatty acids and reduced saturated fatty acids (Sawan *et al.,* 2001). Agronomic characteristics such as spike length, peduncle length and stem diameter have not been altered in wheat following Ca foliar treatment (Zoz *et al.,* 2016). Calcium nitrate when applied as a foliar spray in Rosa damascena at a rate of 10 gL^{-1}, increased flower yield but any concentration of calcium nitrate did not influence the content or composition of essential oils (Mahajan and Pal, 2020).

Potentially toxic components of essential oil, estragole and methyl eugenol may be significantly reduced by foliar application of 6 gL^{-1} calcium nitrate in an experiment conducted in French tarragon (Heidari *et al*., 2014). Growth and yield of plants grown in acidic soils can be improved by the use of calcium (Dordas, 2009). Under limited water supply conditions or drought stress, foliar application of 40 mgL^{-1} Ca^{2+} to Maize increased crop growth by increasing photosynthesis, turgor potential, water potential, stomatal conductivity, deposition of total soluble sugars, transpiration rate and decreased hydrogen peroxide content that help the plant to thrive under these conditions (Naeem *et al.,* 2017). Apply Ca foliar in combination with other nutrient solutions and growth regulators, resulting in increased growth, yield, morphological, physiological and biochemical parameters. Sugar ester or zinc used along with Ca solutions may reduce the incidence of blossom-end rot in tomato fruits (Wada *et al.,* 1996). 15 mM Calcium chloride and 30 ppm humic acid applied individually or together as foliar spray results in good fruit quality with high vitamin C content, maximum total soluble solids (TSS), increased nitrate reductase activity, maximum fruit firmness, high lycopene content and yield (Kazemi, 2014a). $CaCl_2$ increased ascorbic acid content and average fruit weight by 2% and 4 percent sprayed with pomegranate and combined with urea produced a high soluble solid content (Ramezanian *et al.,* 2009). Qualitative and quantitative improvement of pomegranate is observed with calcium application alone or in combination with a foliar spray of 1.5 per cent Ca, 150mM GA_3 and 3000 ppm Boron which improves the integrity of the fruit peel to avoid fruit cracking and sunburn disorders (Hosein-Beigi *et al.,* 2019). Combined foliar spray 2.5mM Ca and 0.25mM salicylic acid increased vegetative growth, reproductive growth, total flavonoids, total non-flavonoids, decreased lipid peroxidation, high TSS, high titration acidity and Vitamin C in strawberry (Kazemi, 2013). Individual application of 0.6 per cent Ca through $CaCl_2.2H_2O$ or in combination with 0.25 per cent boron and 0.5 per cent Zn increased height of the plant, number of primary as well as secondary branches, number of fruits and number of leaves per plant in tomato (Haleema *et al.,* 2018). A nutrient solution, $Ca(NO_3)_2$, applied as a foliar spray in rice plants under salinity stress, helped to reduce stress through Ca^{2+} by including in photosynthesis-related parameters, increased accumulation of dry matter and increased yield of grain (Sultana *et al.,* 2001). Calcium ions can be used to relieve sodium and chloride ion injuries in susceptible crops. Calcium nitrate foliar spray increased 10 mM in salt-stressed strawberry shoot and root dry weight (Yildirim *et al.,* 2009). The effect of calcium on the enhancement of photosynthesis is beneficial to the increase of the fruit set. A foliar spray containing 10 mM of calcium chloride increases the area of the leaf, the weight of primary fruits and secondary fruits and the number of flowers (Kazemi, 2014). Three Ca preparations, such as $Ca(NO_3)_2$, Insol Ca and Liberal Ca, were foliar sprayed with sweet pepper and observed that Ca supplementation through these three sources could increase marketable yield, reduced BER incidence on fruit and $Ca(NO_3)_2$ had a positive effect on the deposition of carotenoids and Vitamin C (Buczkowska *et al.,* 2016). Omega Cabor II foliar spray at 7.2 Lha^{-1}, a chelated fertilizer consisting of 125g Ca

L^{-1} and 6g B L^{-1} in wheat, increased number of spikelets per spike, number of grains and weight per spike, increased flower fertilization, number of fertile tillers and yield of grain (Zoz *et al.,* 2016). The maturation and maturation of the harvested products may be regulated by the application of $CaCl_2$ to the foliar before harvesting. $CaCl_2$ applied through foliar treatment increased the shelf life of fruit such as strawberry by delaying the ripening process as well as the development of grey moulds which deteriorate the quality of the fruit (Cheour *et al.,* 1990). Early flowering of the crop is increased by an average of 3-4 days with Ca foliar application (Dordas, 2009).

B. Effect of foliar application of Potassium on crop growth and yield

Potassium foliar use is more beneficial to crop growth, yield and economic return than to soil application (Ali *et al.,* 2016). The soil-applied potassium fertilizer is likely to become unavailable to plants by attaching to clay complexes. Although soil is capable of providing the required potassium to plants under normal conditions, some factors such as high crop intensity, the introduction of high yielding hybrid varieties, excessive K removal of straw from the field, the use of well-water tubes for irrigation and low organic matter can lead to soil exhaustion K (Mengel and Kirby, 1980). The application of foliar is therefore an economically efficient way of applying potassic fertilisers to plants.

The 3 per cent K_2O foliar application in maize yielded the highest organic yield, the quality characteristics of grain and the net B: C ratio (Ali *et al.,* 2016). Application of 1200 ppm K by potassium sulphate as a foliar spray along with nitrogen fertilization and plant growth retardant Pix in Cotton, increased seed index, cottonseed yield per hectare, protein content in seed, refractive seed oil index, oleic and linoleic content (total unsaturated fatty acids), unsaponifiable matter and decreased total saturated fatty acids, oil acid value and saponic acid content. Potassium thiosulphate sprayed on onion plants yielded high yields, increased vegetative growth, bulb quality and bulb chemical composition (Behairy *et al.,* 2015). Growth, yield, fruit quality and macronutrient concentrations in the tomato leaf are enhanced by the use of potassium (Amjad *et al.,* 2014). In tomatoes, 0.5 – 0.7 per cent K levels can lead to increased growth, fruit quality attributes such as lycopene content, ascorbic acid content, potassium content and fruit weight (Afsal *et al.,* 2015). Foliar spray of 4 per cent KNO_3 in Mango produced an earlier appearance of panicle, with an increased number, length and breadth of panicle in each plant, increased number of fruits per plant and maximum fruit yield (Sarker and Rahim, 2013). A comparison of different sources of potassium foliar spray in Rice was made and it was observed that 1.5 per cent K of K_2SO_4 produced high yields of grain, straw yield, the potassium content of plants, number of tillers, agronomic efficiency and potassium recovery compared to KCl and KNO_3 (Ali *et al.,* 2005).

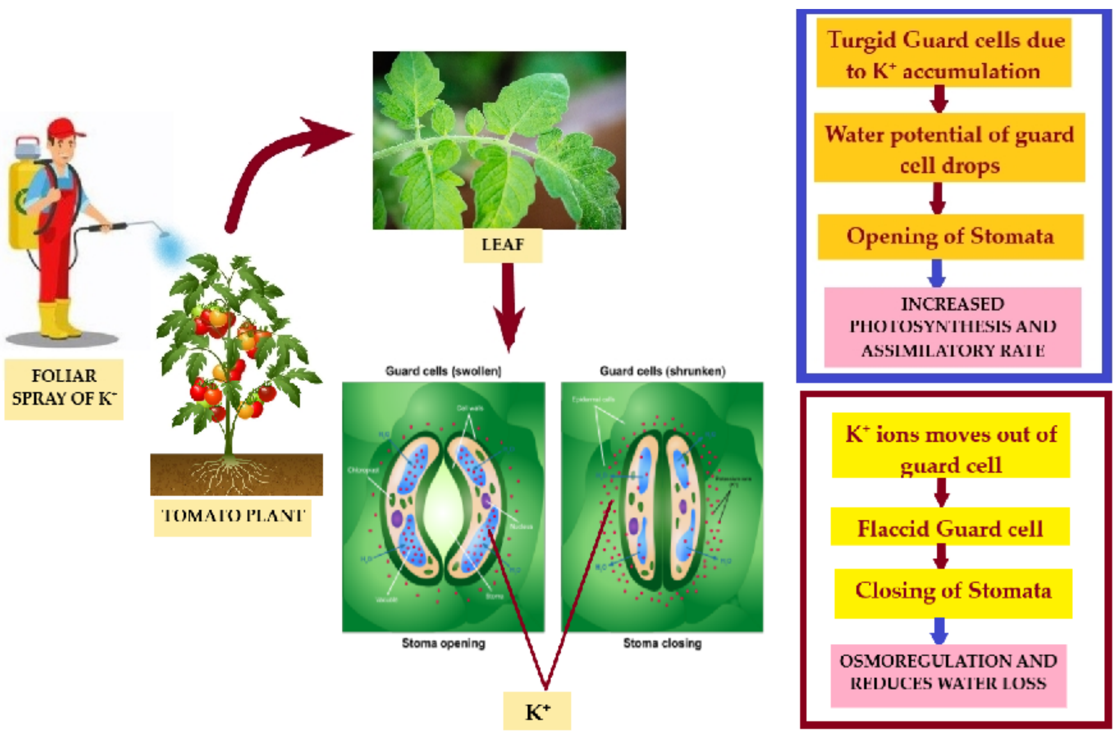

Fig 1. Regulation of opening and closing of stomata by Potassium ions.

There is a complex interaction between mineral nutrition and abiotic stress in plants. Plants under drought stress have increased demand for internal potassium (K) as it can reduce the harmful effect of increased ROS (Reactive Oxygen Species) production, regulate photosynthesis, enzyme activation, transport of cations to the sink, carbohydrate metabolism and alter turgor pressure of plant cells (Aown *et al*., 2012). Certain nutritional disorders are observed in plants under salinity stress as the concentration of salt can disrupt the availability of nutrients, disperse nutrients within the plant body and offer competition for nutrient uptake (Hussein *et al.,* 2012). Sodium chloride (NaCl) causes phosphorous and potassium deficiencies within plants. This can be corrected by supplementation of P and K by foliar spray as observed in tomatoes complemented by increased water use of 5 mM KH_2PO_4, decreased membrane permeability to reduce electrolyte leakage and increased concentration of P and K in plant tissues (Kaya *et al.,* 2001). The one per cent K used as a foliar spray in three critical stages of wheat (tillering, flowering and milking) under the water deficit condition helped the plant to improve its drought tolerance by increasing yield components such as spike length, several grains per spike, grain yield and 1000 grain weight (Aown *et al.,* 2012). In mung bean, foliar spray of 2% KNO_3 under drought stress has a positive effect on vegetative characteristics, growth parameters and yield components (Thalooth *et al.,* 2006). Leaf potassium levels may be increased by the use of KOH as foliar therapy. Under the salinity-stressed condition, KOH foliar spray accumulates K+ ions in the leaf which decreases Na+ ions by increasing the K+/Na+ ratio in sunflower (Akram *et al.,* 2007). Potassium monophosphate sprayed at 200 ppm in pepper under irrigation water salinity enhanced all growth parameters such as fresh and dry stem, leaf and fruit, leaf area, several leaves and plant height, a 2.6-fold increase in total phenols and increased chlorophyll a: chlorophyll b ratio (Hussein *et al.,* 2012). Salt-tolerant wheat varieties cultivated by foliar application of KNO_3 at the heading stage could provide better grain quantity and quality by alleviating salt-induced injury by increasing photosynthetic capacity, chlorophyll content, ROS scavenging activities and a high K+:Na+ ratio (Zheng *et al.,* 2010). Although the foliar application of K has innumerable benefits, there are some areas where it does not have an impact as reported in some literature. In soybean plants grown under salinity stress, 2.5 per cent KCl and K_2SO_4 foliar spray did not help to reduce salinity stress but K_2SO_4 helped to increase antioxidant activity, chlorophyll content, carotenoids and flavonoid content compared to KCl (Adhikari *et al.,* 2020). Exogenous potassium foliar spray does not influence the quality of cotton fibers (Blaise *et al.,* 2009).

SUMMARY AND CONCLUSION

The use of foliar nutrients has a more beneficial effect on crop growth and yield than the application of soil. Calcium can be used as a foliar treatment with calcium chloride, calcium nitrate and chelated calcium individually or in combination with other nutrient solutions and growth regulators at different concentrations depending on the source and crop species. Foliar application of Ca improves the shelf life of harvested products by delaying senescence and fungal growth of stored fruit, maintaining cell wall structure, correcting deficiency disorders in plants such as blossom end rot and alleviating stress conditions. Potassium is a key element in plant nutrition that maintains innumerable functions within the plant body, such as enzyme activation, osmotic balance, stomatal closure and opening, water uptake, stress relief and photosynthetic transport within the plant. Potassium can be sprayed on crops in the form of KCl, KNO_3, K_2SO_4, KOH and KH_2PO_4 at different concentrations depending on the species and the source of the crop. Both nutrients can be complemented by other nutrient solutions and growth regulators to achieve enhanced growth and yield. The use of calcium and potassium as foliar spray has an impact on the quantitative and qualitative parameters of crop production. There is a necessity to widen the research to those crops included in daily human diet as it serves the way for healthy food. Also, scope of study exists in the role of calcium in preventing pre-harvest losses of all crops as it can strengthen the cell wall.

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