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RESEARCH ARTICLE

ROLE OF POTASSIUM NUTRITION IN IMPROVING GROWTH, YIELD AND QUALITY OF SUGARCANE- A REVIEW

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ABSTRACT

Sugarcane (*Saccharum officinarum* L.) is an important commercial crop and the sugar industry is the second largest agro-based industry in the country. It is mainly grown in tropical and sub-tropical region of India. Balanced nutrition is one of the critical components in augmenting crop production and among the nutrients; potassium is an important element contributing to production and quality of sugarcane. Application of potassium plays an important role in translocation of sugar in plants, starch formation, chlorophyll development and promotion of photosynthesis, prevention of premature cell death, stomatal opening and closure and uptake of water. Further, it was also observed to improve purity of juice, sucrose content and sugar yields, with reduction in fibre per cent. Potassium must be kept adequate to produce optimum yields and to regulate maturity so that maximum sugar is recovered from the millable stalks. The research findings on various aspects of potassium in sugarcane are reviewed.

INTRODUCTION

Sugarcane (*Saccharum spp*. complex hybrid) is an important cash crop of India which is cultivated in an area of about 5.1 million hectare with an average productivity of 70.0 t/ha during 2014-15 (Economic Survey, 2015-16). The crop is of long duration and nutrient exhaustive which removes about 2.05, 0.24, 2.28 kg NPK/tonne of cane produced (Singh *et al*., 2007). Balanced nutrition is one of the critical components in augmenting crop production and among the nutrients; potassium is an important element contributing to production and quality of sugarcane. Sugar and starch crops require larger quantities of potassium than other crops. Potassium is an essential nutrient in sugarcane production, with a number of roles being attributed to it within the plant. Potassium plays a pivotal role in sugarcane production. All facets relating to K in the soil-plant system need to be optimized to ensure efficient K supply, uptake and utilization by the crop. In the mature crop, about 45% of the K is in the leaves and trash, with the remainder being in the stem. Potassium is extremely mobile in the plant and redistributes rapidly from older leaves to newer ones. Sugarcane is capable of rapidly depleting soil of nutrients, particularly potassium.

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In a general survey of experiments in India, it was observed that maximum uptake of K occurred in early stages followed by steady level subsequently. Deficiency of N in soil is reported to depress uptake of K. It is generally reported that potassium application is beneficial for tillering, stalk population and yield. In this context, results of field experiments conducted in different agro-climatic regions of India, are discussed in this paper.

Role of potassium in sugarcane

Sugarcane is known as a devourer of potassium due to very heavy uptake by the crop, sometimes in excess of the requirements particularly under limited supply either due to excess application or due to greater native available potassium status (Sundra, 1998). Potassium fulfils a number of important roles in plant growth (Anderson and Bowen, 1990; Calcino, 1994), while K deficiency can result in reduced yields and lower CCS values. It is required for cells structure, carbon assimilation, photosynthesis, protein synthesis, starch formation, translocation of proteins and sugars and entry of water into plants. More than 60 enzymes are activated and it is basic to sugarcane for synthesis and accumulation of sugar (Clements, 1980). Application of K is prophylactic measure against diseases like eyes pot and cercospora. Lodging or layover of cane is greatly restricted due to K fertilization.

Potassium helps sugarcane under moisture stress by maintaining cell turgidity. The most important function of K in sugarcane is improvement in cane quality by converting reducing sugars to recoverable sugars. Potassium is directly associated with the quality of canes as it improves pol % cane. This nutrient helps to flush out N and tissue moisture to assist sugarcane to reach a stage of maturity. In general, improvement in commercial cane sugar (CCS) yield (t/ha) is due to increase in cane yield and pol % cane (sucrose). But, K deficiency is seen in older leaves first as it is highly mobile in the plant. Emerging leaves and tips turn brown with necrotic spots which coalesce and show typical "marginal firing" under severe K deficiency. As rate of photosynthesis decreases with increasing severity of K deficiency, plant growth is retarded, internodes become shorter and the stalks themselves are shorter and smaller in diameter than those of well-fertilized sugarcane plants. Potassium is in fact reported to control the hydration and osmotic concentration of the stomata guard cells. When K is deficient it causes a loss of turgor pressure resulting in closing of the stomata and a reduction in the rate of transpiration and CO_2 assimilation (Humbert, 1968). It is also well documented that over-application of K decreases cane quality (Anderson and Bowen, 1990) and causes a reduction in the recovery of raw and refined sugar (Clarke, 1981) due to elevated levels of ash in sugarcane juice (Leverington *et al.*, 1965; Kingston, 1982).

Dose and time of application

Four forms of K are recognized as regards its availability to plants namely; structural (matrix), non-exchangeable (not easily available), exchangeable and solution K. Most of the Indian soils have either high or medium potassium availability. Even then, not all the potassium fertilizer applied is available to the crop. Some of it is fixed in the soil in between the clay layers. Though the potassium uptake by a sugarcane crop is high, it is not necessary to apply a fertilizer dose equal to that of crop removal. Every soil is capable of supplying the crop requirement of K to some extent. Therefore, it is sufficient if part of the crop removal is applied to soil as fertilizer. The dose could be in between 100 to 200 kg K_2O/ha depending on whether a soil is high or medium or low in available potassium. Absorption of K by sugarcane is most active after four months age during grand growth period. During this period, about 85% of K_2O is absorbed. Therefore, the potassium fertilizer will have to apply in such a way that its availability is maximum during the grand growth stage of the crop. Potassium applications are usually done along with nitrogen application. However, potassium is applied basally in several sugarcane growing regions. Since potassium is also subject to losses by fixing and leaching, it is advisable to go for split application along with nitrogen. Potassium may be applied in two equal splits along with nitrogen, one at 45th day and the other at 90th day. It can also be applied in two splits, one as basal does at planting and the other at 45th day. Apart from the general recommendation, additional does of potassium is advocated to overcome drought. In case of early drought, foliar application of 2.5% nitrogen and 2.5% K_2O solution is advocated at 30 days intervals. For late drought, soil application of K_2O @ 100 kg/ha is advocated (Alexander and Arulraj, 1995). Major sources of potassium fertilizers are potassium chloride, potassium sulphate, potassium nitrate and potassium magnesium sulphate. Of these, potassium chloride (Muriate of potash) is most common fertilizer in use. Indigenous sources such as crop residues, farmyard manure (FYM), organic cakes, organic manures, wood ash etc., are also utilized as potassium sources from time immemorial. Potash is band placed in cane furrows below the set, but 3-5 cm away from it.

Effect of potassium on sugarcane

Effect potassium on growth attributes

Dagade (1976) reported that germination was not affected and tillering increased slightly when K_2O was applied to sugar cane @ 100, 200 or 300 kg/ha. The lowest rate of application was found optimum. Sinha and Singh (1977) reported that potassium deficiency resulted in a reduced rate of dry matter accumulation and a decrease in the final weight of the plant. The critical period of percentage N absorption was shifted from 90 to 180 days due to K deficiency while the peak for other elements (Ca, Mg and P) remained unaffected. Hence, it was suggested that for successful cane growth the supply of mineral elements should be made available from the beginning until 135 days of growth. Sudama *et al.* (1998) conducted a pot experiment with sugarcane and concluded that application of potassium at the time of planting significantly increased the stomatal diffusive resistance and thereby decreased the transpiration rate and increased the leaf water potential, leaf area of first open leaf and cane length. Karthikeyan *et al.* (2003) reported that potassium was applied as potassium chloride in three equal splits at 30, 60 and 90 days after planting followed by irrigation in field trials at farmers' field and observed that the benefits of K fertilizer application on nutrition and growth, yield and juice attributes of sugarcane were similar on sandy loam and sandy clay loam soil but their magnitude was higher in the latter than the former. Sanjay *et al.* (2005) conducted an experiment at Pantnagar and reported that the number of shoots, dry matter accumulation and cane yield increased with the increase in the potassium rates in plant crop. Shukla *et al.* (2009) concluded that application of 66 kg K/ha with irrigation water in standing plant cane before harvest improved bud sprouting, dry matter accumulation and nutrient uptake in ratoon crop. Thus, potassium nutrition holds great promise for improving growth of ratoon cane and sugar yields. Indirajith and Natarajan (2011) opined that split application of recommended dose of potassium on 30, 60, 90, 120 and 150 days after planting along with the recommended dose of nitrogen and phosphorus significantly recorded the maximum mean shoot population, cane length, individual cane weight and seed cane yield.

Effect of potassium on yield and yield attributes

Gupta and Agarwal (1976) at IARI, New Delhi, concluded that 50 kg K_2O/ha was the most effective and economic potassium rate for sugar cane production. The effect of potassium was more pronounced with the ratoon than with the plant crop. Yadav *et al.* (1986) while conducting a field experiment at IISR, Lucknow reported that application of 120-240 kg K_2O/ha to an alluvial soil (132 kg exchangeable K/ha) increased cane and sugar yields due to improved cane length, thickness and weight. The highest yields and the best cane quality were obtained with the application of 113 kg K_2O/ha (Pandian *et al.,* 1989). Rani *et al.* (1989) reported that sugarcane yields increased with the K_2O rate up to 75, 150 and 225 kg/ha at the 3 sites, respectively. Sugar yield also followed the same trend as cane yield. Narasimham and Ramalingaswamy (1991) reported that application of potassium to sugarcane cv. Co7219 within 90 days of planting gave higher yields than application at later dates. Contrary Dhillon *et al.* (1993) reported that application of potassium did not significantly affect sugarcane yields in field experiments conducted in farmer's fields at 4 sites in Punjab. Rathore *et al.* (1996) noted that cane yield was highest with 100 kg K_2O/ha applied as a basal application or 50 kg K_2O as basal + 50 kg at onset of monsoon. Singh *et al.* (1999) reported that mean cane yield was highest with 125% of the recommended potash rate (70 kg K_2O/ha was the recommended dose of potash). Cane yield was not affected by K basally or in 2 split dressings. Vijay *et al.* (2000) working on sugarcane at Karnal found that application of 50, 75, 100 and 125 kg K_2O significantly increased cane yield from 48.98 (no K) to 53.57, 53.28 to 57.56 and 52.88 to 56.06 t/ha, respectively. Aneg *et al.* (2001) observed that application of K (0, 40, 80 and 120 kg/ha) showed that the available K level in soil and different doses of K significantly affected cane yield. Generally, the increase in yield was noted with an increase in available K level of the soil as well as with the rates of applied K. The obtained critical limits in soil and plant was 149.0 kg/ha and 1.68% K, respectively. Ramesh and Sumamsusan (2003) conducted a field experiment at Hyderabad and they concluded that K (0, 82.5 and 165 kg/ha) had no significant effects on the yield of the sugarcane crop. Vijay *et al.* (2003) concluded that the continuous application of K @ 50 kg K_2O/ha and above significantly increased cane yield from 49.58 to 57.07 t/ha and from 51.70 to 58.69 t/ha in plant and ratoon crop, respectively, over control. Significant quadratic relationship was found between K application levels and cane yield of plant and ratoon crop. Vijay *et al.* (2008) reported that sugarcane variety CoH-56 showed a significant increase in cane yield of both plant and ratoon crops up to the application of 75 kg K_2O/ha, while variety CoH-110 showed a significant increase in cane yield of both plant and ratoon crops up to the application of 50 kg K_2O/ha. The yield contributing characters were also increased with the application of potassium. Vijay *et al.* (2009) concluded that the application of potassium @ 50 kg K_2O/ha at the time of planting or preparing for ratoon increased the cane yield for both plant and ratoon crop, over no K application in Haryana.

Effect of potassium on nutrient content, uptake and quality

Patil and Shingte (1982) reported that the best quality and colour of brown sugar were obtained when 100 kg K_2O/ha applied to sugarcane crop. Rani *et al.* (1989) reported that the quality parameters (% CCS, sucrose and purity) of cane significantly improved by potassium application. Patil and Shingte (1992) conducted a field experiment on a silt clay soil in Maharashtra, India and concluded that application of 110 and 165 kg K_2O/ha significantly increased the sucrose content and decreased the reducing sugar content of jaggery. Prasad *et al.* (1996) observed that potassium uptake increased with increasing K rates. The brix, pol and purity coefficient of cane juice increased significantly up to 60 kg/ha of K_2O. Commercial cane sugar (CCS) per hectare also increased significantly with K application. The fibre content in cane decreased significantly with increasing levels of K. The minimum and maximum values of available K_2O in soil were observed at grand growth and formative stages. Ramesh and Sumansusan (2000) conducted a field experiment in the riverine alluvial soils of Kerala and they concluded that cane yield increased with up to 165.0 kg N/ha but was not significantly affected by P or K. The interaction among the treatment combinations of NPK was also non significant. Moreover, the different levels of K failed to influence the brix, pol, CCS (commercial cane sugar) percent and sugar yield. Tiwari *et al.* (2000) reported that potassium uptake and available soil K increased with increasing K rate. Cane yield was highest when half the K was applied basally and half at the onset of monsoon. Vijay *et al.* (2000) reported that juice quality parameters viz sucrose % and commercial cane sugar content increased with the application of 50 and 75 kg K_2O/ha, respectively. K availability in soil increased with increasing K rate. Singh *et al.* (2001) conducted an experiment at Lucknow and reported that the application of 40 kg K_2O/ha did not significantly influenced the yield of seed cane but improved its quality characteristics such as sett moisture (69.2%) and reducing sugars (2.75%). Vijay *et al.* (2003) revealed that continuous application of K @ 75 kg K_2O/ha and above significantly increased commercial cane sugar from 11.51 to 11.92% and 11.38 to 12.82% in plant and ratoon crop, respectively, over control. Rakkiyappan *et al.* (2007) conducted a field experiment at SBI, Coimbatore and results revealed that the total K uptake in above ground parts varied from 108.55 kg/ha (CoTl 93116) to 305.98 kg/ha (Co 7219) with a mean of 210.25 kg/ha. The K uptake per tonne of cane ranged from 1.44 kg in CoTl 93116 to 2.91 kg in Co 7219 with a mean of 2.09 kg. Sanjay *et al.* (2007) reported that P:K applied @ 120:80 kg/ha gave the highest mean number of millable canes, cane yield, commercial cane sugar (CCS) yield, net returns, monetary efficiency, mean P uptake and mean K uptake while the highest mean juice sucrose percentage and nutrient use efficiency was obtained with 60:40 and 90:60 kg P:K/ha, respectively. Patil *et al.* (2009) reported that significantly higher K content was recorded with the application of K_2O @ 75 kg/ha.

Conclusion

Sugarcane has a high demand of potassium. Potassium removal by the crop is greater than both nitrogen and phosphorus and always exceeds application rates leaving negative soil balance. There is luxury consumption by the crop under increased supply. It plays an essential role in numerous physiological processes in the crop and adequate supplies of K are crucial for sustainable and profitable sugarcane production. The fact that a large amount of K is needed to drive N-stimulated growth towards maturity serves to show that K fertilization of sugarcane cannot be considered in isolation from the requirements of the sugarcane for other nutrients particularly N. Instead a balanced nutrition approach must be adopted if the optimum sugarcane yield and benefits from potassium fertilization are to be attained. The response of sugarcane to potassium fertilization is dependent on the available K status of the soil; hence, the importance of a soil testing programme in K fertilizer recommendations cannot be overemphasized. Potassium application doses must be decided on the basis of field response studies conducted over the entire sugarcane crop cycle.

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