FOLIAR NUTRITION IN COTTON - A REVIEW

K. Rajendran, M. Mohamed Amanullah and K. Vaiyapuri
Department of Agronomy,
Tamil Nadu Agricultural University, Coimbatore - 641 003, India

ABSTRACT

Nutrients play a major role in influencing the growth and development in cotton. Generally major nutrients viz., N, P and K are supplied to cotton either through soil or foliage and the micronutrients and growth promoting substances applied as foliar feeding. But, foliar application of nutrients through fertilizers such as Di ammonium phosphate (DAP), Potassium chloride (KCl) and micronutrient mixtures during flower and boll development stages have been shown to be effective in efficient utilization of nutrients by cotton and thereby reduce boll shedding and increase the yield. In this context, the literatures on foliar nutrition of major and micronutrients on the growth, yield and quality of cotton are reviewed in this paper.

Key words: Foliar nutrition, Cuticular absorption, Water soluble nutrients, Spray solution

Cotton regarded as the ‘white gold’ is an important commercial crop throughout the world. It is the chief source of raw material to the textile industry. The growth and yield of cotton is governed by the interaction of environment with the genetic makeup of the variety or hybrid, various inputs, such as water, fertilizer, pesticides etc. Among the various inputs, fertilizers play a major role in influencing the plant growth and development of cotton. Generally major nutrients viz., N, P and K are supplied to the crop through soil and the micronutrients and growth promoting substances applied as foliar feeding. The yield of cotton is affected due to many reasons viz., flower and boll shedding due to imbalance in nutrients, hormones etc.,

Foliar fertilization can be used to improve the efficiency and rapidity of utilization of a nutrient urgently required by cotton crop for maximum growth and yield. However, foliar nutrition should only serve as a supplement to traditional soil applied fertilizer for a sufficient supply of nutrients to the developing cotton crop for optimum yields and fibre quality. In general, foliar application should be done either in the early morning or late evening for maximum efficiency and should not be done to water stressed cotton. There is lot of conflicting information about the benefit of foliar fertilization but scientific evidence to date and the widespread practical use of this phenomenon indicate that it is a viable and useful practice for improved cotton production.

However, indiscriminate foliar application of nutrients without due consideration of soil available N and plant N can be wasteful.

Research needs to determine the amount of nutrients that actually reach their targets (bolls) and how much of the total budget of them to organs this constitutes. An improved understanding of this fundamental aspect of foliar additions of nutrients in cotton would help to more precisely predict when to use foliar fertilization for maximum benefit and enhance the success and reliability of this practice.

Foliar application of nutrients through fertilizers such as Di ammonium phosphate, Potassium chloride and micronutrient mixtures during flower and boll development stages was found to reduce flower and boll shedding and increase the
yield and fibre quality (Mehetre et al., 1990). Hence, work done on foliar nutrition of major and micronutrients in cotton are reviewed in this paper.

**Nitrogen**

Foliar spray of 3 per cent urea in the morning at weekly intervals from squaring to bolling stage appeared to be an efficient technique of foliar urea fertilization and gave better yield than control (Bhatt and Nathu, 1986). Foliar application of nitrogen was reported to increase cotton lint yield when soil applied N was low despite petiole NO$_3$-N concentrations were primarily dependent on soil applied nitrogen fertilizer (Me Connell et al., 1996).

Application of 50 per cent N (60 kg ha$^{-1}$) at the time of sowing in soil and split application of the remaining 50 per cent N in one to two splits through one or two foliar sprays gave significant yield increase in cotton under rainfed condition at Madurai. However, application of N as foliar spray gave better results than split application of N through soil. Application of 150 per cent of recommended level of fertilizers registered the highest number of good opened bolls per plant (24.8) and seed cotton yield of 3090 kg ha$^{-1}$ and it was at par with 125 per cent of recommended dose of fertilizers at Coimbatore (Sankaranarayanan, 2004).

**Phosphorus**

Patil et al. (2004) reported that application of recommended dose of phosphorus (60 kg ha$^{-1}$) produced significantly higher dry matter than control which was 30 per cent lower than recommended dose of phosphorus level. Foliar application of P at the rate of 7.5 kg P$_2$O$_5$ ha$^{-1}$ combined with 40 ppm Zn at 75 and 90 DAS, 7.5 kg P$_2$O$_5$ with 60 ppm of Ca at 80 and 95 DAS under clay loamy soil condition gave significantly higher kapas yield in cotton (cv. Giza 75). In a transplanted cotton cv. Giza 70, the number of bolls per plant, number of open bolls per plant, yield of kapas per boll and lint yield was the highest with foliar application of P at budding stage and pre flowering stage when 30 days old seedlings were transplanted. Application of 2 per cent DAP increased the number of bolls per plant over control. Pandrangi et al. (1991) reported that at Akola (Maharashtra) foliar application of P (0.2 per cent or 0.5 per cent) in three applications ten days after squaring gave higher seed cotton yields (1.21 - 1.26 t ha$^{-1}$) than 15 or 20 kg P ha$^{-1}$ as single super phosphate applied to the soil (1.13 - 1.14 t ha$^{-1}$). Seed cotton yield and oil content and N, P and K uptake of cotton were higher due to foliar application. Raju et al. (2008) reported that foliar application of DAP produced 10 per cent more seed cotton yield, 16 per cent higher B: C ratio with 7 per cent higher boll numbers over soil application alone.

Foliar application of DAP (2 per cent) increased mean seed cotton yield between 219.5 and 500 kg ha$^{-1}$ compared to control. The highest seed cotton yield of 1.79 t ha$^{-1}$ was obtained by 15 kg P$_2$O$_5$ ha$^{-1}$ at first irrigation through soil + 15 kg P$_2$O$_5$ ha$^{-1}$ through 2 per cent DAP spray. Phosphorus application improved seed and fibre strength (Sharma et al., 1992).

**Potassium**

Foliar application of KNO$_3$ (in addition to soil application of recommended dose of fertilizers) at 25 days after planting gave 31, 29 and 49 more squares than application of water, K$_2$SO$_4$ and KNO$_3$ respectively (Keino et al., 1997). Brar et al. (1998) found that the number of flowers per plant was significantly increased by the application of potassium. Four sprays of 2 per cent KNO$_3$ resulted in higher seed cotton yield at Nanded and Siruguppa. Whereas four spray of 3 per cent KNO$_3$ seemed beneficial at Surat (AICCIIP, 2006). Howard et al. (1998) reported that soil and foliar application of potassium (one per cent KCl) improved the fibre quality parameters of cotton. Foliar application of different potassium sources viz., KNO$_3$, K$_2$SO$_4$ each at the rate of 5.0 kg ha$^{-1}$ had increased lint yields compared with an untreated control. Maximum positive benefits occurred when applications were made between one and three weeks after the start of flowering. Increase in lint yield was up to 100 kg
Oosterhuis (1993) pointed out that the peak demands for K is at boll filling stage, with higher boll load and potential yield and spraying of foliar K at first bloom (45 to 60 DAS) or squaring and flowering or one to four weeks after first flowering in one to four rounds at 7 to 15 days interval was found to increase kapas yield.

Sharma and Singh (2007) found that foliar application of K$_2$O (2 per cent) at initial and peak boll formation significantly increased seed cotton yield, number of open bolls plant$^{-1}$, boll weight, K content and uptake. Fibre quality parameters viz., ginng percentage, staple length, uniformity ratio, micronaire and fibre strength were also improved with foliar application of K$_2$O. Potassium was particularly important for seed cotton production as reported by Dhanwinder Singh et al. (1990).

Comparison of 1.5 per cent Polyfeed (19:19:19) two and four weeks after flower initiation and soil application of 24 kg K$_2$O at 40 DAS + foliar application of one per cent K$_2$O as potassium sulphate and Polyfeed revealed that the kapas yield was the highest with the soil and foliar (Potassium sulphate- Poly-feed) applications of K (Makram and Shihawy, 1995). Srinivasan (2004) revealed that the dry matter accumulation by cotton and seed cotton yield were the highest with the application of NAA 40 ppm twice at 45 and 60 days after sowing in combination with KCl one per cent at 50 and 70 days after sowing with a cost benefit ratio of 2.93 and 3.05 respectively.

Application of 1.3 per cent KCl at 45 and 60 DAS gave significant increase in seed cotton yield than control (Krishnan et al., 1994). Maintaining of 2.5 to 3.6 per cent of K in leaves through foliar application of K was found to improve fibre length, fibre maturity, uniformity, fineness and strength in winter irrigated cotton viz., G.hirsutum cv. MCU-5 and G.barbadance cv. Suvin and PSH (Shanmugam and Bhatt, 1991).

**Combined foliar nutrition of NPK**

Reddening in Bt cotton leaves was reduced by 30-40 per cent with foliar application of urea @ 2 per cent + DAP @ 2 per cent + MgSO$_4$ @ 1 per cent given at boll formation stage (CICR, 2009). Ebelhar et al. (1998) found that application of foliar spray of urea combined with KNO$_3$ did not give any significant yield increase in irrigated cotton at Stoneville (USA). But the growth regulators like mepiquate chloride increased lint yield by 4 per cent (15 kg lint ha$^{-1}$). Growth regulators combined with foliar applied urea and KNO$_3$ increased lint yields by 5 to 6 per cent (53.3 and 47.5 kg lint per ha, respectively).

**Micronutrients**

Katkar et al. (2005) concluded that either three sprays of MgSO$_4$ (one per cent) + ZnSO$_4$ (0.5 per cent) at squaring, flowering and boll development stage or two sprays of 2 per cent urea at flowering and 2 per cent DAP at boll development stage were recommended to obtain increased seed cotton yield. Application of mepiquat chloride at first flowering and 2 weeks after first flowering stage and boron @ 0.15 liter ha$^{-1}$ at first flowering and 4 weeks after first flowering resulted in significantly highest number of open bolls and seed cotton yield (Gormus, 2006).

Boron at lower dose (0.15 kg B ha$^{-1}$) as foliar spray at the early stages increased yield and fibre length. But when applied at the later stages (flowering) better effects were observed only at the higher rates (Carvalho et al., 1996). In a green house study, there was a difference in tissue B concentration in cotton (8-11 mg kg$^{-1}$) by foliar application of different sources of B like boric acid (17.5 per cent), sodium borate (Solubor R 20.5 per cent) and Traco liquid B (10 per cent) but there was no effect on tissue B concentration in soybean (Guertal et al., 1996).

Dong Jin Feng (1995) reported that three rounds of foliar application of 0.2 per cent B as
borax or boric acid at the seedling stage, early flowering or boll formation stages increased kapas yield by 15.1 per cent. The yield increases was 13.1 per cent and 8.6 per cent for two and one round of spray, respectively. The average yield increase was 16.1 per cent. The CGR, RGR and NAR of cotton during vegetative growth were unaffected by foliar spray of either Cu (15 g 10 per cent Cu-EDTA per liter water) or B application (0.2 g boric acid per liter). Leaf area ratio was generally increased by B and decreased by Cu. Boll weight was unaffected by B or Cu application while seed cotton yield (1468 kg ha\(^{-1}\)) and number of open bolls per plant (19.13) were increased (Hosney et al., 1984).

Sun and Xu (1986) observed that when soil available B ranged from 0.05 to 4.48 ppm with soil pH of 8.0, foliar spray of 0.2 per cent boric acid at square formation, early and peak flowering increased the seed cotton yield by 0.03 to 17.3 per cent and staple length by 0.17 mm and also reported that the critical value of B application was 0.55 ppm. Biswas (1984) reported that the two foliar sprays of 0.02 per cent boric acid + 0.1 per cent ZnSO\(_4\) in 1:1 ratio at the beginning and full flowering stages markedly increased the B and Zn contents in different plant organs. Foliar application of boron on cotton at the rate of 0.2 to 3.2 kg ha\(^{-1}\) as borax (11 per cent B) gave the highest yield of seed cotton.

Foliar application of one per cent Micnelf MS-16 (consisting of Zn, Cu, Fe, Mn, Mo and B) on 30, 65 and 90 DAS produced greater yields than foliar application of Micnelf MS-16 supplemented with MgSO\(_4\) in Kharif season in Khandwa (India). The highest seed cotton yield of 8.12 t ha\(^{-1}\) was obtained from the combined application of the recommended NPK rate (120:60:60 kg ha\(^{-1}\)) + one per cent Micnelf MS-16 at 30, 65 and 90 DAS (Namdeo et al., 1992). Heitholt (1994) studied foliar application of 0.32 kg boron per hectare combined with 16.6 kg N as triazone-N (24 per cent of N as S-Tetra hydro triazone) or urea. Application of Boron alone decreased lint yield (1.4 t ha\(^{-1}\)) than control (1.56 t ha\(^{-1}\)). There was no N x B interaction on most of the fibre properties. The effect of triazone-N was similar to urea-N.

Cheng-Lin Hay et al. (1997) observed that foliar application of CaCl\(_2\) (0.01 mol CaCl\(_2\) / litre) on young cotton seedlings promoted the water holding capacity of cotton leaves, strengthened physiological activities, and maintained the structural stability and integrity of cytoplasmic membranes, thus improving the drought resistance of cotton plants. Combined foliar application of chelated Ca at 50 mg per litre and Cu, Zn, or Co at 12.5 mg per litre and Fe or Mn at 25 mg per litre, all applied 3 times as foliar spray at 70, 85 and 100 DAS increased the seed cotton yield, viability and seedling vigour with increasing N rate and application of Ca, Cu, Zn, Fe or Mn. Seed index increased with increasing N and with application of Cu, Fe or Mn. A significant increase in length of the hypocotyls and the entire seedlings was found due to Co application. N rate, Ca and microelements had no significant effect on germination rate index (Sawan et al., 1989).

At Kovilpatti, Chitdeshwari et al. (1997) studied the foliar application of Mg on cotton and concluded that the foliar application of MgSO\(_4\) reduced the reddening of cotton and seed cotton yield was increased by soil or foliar application under rainfed condition. In addition to soil application of 150 to 200 kg N ha\(^{-1}\), foliar spraying of 66 g Zn +197 g N per litre increased the kapas yield, whereas foliar spray of 52 g Fe +205 g N per litre did not increase the yield. Seed cotton yield was increased by the higher N rates, mainly due to an increase in open boll number per plant (Basilious et al., 1991). In a fine sandy loam soil, cotton was given with 0 or 16 kg Mn ha\(^{-1}\) as foliar applied MnSO\(_4\) besides 40 kg N ha\(^{-1}\) or 45 kg ha\(^{-1}\) + 45 kg P\(_2\)O\(_5\) + 45 kg K\(_2\)O ha\(^{-1}\) as basal dose as well as 57 kg N + 57 kg K\(_2\)O as a side dressing. Foliar Mn application was found to produce darker green leaves but had no effect on yields.
The balanced fertilization package includes, application of recommended NPK with N and K in splits of either at 4, 6 or 8 applications along with MgSO\(_4\) (50 kg as basal) and boron as Solubar at one kg basal combined with foliar spraying of DAP (1.5 per cent) + K (0.5per cent) + MgSO\(_4\) (0.5per cent) + Solubar (0.15 per cent) twice during flowering to boll development stages (CICR, 2009).

Foliar application of Zn at the rate of 0.1 to 0.3 per cent at the 3\(^{rd}\) leaf stage was found to increase the seed cotton yield by 22.7 per cent in coastal areas of Dafeng county (China) where the soils contained 0.12 to 0.93 ppm Zn (Lu and Shi, 1986). Kumar and Gupta (1981) stated that foliar application of 0.5 per cent ZnSO\(_4\) alone and mixed with 2 per cent urea or 0.25 per cent lime gave the highest seed cotton yield when compared to control. El-Gharcib et al. (1986) reported that application of 0.2 or 0.4 per cent solution of Fe, Zn or Mn or 0.2 per cent solution of two or all the three elements at 75 DAS as foliar spray gave significantly higher yield in cotton. Zn, Fe and Mn with the concentration of 0.2 per cent gave the highest seed cotton yield of 3950 kg ha\(^{-1}\); hundred seed weight ranged from 11.4 to 12.8 g. Application of 0.4 per cent Fe markedly increased the number of open bolls.

Foliar application of Cu (37.5 ppm) with Mn (50 ppm) gave the highest seed cotton yield, seed index and seed oil content. The highest oil and protein yields resulted from applying 25 ppm Cu or Mn, while oil refractive index and iodine value increased with the application of Cu and/or Mn (Sawan et al., 1993).

Cotton yield was significantly increased by the foliar application of 2 per cent MnSO\(_4\) in a peat soil at Hula Swamp (Israel). Cotton yields were 4.48 and 3.68 tonnes per hectare with early and late Mn application respectively, compared with 1.96 tonnes per hectare without foliar Mn application (Levin et al., 1992). Biozyme (GA\(_3\) + IAA + Zeatin + micronutrients) application at 600 ml ha\(^{-1}\) increased the plant height, number of sympodial branches per plant, number of bolls per plant and seed cotton yield as compared with water sprayed control (Thakar Singh and Sidhu, 1997). Gomaa (1991) reported that in cotton cv. Giza 70 foliar spray of 1.0 kg ZnSO\(_4\) ha\(^{-1}\) in a soil applied with 125 kg P\(_2\)O\(_5\) ha\(^{-1}\), resulted in the highest seed cotton yield in Alexandria University (Egypt). Total and open boll numbers were increased only by the foliar Zn application.

Sharma et al. (1988) observed that foliar application of Zn (0.5 per cent) on 50 and 65 DAS gave seed cotton yields of 14.6 q ha\(^{-1}\) compared with 11.82 q ha\(^{-1}\) without Zn. Zinc increased the dry matter production and weight of leaves and stems at different growth stages, number of bolls per plant and boll weight, but had no effect on plant height.

Application of boron at 45 to 80 days after sowing increased the B concentration in leaves but not always related with yield increase. Micronutrients spray from seedling stage to boll formation stage (Guertal et al., 1996; Cheng-Lin Hay et al., 1997) or up to 100 days after sowing (Cheng-Lin Hay et al., 1997) was found to influence cotton yields positively.

**CONCLUSION**

From the above review it can be concluded that foliar application of nutrients viz., macro and micronutrients either alone or in combination has a great effect in improving the efficiency of utilization of nutrients and thereby improves the growth and seed yield and quality characters in cotton and hence, foliar nutrition in cotton can be considered as a useful practice for improved cotton production.
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