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NUTRIENT MANAGEMENT IN RAINFED COTTON

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FOREWORD

Nutrients are the second most important limiting factors of crop production, after water. Most often soils in the rainfed regions are not only thirsty but also hungry. It is now well established that for achieving high yields, the nutrient demand of the crop should be met.

*Of the 16 essential elements, three are provided by the atmosphere **(C,H,O)** and three are supplied through fertilizers **(N,P,K).** It is taken for granted that soils provide a continuous supply of the remaining ten elements. In the long run, nutrient deficiencies are likely to crop up. Most common examples are those of Sand Zn. In order to diagnose nutrient deficiency, it is essential to know the symptoms and their management strategies. To fill this gap, all the available information is provided at one place in this technical bulletin. I congratulate the authors for doing this splendid job.*

It is hoped that this bulletin written in a simple language will be of immense use to researchers, planners, extension workers, farmers and fertilizer industry personnel.

Nagpur,
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M. S. Kairon
Director

1.0 INTRODUCTION

Cotton crop growth follows a typical sigmoidal pattern (Fig.1). Dry matter accumulation is maximum during the active growth phase (40-100 days). Application of nutrients should

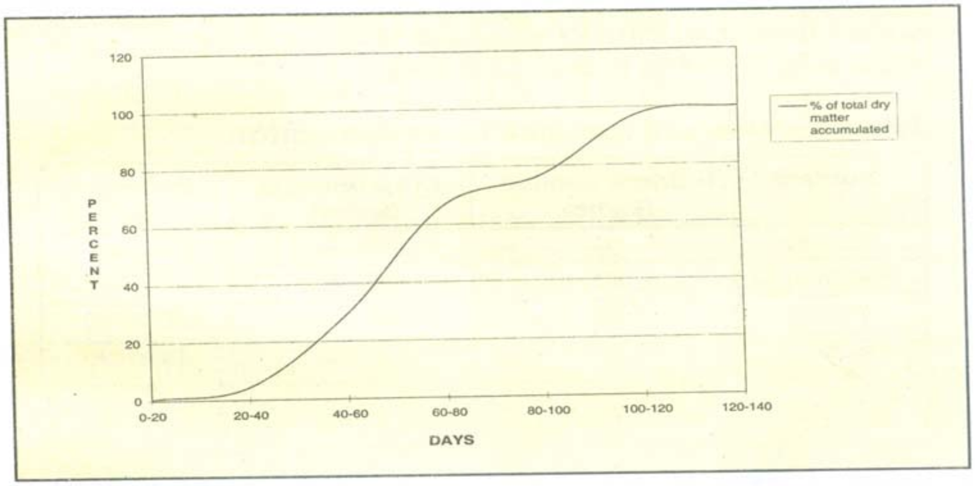

Fig. : 1. Cotton growth (% of total DMA)

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be done well before the grand growth period between 45-60 days. Nutrient management in cotton is complex due to the simultaneous production of vegetative and reproductive structures during the active growth phase. The nutrient demand by the fruiting parts is very high. High nutrient demand at this stage results in reduction of root growth due to less partitioning of assimilates to the root and ultimately reduced capacity to absorb nutrients (Bassett et al., 1970) An excess of nutrient applied, especially N before the crop attains the grand growth period could revert the crop to putting up more of vegetative growth. A deficiency could result in hastening maturity. In a rainfed crop, water stress is not uncommon. It is another important variable which restricts the availability of nutrients and uptake.

Cotton being deep rooted removes large quantities of nutrients from the soil profile. For every 100 kilogram of seed cotton produced the crop depletes the soil by 6-7 kg N, 1.9-2.5 kg P, 6-8 kg K and 1.2-2.0 kg S.

Nutrient	Nutrient applied (kg/ha)	Crop removal (kg/ha)	Balance
Nitrogen	60	60 -70	0 to -10
Phosphorus	30	19-25	+5 to + 11
Potash	30	60 - 80	-30 to -50
Sulphur	-	12 - 20	-12 to -20

The data presented in Table 1, clearly points out that a negative balance exists for most of the nutrients, except P. The nutrient balance given in Table 1 should be treated with caution for two reasons. Firstly, this holds good for an experimental farm. Generally, the farmers may not apply the level of nutrients indicated in the table, therefore, the balance-could be much more on the negative side. Secondly, the nutrient uptake is different for the different soil types. Cotton in the rainfed region of central zone is grown on the vertisols of varying depth (shallow, medium deep and deep soils). Although deep soils are recommended for cotton, more than 67% of the area belongs to shallow and medium deep soils. The nutrient uptake in the three soil types is given in Table 2. High nutrient uptake in the deep soils is coupled with high soil moisture which ultimately results in high seed cotton yield (Pundarikakshudu et.al., 1992)By and large the cotton growers apply N and P. Potash application is limited, so also that of S and the micro-nutrients.

Table-2: Total nutrient uptake (kg/ha) of cotton in vertisols of varying soil depth

Soil Type	N	P	K
Deep	55.2	20.1	56.5
Medium deep	44.0	13.0	43.4
Shallow (<45 cm)	44.0	12.1	45.2

(Pundarikakshudu et al., 1992)

Results of the long term studies initiated by Dr. R.Pundarikakshudu in 1985, has indicated the importance of balanced fertilization. For the long term sustainability of cotton

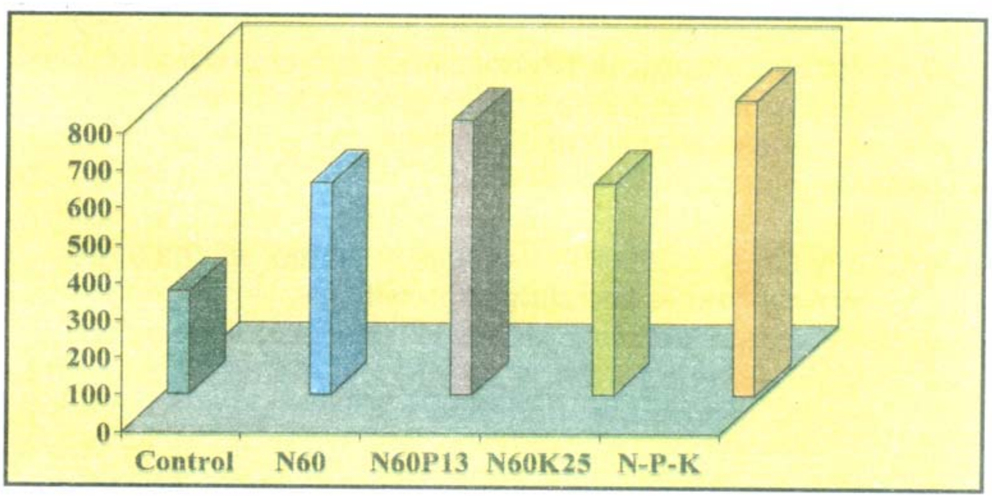

Fig. : 2. Effect of balanced fertilization on seed cotton yield (kg/ha)

and the soil health, it is essential to atleast replenish the soil with the amount of nutrients removed. Otherwise, long term cropping may result in deficiency of the nutrients. Deficiency symptoms of sulphur (S) and micronutrients such as zinc (Zn) are becoming fairly widespread. Nutrient management in cotton has to be adjusted according to the situation prevalent (soil type, moisture availability and crop growth stage). In the following sections, the role of the essential elements in cotton, their deficiency symptoms and management strategies are outlined.

2.0 NITROGEN (N)

Nitrogen (N) is the kingpin among the macronutrients and is the most commonly applied fertilizer nutrient to crops. Nitrogen is an essential constituent of aminoacids, nucleic. acids, chlorophyll and protoplasm. N is taken up from the soil predominantly as nitrate and this inorganic N is converted to organic N compounds of low and high molecular fractions.

Deficiency Symptoms: N deficiency symptoms first appear on the older leaves at the bottom of the plant. N is a mobile element and is rapidly translocated to the young developing parts.

- Early season deficiency results in plants with pale green yellowish leaves and stunted growth
- Late season deficiency leads to reduced boll retention
- Plants suffering from N deficiency, mature earlier and vegetative growth is shortened

Foliar application of 3% N as urea at the boll formation stage, takes care of the late season deficiency.

Management: Nitrogen is the fertilizer nutrient to which cotton shows a good response, as most of the soils are low in N. It is most often the major limiting factor to cotton production, after water. Nitrogen management is essential and critical in a dynamic crop like cotton. An excess of N supply would result in more of vegetative growth and delay maturity. A more succulent crop is susceptible to infestation by sucking pests. Excessive N also leads to *weakening of fibre* and thereby affects quality. The key to N management is, therefore, to provide adequate amounts rather than low or high amounts to the crop as it is needed by the crop (Mc Connell et al., 1996). For varieties, 50-60 kg N/ha is adequate and 90-120 kg N/ha is recommended for hybrids.

Among the macronutrients, N is the most susceptible to losses (Prasad and Power, 1995) and the nitrogen use efficiency (NUE) is very low (Singh and Mannikar, 1988). Various management options are available to enhance the NUE which are listed below.

- Use of coated urea fertilizers and nitrification inhibitors
- Split application.
- Spot or band placement

3.0 PHOSPHORUS (P)

It is the second most commonly applied fertilizer nutrient. The plant takes up P as inorganic anion ($H_2PO_4^-$ and HPO_4^{2-}). The form of uptake is largely governed by pH. The plant roots contain more of active sites for absorption of primary orthophosphate than the secondary orthophosphate. At low pH, uptake of $H_2PO_4^-$ is more than HPO_4^{2-}. At pH 7, both forms are taken up equally. Most of the cotton is grown on high pH soils and the form preferred for its uptake is HPO_4^{2-}.

Phosphate in the plant occurs as orthophosphate and to a minor extent as pyrophosphate. The most important role of P is in energy transfer through the formation of pyrophosphate bonds ex. ATP (adenosine triphosphate) and its analogous compounds: UTP, CTP and GTP. These triphosphates are also involved in the synthesis of nucleic acids (RNA and DNA).

Deficiency Symptoms: P is mobile in the plants and the deficiency symptoms are reflected in the lower leaves of the plant

- Plants are stunted and have dark green leaves
- Accumulation of anthocyanins, imparts the leaf a purplish colour.

Soil moisture stress particularly affects P availability due to its immobile nature in the soil. At peak boll formation stage the nutrient demand is at a peak. Moisture stress at this stage is not uncommon in the rainfed regions which may result in P deficiency symptoms. The deficiency symptoms can be taken care of by foliar application of DAP @ 12 kg/ha/spray or granular ammonium polyphosphate @ 9 kg/ha/spray (Venugopalan *et.al.* 1995).

Management: Next to nitrogen, P is considered to be the most limiting nutrient. Response to P has been inconsistent (Mannikar, 1993). *The non response of the earlier varieties resulted in the removal of* P *application from the fertilizer packages.* This could be due to the low P requirement of earlier varieties. Also cotton is known to explore the subsoil layers (Kapur and Sekhon, 1985). Present day cultivars (high yielding) have been found to respond to P fertilizers (Mannikar, 1993). The nutrient requirement is also high in systems receiving adequate N fertilizers. Most of the P requirement of crop is met through DAP (diammonium phosphate) and use of complex fertilizers. The P in these fertilizer is mostly water soluble. In the vertisols, calcium is the dominant cation and the soils are mostly calcareous. The added P is rapidly transformed to calcium phosphates ($CaHPO_4$, $Ca_3(PO_4)_2$ etc.) of low water solubility. This is the main reason which necessitates annual P application inspite of positive balance in the soil. For efficient P fertilizer use the following points need to be followed:

- Placement of P fertilizers is a superior method due to less P fixation
- 40 kg P_2O_5 ha^{-1} is adequate (Pundarikakshudu, 1981)
- Need for P is high where more N is applied
- In calcareous soils, yearly application is needed

4.0 POTASSIUM (K)

Potassium remains in an ionic form in the plant cells and tissues and plays an important role in osmoregulation. K plays an *important role in fibre development* and the turgor driven expansion of fibre cells ultimately determines the fibre length (Dhindsa et al., 1975). Equally important is its role in enzyme activation. There are more than 50 enzymes which either completely depend on or stimulated by K^+ (Suelter, 1970).

Deficiency Symptoms: K is a mobile element in the plant and deficiency symptoms appear on the lower leaves

- At first as interveinal chlorosis
- Subsequently the areas become necrotic and leaves dry and shad prematurely.

Management: Most of the soils are rich in K and sufficient in meeting the K demand of the crop. The exchangeable K of the montmorillonitic clay often ranges from 1-3% which is a fairly good supply of available K. Crop response to K has been inconsistent in the different cotton growing regions. However, long-term studies indicate that supplying K every year is beneficial to realize the potential yield levels (Venugopalan and Pundarikakshudu, 1999).

A summary of the recommended schedule for the macronutrients is presented in table-3. The nutrient schedule recommended is in the ratio of 2:1:1.

Table -3 : Summary of N-P-K recommended schedule

Cotton type	N-P_2O_5 -K_20	Method of application
Varieties (Desi)	40-20-20	Half N at sowing or 10 -
(American)	60-30-30	15 DAS, entire P & K at pre plant
Hybrid	90-45-45	Remainder N, one fourth at squaring and one fourth at peak boll development

5.0 SECONDARY NUTRIENTS (Sulphur, Calcium and Magnesium)

5.1 Sulphur (S)

Sulphur is a constituent of aminoacids (cysteine and methionine), coenzyme A, thiamine and biotin. It plays an important role in protein synthesis by the formation of disulphide bonds between polypeptide chains. Sulphur is taken up by the plants as SO_4^{2-} and is assimilated in the plants.

Deficiency symptoms: The deficiency symptoms are similar to that of N deficiency and are manifested as:

- deficiency is first seen on upper young leaves
- leaves first turn to light green to light yellow followed by pronounced yellowing
- deficient plants show high levels of NO - and accumulation of amide - N.

Management: Sulphur is rarely a limiting nutrient in the vertisols. Available S (SO42-) content of 10 ppm is considered the critical limit, below which crop responses to S have been observed (Singh, 1999).

Application of S does not assume the importance of P fertilization due to the fact that sulphate is not as strongly bound as phosphate. However, need for S fertilizers is closely related to the amounts of N applied. As N and S are both involved in protein synthesis, full benefit of N is dependent upon the ample supply of S.

In arable soils a shift from positive to a negative balance is being observed due to the consumption of S free fertilizers. It is recommended to apply S @ 20-30 kg S/ha in the form of gypsum or elemental S. Single superphosphate is the best fertilizer meeting the crop requirements of S, P and Ca.

5.2 Calcium (Ca)

Calcium is the second of the secondary nutrients, taken up by the plants as Ca^{2+} ion. It is readily transported to the root surfaces by mass flow. Inspite of sufficient amounts of Ca^{2+}, plant uptake is limited because of its absorption by young root tips where the cell walls of the endodermis are unsuberized. This is the reason why Ca^{2+} uptake is less compared to K.

Deficiency Symptoms: Ca deficiency does not arise in cotton growing regions as most of the soils are calcareous and have pH > 7. In case of Ca deficiency the symptoms manifest as deformed and chlorotic leaves at the growing tip and stunted growth. Deficiency of Ca can be corrected by application of gypsum @ 20-30 kg Ca.

5.3 Magnesium (Mg)

The uptake of Mg is similar to that of Ca. Due to cationic competitive effects, uptake of Mg is lower than K or Ca.

The most important function of Mg is its occurence in the centre of the chlorophyll molecule. The other major role Mg^{2+} is as a cofactor in enzymes activating photophosphorylation processes. Inadequate levels of Mg in the plant can inhibit CO_2 assimilation. It is also required to activate the enzyme ribulose diphosphate carboxylase. It plays an important role in N metabolism. Proportion of protein-N decreases in Mg deficient corp caused by the dissociation of the ribosomes. Mg helps in translocation of cellulose and determines fibre quality.

Deficiency symptoms : Presence of high Ca may induce Mg deficiency leading to ‘'re**ddening**" of leaves. In contrast to Ca, deficiency symptoms are initially observed in the older leaves. The reddening occurs due to reduced photosynthetic activity if1 the plant, which may be due to immobilization of Mg in cotton. Sometimes the Mg deficiency is confused with natural ageing late in the season (Ramesh et al, 1999).

Management : In the vertisol cotton growing regions, Mg occupies about 10-30% of the cation exchange sites. Broadly speaking, Mg fertilization is unnecessary for the vertisols. Mg deficiency is most likely to appear in the sandy soils. Foliar application of MgSO. (3%) is essential for correcting the deficiency (Ramesh et al, 1999)

6.0 MICRONUTRIENTS

The micronutrients essential to cotton are zinc, iron, maganese copper, boron, molybdenum and chlorine. In the rainfed cotton growing areas, deficiency symptoms of micronutrients do not arise due to the low intensity cropping cycles. Wide spread deficiencies are commonly observed in the intensive cropping zones of the irrigated regions. However, in the long run the deficiencies of micronutrients may crop up in the rainfed areas, too.

6.1 Zinc (Zn)

Zinc is a metal components of several enzymes (carbonic anhydrase, aldolase ect.) It is alson involved in the auxin production and synthesis of RNA.

Deficiency Symptoms: Zinc d eficjency is commonly observed in light sandy soils and calcareous soils (antagonistic effect of Ca and other cations on Zn uptake). The deficiency symptoms are manifested as:

- bronzing of first true leaves and pronounced interveinal chlorosis
- shortening of internodes (gives the plant a bushy appearance "rosetting")
- drastic decrease in leaf size ("little leaf”)
- dwarfism and growth reduction (the most distinct symptom of Zn deficiency)

Management: Foliar application of Zn is better than soil application for correcting deficiency symptoms. Spray of ZnSO4 (0.3 – 0.5%) or soil application @ 15-20 kg/ha is recommended.

6.2 Iron (Fe)

It plays an important role in photosynthesis, nitrate and sulphate assimilation and synthesis of chlorophyll.

Deficiency symptoms: Iron deficiency commonly occur in soils with high Ca and Mg content. Symptoms are manifested as:

- interveinal chlorosis of young leaves which progresses over entire leaf.
- in severe cases leaves turn completely white.

Management: Iron is taken up by the plant as Fe^{2+} ion. However, in the arable, well drained, oxidized soils, Fe^{3+} form predominates. Low solubility of Fe^{3+} severely limits uptake. Solubility is pH dependent and is inversely related. Most of the vertisols are rich in Fe, but the high pH and calcareous nature of the soils may limit uptake and induce deficiency (*lime induced chlorosis).*

Crop deficiencies can be corrected by applying iron compounds to the soil or foliage. Soil application of 15-20 kg $FeSO_4$/ha or spray of $FeSO_4$ (0.3-0.5%).

Management: Soil application of Mn SO_4 (20 kg/ha) or spray (0.3-0.5%) would correct Mn deficiency

6.4 Copper (Cu)

Copper is the metal activator of enzymes tyrosinase (polyhenol oxidase), ascorbic acid oxidase and laccase. Copper along with Zn is a constituent of the enzyme superoxide dismutase (SOD) which catalyzes the dismmutation of superoxide radicals.

Deficiency Symptoms: Plants deficient in Cu have high amounts of soluble-N compounds due to impaired protein synthesis. Young leaves at the growing point become chlorotic. In case of severe deficiency the tissues at the growing point die. Cu uptake is inversely related to Fe uptake. Cu deficiency results in accumulation of Fe in plants.

Management: Copper uptake is hardly 30-50g Cu/ha. However, the Cu applied is strongly bound to soil and availanility is low especially in high pH soil and is the main reason the amount applied is in excess of Cu uptake. When the salt ($CuSO_4$) is applied, most of the Cu^{2+} ions are brought into solution form and is immobrilized . Cu chelates release Cu at a slow rate and is recommended for alleviation Cu defiency. Spray of $CuSO_4$ (0.3 – 0.5%) or soil application of 10-20 kg $CuSO_4$/ha is recommended.

6.5 Boron (B)

Boron is the most important among micronutrients in obtaining *high quality crop*. The major function of B in cotton is in the elongation of cotton fibre and prevents callusing of the fibre (Birnbaum et al., 1974). It also plays an important role in the translocation of sugars. It forms polyhydroxy compounds with cell wall constituents to increase its stability.

Deficiency Symptoms : Boron is not readily translocated within the plant and symptoms are first visible at the growing point where the leaves give a wrinkled appearance. With progress in deficiency, the terminal growing point die.

Management: Boron deficiency known to occur, only exceptionally on vertisols. High clay content may impair B availabity due to borate adsorption. Deficiency is more common in the sandy soils as borate is very easily lost by leaching. Available B (hot water extraction) is often in the normal supply range of 0.5 - 1.0 ppm. application of borax (10 kg/ha) is recommended. One problem of B application is the very narrow range of concentration in soil which neither the deficiency nor toxicty occur.

6.6 Molybdenum (Mo)

Molybdenum is an essential component of the enzyme nitrate reductase which catalyzes the reduction of NO_3- to NO_2-. It is taken up by the plant as molybdate anion (MoO_4^{2-}).

Deficiency Symptoms: Plants grown on soils deficient in Mo rarely show any symptoms at earlier growth stages. Recently matured leaves are affected first with mild symptoms. As the plant grows, .older leaves show a pronounced effect. First symptoms appear in the form of small spots of dead tissue at the tip of the leaf (ICAC, 1999). The availability of Mo is increased with increase in pH. As most of the cotton growing soils are alkaline in nature, the deficiency of Mo does not arise, and therefore not a problem element on vertisols.

In a standing crop, deficiency of micronutrients can be corrected by spraying the micronutrient salt (0.3-0.5%) mixed with 0.3% lime solution for quick recovery. In areas with a history of any particular element, soil application of that micronutrient salt is recommended. Most of the arable soils are alkaline (high pH). The Salt that is applied may be reduced to unavailable forms. To overcome this problem, application of chelated micronutrients is recommended.

Most of the cotton in the rainfed regions is grown on soils with an alkaline reaction range. Vertisols are calcareous in nature. Except Mo, the availability of micronutrients is low. Although the soils are sufficient, nutrient deficiencies may be occasionally observed. Soil pH greater than 6.3 plays a significant role in decreasing the uptake of B (Gupta, 1979). Solubility of Fe Mn and Zn is also pH related (inversely). Deficiency of micronutrient is also directly related to the clay content. It is for this reason, widespread deficiencies of micronutrients such as Zn and B are reported from the sandy soils (inceptisols and entisols) of the north. Intensive cropping also aggravates the problem.

Nutrient	Form taken up by the crop (preferably)	Plant part affected	Deficiency symptoms	Nutrient sources	Remarks/ recommendations
Macronutrients					
N	NH_4^+, NO_3^-	Older leaves	Light green leaves and yellowing	Urea, Diammonium phosphate (DAP), N-P-K complexes	Advisable to use N in 3 splits to improve use efficiency and reduce loss
P	$H_2PO_4^-HPO_4^{2-}$	Older leaves	Dark green leaves	Superphosphate (SSP), DAP and complex fertilizer	Annual application of 30-40 kg P_2O_5/ha is essential
K	K^+	Older leaves	Initial interveinal chlorosis, later become necrotic	Muriate of potash (KCl), Potassium Sulphate (K_2SO_4) and complex fertilizers	Basal application of K (30-45 kg/ha) is recommended as a balanced fertilization approach for realisinq high yields
Secondar\ nutrients					

S	SO_4^{2-}	Young leaves	Symptoms resemble N with exception that younger leaves are affected	Ammonium sulphate, Single uperphosphate, Elemental Sand K_2SO_4	In severely deficient soils, S to be applied in $SO4^{2-}$ form (when applied just before planting). Elemental S should be applied 4-6 months before planting. 20 kg S/ha is sufficient
Ca	Ca^{2+}	Young leaves and growing point	Deformed and chlorotic leaves	Gypsum ($CaSO_4$), Superphosphate	In case deficiency arises, can be remedied by application of 20-30 kg Ca/ha
Mg .	M_g^{2+}	Older leaves	Leaf redenning	Epsom salt ($MgSO_4$ H_20)	In standing crop, spray of 3% MgSO4 is recommended
Micronutrients					
Zn	Zn^{2+}	Young leaves	Little leaf, shorte-ning of internodes (rosetting)	Zinc sulphate, zinc frit and Zn chelates (Na_2Zn EDTA, NaZn HEDTA etc.)	Soil application of 15-20 kg of the micronutrient salt/ha is recommended. It should be mixed well into the soil.
Fe	Fe^{2+}	Young leaves	Interveinal chlorosis	$FeSO_4$, Fe chelates	Soil application of 20 kg/ha $FeSO_4$
Mn	Mn^{2+}	Older leaves	Chlorosis followed by necroses	$MnSO_4$, Mn Chelates	Foliar application (0.3-0.5%) is more effective
Cu	Cu^{2+}	Young leaves	Chlorosis	$CuSO_4$, Cu chelates	- do-
B	H_3BO_3, $H_2BO_3^-$, HBO_3^{-2}, BO_3^{-3},B_4O_7	Growing point	Deformed leaves	Sodium tetraborate ($Na_2B_4O_7$) Solubor, B fnts ($Na_2B_4 \cdot XH_2O$)	Solubor is recomme-nded for foliar spray. Soil application of Na_2 B_4O_7 @ 1-2 kg/ B/ha
Mo	$M0O_4^{2-}$	Old leaves	Small spots of dead tissue	Sodium molybdate (Na_2MoO_4), Ammonium molyb-date $(NH_4)_2$ M $_00_4$)	Mo deficiency is very rare as most of the Indian cotton growing soils are alkaline.

7.0 EFFICIENT USE OF N-P-K FERTILIZERS

For efficient management of fertilizers and its profitable use, it is desired to first know about

- Soil nutrient status
- Crop variety/hybrid
- Cropping history and
- Use of organic residues

By gathering information on the above points, the level of nutrient required can be estimated and the efficiency of the nutrient element can be enhanced by adopting the following points:

- right choice of fertilizers
- right method and
- right time of application

Table-5: Effect of improved fertilizer nitrogen sources on cotton

Location	N source	Seed cotton yield (q/ha)	Source
Nagpur (vertisols)	Urea NCBU	9.90 11.52	Singh and Mannikar (1988)
Indore (Vertisols)	Urea NCU	4.90 5.56	Jain et. al. (1982)
Coimbatore (alfisols)	Urea NCU	13.7 15.1	Seshadri (1985)

i) Right choice of fertilizers: Selecting the right fertilizer is most important for improving nutrient use efficiency. A large number of coated urea fertilizers are available. Indigenous neem cake coating and blending of urea is an option to costlier products such as sulphur coated urea, polymer coated urea etc. In case of P fertilizers, it is essential to apply P in the water soluble form. Chelated micronutrients are recommended than micronutrient salts for soil application.

ii. Right method of application: Phosphorous on application is immediately reverted to insoluble forms. To avoid precipitation, P fertilizers should be band applied. Placing N fertilizers below the soil surface is a method to curb NH_3 volatilization (Blaise et al., 1996). In a standing crop showing nutrient deficiency symptoms, spraying of the nutrient salt is a better method than soil application.

iii. Right time of application: It is advisable to apply N in splits to enhance NUE and to meet crop requirement at the peak demanding phases of crop growth. Field studies at CICR indicate that N application in three equal splits (Table 6) at 1520 days after sowing (DAS), 45 and 60-90 DAS significantly improved seed cotton yields (Pundarikakshudu and Raju, 1995). The second split application at 45 DAS is the most critical one for realizing good yield. Application of N should be completed before peak bloom. This provides N to meet the peak N demands at the boll development stage.

Table-6 : Effect of time and split application of N (60 kg N/ha) on seed cotton yield *(Mean of 3 years)*

Treatment		Seed cotton yield (kg/ha)
1.	Control	525
2.	1/3 N 20 DAS 1/3 N 45 DAS 1/3 N 60 DAS	1085
3.	1/2 N 20 DAS 1/.4 N 45 DAS 1/4 N 60 DAS	999
4.	1/3 N 20 DAS 1/3 N 60 DAS 1/3 N 90 DAS	958

References :

1. Bassett,D.M., Stockton,J.R. and Dickens,W.L. (1970). Root growth of cotton as measured by 32 P uptake. Agron. J. 62: 200-203.
2. Birnbaum, E.H., Beasley, C.A. and Dugger,W.M. (1974). Boron deficiency in unfertilized cotton *(Gossypium hirsutum)* ovules grown *in-vitro* PI. Physiol. 54: 931-935.
3. Blaise,D., Tyagi,P.C. and Khola, O.P.S. (1996). Ammonia volatilization from urea as affected by the addition of iron pyrites and method of application. Nut. Cycling Agroecosys. 46 : 97-101.
4. Dhindsa, R.S., Beasley,C.A. and Ting, I.P. (1975). Osmoregulation in cotton fibre. PI. Physiol. 56: 394-398.
5. Gupta, U.C. (1979). Boron nutrition of crops. Adv. Agron.31: 273-307.
6. ICAC (1999) Micronutrients with emphasis on boron. ICAC Recorder 17(2): 3-6.
7. Jain,S.C., Kutty,G.U., Jain, N.K. and Iyer, B.J. (1982). Efficacy of blended urea in upland cotton under different nutrient levels and field conditions. J. Indian Soc. Soil Sci. 30: 224-226.
8. Mannikar, N.D. (1993). Fertilizer management in cotton. In : Fertilizer management of commercial crops (H.L.S. Tandon ed.), FDCO pub., New Delhi, p 28-46.
9. Mc Connell, J.S., Baker, W.H. and Frizzell, B.S. (1996). Distribution of residual nitrate-N in long term fertilization studies of an alfisol cropped for cotton. J. Environ. Qual. 25 : 1389-1394.
10. Prasad, R. and Power,J.F. (1995). Nitrification inhibitors for agriculture, health and environment. Adv. Agron. 54 : 233-281.
11. Pundarikakshudu, R. (1989). Studies of the phosphate dynamics in a vertisol in relation to the yield and nutrient uptake of rainfed cotton. Exptl. Agric. 25 : 39-45.

12. Pundarikakshudu,R., Mudholkar,N.J. and Wankhede,N.P. (1992). Effect of comparative efficiency of planting methods and soil depth on rainfed cotton *(Gossypium hirsutum)* in vertisols. Indian J. Agric. Sci. 62 : 263-267.
13. Pundarikakshudu, R. and Raju, A.R. (1995). Study of soil fertility and fertilizer nutrients management through split application of NPK and S on nutrient utilisation efficiency and yield of cotton in vertisols. CICR Annual report (1994-95).
14. Ramesh,K., Thirumurugan, V. and Kumar, P.S.S. (1999). Magnesium nutrition of cotton. Micronutrient News. 13(10) 2-3.
15. Seshadri,V. (1985). Efficiency of applied nitrogen on varalaxmi hybrid cotton as influenced by different agrotechniques. Indian J. Agron. 30 : 305-309.
16. Singh,Jagvir and Mannikar, N.D. (1988). Studies on nitrogen transformation in vertisol as influenced by different N carriers and its effect on growth, yield and uptake in rainfed cotton. In: classification, management and use potential of swell shrink soils, Oxford IBH, New Delhi p: 207-210.
17. Suelter, C.H. (1970) Enzymes activated by monovalent cations. Science 168 : 789-795.
18. Venugopalan, M.V. and Pundarikakshudu, R. (1998). Long term effects of nutrient management and cropping system on cotton yield and soil fertility in rainfed vertisols. Nutr. Cycling Agroecosys, 55:159-164.
19. Venugopalan, M.V., Tarhalkar, P.P. and Singh, Jagvir (1995). Efficacy of phosphate carriers as foliar fertilizer on rainfed upland cotton *(Gossypium hirsutum).* Indian J. Agric. Sci. 65 : 328-333.

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