Foliar Fertilization in Cotton

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ABSTRACT

The supply of nutrients through the soil can be restricted by different factors such as soil compactness, extreme conditions of soil/water regime, pH of the soil solution, etc. Excessive N application to the soil might lead to environmental hazards. Foliar fertilization, when correctly applied provides solutions to many of these cases and helps to optimize nutrient management as supplement to soil application of nutrients.

Why foliar fertilization in cotton?

To decrease N applied to soil

There are great losses in soil applied N, especially in irrigated systems. El-Fouly and Fawzi (1996) calculated the losses in Egypt, which reached about 51% of the total available N to cotton, which equals 145,000 tons per year. This is also true for other countries. Ahmed (1995) found that about 83 % of the soil applied N can be substituted by three foliar sprays with a minor loss in the seed yield of 5.6% (Table 1). He found also that 100 % of the N can be supplied by four urea sprays with a loss in the seed yield reaches only about 9 %.

Saad (1994), proved that foliar nutrition of cotton plants using urea increases seed yield, number of open bolls/plant and boll weight. The increase was dependent on the applied dose, where 3g/L gave the highest seed cotton yield and boll weight (Table 2). Mc Connell *et al.,* 1997, stated that preliminary results indicate that foliar N may increase cotton yield, when soil N is low. Kesawapitak *et al.,* 1995 could demonstrate positive effects for different foliar fertilizers on cotton yield.

To overcome problems with Phosphorus absorption

High pH values and high $CaCO_3$ levels, low solubility and buffering can limit P-absorption rates. Foliar spraying of cotton plants with P-containing compounds can partially solve the problem of P in availability in the root zone and compensate P shortage in the plant tissues. Seed cotton yield increases as the number of P sprays increases at two nitrogen levels (Girgis *et al.*, 1993) (Table 3).

To add the neglected nutrient "potassium"

Cotton lint yields in four locations in Arkansas, USA were influenced significantly by soil and foliar applied K (Oosterhuis, 1997) (Table 4). Preplant K-dose and location are important for a good yield. This can be improved by foliar K applications (Rodriguez and Gutierrez, 1997) (Table 5).

The stage of plant growth when foliar K is applied and the K-dose were found to affect the yield increase. Foliar K applied at pinhead square was in general less effective in yield increase than that applied at first flowers, indicating that there is a higher K-demand at first flowers at the pinhead square stage (Eid *et al.*, 1997) (Table 6). On the other hand, data show that the yield response to the graduation of K-dose and the response during PS-stage is higher with the high N-level.

K-foliar application significantly improved cotton fiber quality and KCl was more effective than KNO_3 (Oosterhuis, 1995) (Table 7).

To overcome micronutrient deficiencies

Cotton growth, yield and yield components are negatively affected by micronutrients deficiency in the growth medium (Abou Khadra and Zahran, 1979, Abdrabou *et al.*, 1995 El-Fouly *et al.*, 1997). In a study NRC-GTZ 1992, 1993, 1994a,b) and El-Fouly *et al.* (1995), it was found that using micronutrients (Zn, Mn, Fe and Cu) foliar sprays increased cotton yield by an average of 17%. Micronutrient treatments increase dry weight and the uptake of macronutrients and thus their efficiency (El-Fouly *et al.*, 1995). In 1000 hectares of cotton grower's fields, Fawzi and El-Fouly (1995) found that the average yields were increased by 11 % as response to micronutrients spraying, realizing a net return ratio of 5.8:1.

In 1991, 1993 and 1994 Rodriguez (1996) found that seed cotton yields are influenced significantly by the time of application of foliar Boron in two successive years (Table 8). The best results were achieved with applications at the first boll stage, followed by the 50 cm height or the first flower stage.

Advantages of foliar fertilization

Low application rate

Macronutrients are used in grams in case of foliar spraying and in kilograms in case of soil application. This appears more evident with micronutrients as the plant requirements are very low compared with macronutrients, and low rates of foliar application cause significant yield improvements.

Uniform distribution

Soil application can lead to plants receiving varying amounts of nutrients. In case of foliar fertilization, controlled distribution of the sprayed solution over the plant leaves leads to uniformity in the application rate per plants.

Quick response

Absorption of nutrients, especially micronutrients through leaves is quicker than if they were added through soil. This is of importance in case of curing deficiency of one or more nutrients (Table 9).

Hidden deficiencies can be more easily treated

Once a hidden deficiency is identified, applications of the deficient nutrients correct the problem rapidly. Foliar fertilization incorporated in the fertilizer regime automatically resolve deficiency problems.

Disadvantages of foliar fertilization

Possible leaf burn as a result of salt concentration

High concentrations of salts in the spray solution or poor application technology such as spraying in the middle of the day can cause burns to plant leaves. The safe concentration of each product should be determined. Concentrations of chelated micronutrients that might have injurious effects on cotton leaves are given in table 10.

Little residual effect

Foliar applied nutrients are quickly absorbed and have little residual effect, so the duration of the effect is less than that of soil applied nutrients.

Higher costs

Foliar fertilization costs are generally higher than other fertilization techniques, because of the cost of application in addition to the high prices of the foliar spray compounds.

Factors affecting efficiency of foliar applied nutrients

There are many factors affecting the efficiency of foliar fertilization related to plant, environment and spray solution (Alexander, 1986; El-Fouly and Abou El-Nour 1995; El-Fouly and El-Sayed 1997). Some of these factors are discussed in relation to cotton.

Application date and number of applications

Different varieties have different nutrient requirement peaks. Thus in two locations, Acala gave its highest yield with two applications of KNO_3 in the third and fourth week after planting while Pima required four applications at different dates for peak yield (Weir and Roberts, 1995).

In the Sudan, micronutrient chelated compounds gave the best results with two applications, the first at the start of flowering and the second three weeks later (Ishag, 1992) (Table 11). This treatment also resulted in earliness compared with the all other treatments in 1986/87.

Compounds used

Efficiency of a given foliar spray solution is dependent on the compound type and formula. Keino *et al.* (1997) found that KNO_3 was the best in producing squares/pot followed by K_2SO_4 while NH_4NO_3 had no effect. Oosterhuis (1994) used five potassium sources as foliar spray to study their effects on cotton yield and boll weight in three successive seasons. Significant differences in yield only occurred in 1992 and in boll weight in 1992 and 1993. KNO_3 gave the highest yield and also the highest boll weight, followed by KCl.

Ishag (1997) studied the effect of foliar application of Wuxal as micronutrient compound and Bayfolan as macronutrient compound on seed cotton yield of two cotton varieties through two successive seasons. Both macro and micronutrient compounds significantly increased the seed cotton yield of both varieties, the increment being higher with the macronutrient compound in the 1st year but relatively higher with the micronutrient compound in the 2nd year.

Concentrations used

The concentration of nutrient or compound nutrients in the spray solution is critical in achieving good responses to foliar fertilization treatments. High doses may cause injuries to the sprayed plants. With ascending concentrations of seven different compounds, El-Sayed *et al.* (1997) found that the best concentration of Fetrilon and Wuxal compounds was 3.0 g-ml/l in the spray solution, higher concentrations being harmful. However, higher doses of Metalosates compound that contain less solids/ volume continued giving a positive response (Table 12).

Balance among nutrients

El-Sayed *et al.* (1997), using a compound contains Zn: Mn: Fe in different ratios as chelated and non-chelated forms, (Table 13) found that the ratio 2:3:1 gives the best yield response in case of chelated form while the ratio 3:2:1 was the best in case of non-chelated form. Thus yield response to a foliar fertilizer is influenced by both the nutrient ratios within the compound and these ratios may differ for the chelated and non chelated forms. The addition of potassium to micronutrients in the spray solution increased seed cotton yields by 37 % compared to 6 % with potassium alone and 25 % with micronutrients alone (El-Sayed *et al.*, 1997).

Conclusions

From the previous review, it can be concluded that :

- Foliar fertilization can be of benefit in cotton production in different parts of the world.

- Both macro- and micronutrients can be used as foliar fertilizers.
- Foliar fertilization in cotton is site and farming system specific. It should be used according to the given local conditions.
- More intensive attention should be given to study the effect of foliar fertilization in cotton productiong countries.

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Table 1. Seed cotton yield and percent N at pre-flowering stage as influenced by soil and foliar application of N as urea.

Treatment	Seed cotton yield (t/ha)	% increase over control	% N at pre-flowering stage
Control	1.98	-	2.20
120 Kg N/ha (soil application)	2.69	35.8	2.93
80 Kg N/ha (soil application)	2.59	30.8	2.77
60 Kg N/ha (soil application) + one spray of 2% urea solution	2.47	24.7	2.54
40 Kg N/ha (soil application) + two sprays of 2% and 2.5 urea solution	2.33	17.7	2.60
20 Kg N/ha (soil application) + three sprays of 2%, 2.5 % and 3 % urea solution	2.54	28.0	2.49
No soil application + four sprays of 2%, 2.5 % and 3 % and 3.5 % urea solution	2.45	23.7	2.41

Basic fertilization = 60 Kg P_2O_5 + 50 Kg K_2O /ha
Source Ahmed, 1995

Table 2. Effects of urea foliar sprays on yield and yield components of cotton.

Component	Mean of 1990 and 1991 seasons			
	Urea foliar spray			
	Control	1g/L	2g/L	3g/L
Seed cotton yield (t/ha)	1.49	2.75	2.75	3.54
	(100)	(185)	(185)	(238)
Number of open bolls/plant	4.07	6.09	5.49	5.55
	(100)	(150)	(135)	(136)
Boll weight (g)	0.92	2.54	2.59	3.53
	(100)	276)	2.93)	(248)

Source: adapted from Saad, 1994:

Table 3. Seed cotton yield (t/ha) as affected by N rate and P spray.

Nitrogen rate (Kg/ha)	No. of P (4 % superphosphate) sprays				
	0	1	2	3	4
144	2.48	2.70	3.03	3.33	3.53
	(100)	(109)	(122)	(134)	(142)
216	2.74	3.12	3.48	3.72	4.06
	(100)	(114)	(127)	(136)	(148)

Source: Girgis *et al.*, 1993

Table 4. The influence of soil and foliar-applied K on cotton lint yields at four locations in Arkansas (1989-1991).

Treatment	1989	1990		1991			
	MES	CBS	MES	NEREC	MSCO	CBS	SEBES
Control	541 c[2]	1410 c	745 c	877 a	931 b	1033 a	1338 a
Low-soil K	553 bc	1540 b	754 bc	893 a	984 bc	1025 a	1353 a
High-soil K	--	--	--	863 a	1012 ac	1080 a	1330 a
Foliar KNO_3	563 ab	1540 b	810 ab	--	--	--	--
Low-soil + foliar K	579 a	1642 a	815 a	911 a	1122 a	1093 a	1411 a
High-soil + foliar K	--	--	--	906 a	1091 a	1055 a	1245 a
Preplant soil K	358	158	280	488	254	243	194

1. MES = Main Experiment Station, Fayetteville; CBs = Cotton Branch Station, Mariana; NEREC = North East Research and Extension Centre; MSO = R. D. Jackson Farm, AR; SEBES = South East Branch Experiment Station, MS.
2. Values within a column with the same letter are not significantly different (P = 0.05)
3. Treatment not included preplant soil test K-status in 1b K/acre
Source: Oosterhuis, 1997

Table 5. Means final production Duncan grouping.

Production (Kg/ha)	Treatments
4566.1 a	(4) = 50 Kg K_2O preplant. + 36 K_2O foliar
4383.1 ab	(2) = 50 Kg K_2O preplant.
4224.1 -b	(1) = 0 Kg K_2O
4079.1 -b	(3) = 0 Kg K_2O preplant + 36 Kg K_2O foliar

Means with the same letter are not significantly different
Foliar application = week before first flower + 10,20,40 days after first flower
Source: Rodriguez and Gutierrez, 1997

Table 6. Effect of potassium foliar spray on seed cotton yield.

Dose (ml*/ha)	Stage	N (Kg/ha) 114		216	
		(t/ha)	(%)	(t/ha)	(%)
0 (check)	--	1.89	100	2.48	100
1920	PS	2.03	107	2.81	113
2400	PS	2.25	119	2.85	115
2880	PS	2.15	114	3.02	122
1920	PS & 1st F	2.31	122	2.88	116
2400	PS & 1st F	2.36	125	3.02	122
2880	PS & 1st F	2.43	125	3.11	125

* 30 % K_2O
PS = Pinhead Square 1st F – First Flower
Source: Eid *et al.*, 1997

Table 7. The influence of soil and foliar applied K on cotton fiber quality as measured by high volume instrumentation.

Treatment	Length uniformity index (%)	Strength (g/tex)
Control	85.4 b*	24.4 b
Soil-applied KCl	85.8 b	24.2 b
Foliar-applied KCl	87.1 a	26.6 a
Soil + foliar-applied KNO_3	86.0 ab	25.1 ab

Values within a column followed by the same letter are not significantly different (P = 0.05)
Source: Oosterhuis *et al.*, 1995.

Table 8. Effect of boron on seed cotton yield.

Treatment	Yield (kg/ha) 1991	1993	1994
1 boll	5197 a --	4524 a --	---
1 flower	4936 a --	4617 -bc	5179 a--
50 cm height	4630 a --	5080 ab-	4841 -b-
50 cm height + 15 days later	4564 a --	5042 ab-	4847 -b-
Control	4471 a --	4472 --c	4505 --c

Means followed by the same letter within each column do not differ statistically at the level (P = 0.05)
Source: Rodriguez, 1996.

Table 9. Rate of the nutrient absorption into plant tissue.

Nutrient	Time for 50 % absorption
Nitrogen (as urea)	1/2 -2 hours
Phosphorus	5-10 days
Potassium	10-24 hours
Calcium	1-2 days
Magnesium	2-5 hours
Zinc	1-2 days
Manganese	1-2 days

Source: Halliday, 1961; McNall, 1967 and Gray, 1977.

Table 10. Injurious effects of chelated micronutrient solutions observed in cotton leaves.

Compound concentration in spraying solution (g-ml/L)	Observed leaf burn (%)
0.0-2.0	0
3.0	0
5.0	0
7.5	0
10.0	0
12.5	1
15.0	15
25.0	20
30.0	30

Source: NRC-GTZ, 1981, 1993.

Table 11. Effect of time and number of applications of Wuxal suspension polymicro on seed cotton yield of Barakat.

Basal Fertilizer treatment	Timing and No. of applications of foliar fertilizer	Seed cotton yield (t/ha)		% of 2 N		Earliness (t/ha) 1986/1987 (total of 4 picks)
		1986/ 1987	1987/ 1988	1986/ 1987	1987/ 1988	
2 N		2.37	2.89	100	100	2.26
3 N		2.22	3.39	94	117	2.06
2 N	3 wks before flowering	2.82	3.10	119	107	2.59
2 N	At flowering	3.28	3.50	138	121	2.06
2 N	3 wks after flowering	3.01	3.74	127	129	2.82
2 N	3 wks before flowering + after flowering	3.30	3.77	139	130	2.92
2 N	3 wks before flowering + 3 wks after flowering	3.14	3.99	132	138	2.81
2 N	At flowering + 3 wks after flowering	3.98	4.04	168	140	3.41
2 N	3 wks before flowering + at flowering + 3 wks after flowering	3.77	3.80	159	131	3.07
SE ±		0.349	0.170			

Source: Ishag, 1992

Table 12. Effect of micronutrient-compounds dose on seed cotton yield (t/ha).

Dose (Kg-L/ha)	Compound						
	Fetrilon (powder)			Wuxal (suspension)			Metalosate
	Wadi	Sahara	Giri	Mn	Zn	Micro	Multimineral
0.00	3.17 (100)	3.10 (100)	3.00 (100)	3.00 (100)	3.00 (100)	3.00 (100)	2.60 (100)
1.50	--	3.15 (102)	3.49 (116)	3.08 (103)	3.08 (103)	3.40 (113)	--
2.00	--	3.70 (119)	--	--	--	--	2.80 (108)
2.50	3.59 (113)	--	3.53 (118)	3.19 (106)	3.40 (113)	3.40 (113)	--
3.00	3.98 (126)	3.80 (123)	3.68 (123)	3.65 (122)	3.97 (132)	3.97 (132)	2.80 (108)
3.50	3.70 (117)	--	--	--	--	--	--
4.00	--	--	--	--	--	--	3.00 (115)

Source: El-Sayed *et al.*, 1997

Table 13. Effect of Zn : Mn : Fe ratio and chelation on seed cotton yield (t/ha).

Treatment	Zn : Mn : Fe ratio in the compound			
	3 : 2 : 1	2 : 3 : 1	1 : 1 : 1	Mean
	1. Chelated compounds			
1) Control	2.86	3.02	2.58	2.82
2) + 2.80 Kg or L/ha	3.58	3.77	3.38	3.58
Increase	0.72 (25 %)	0.75 (0.25 %)	0.80 (31 %)	0.76 (27 %)
	2. Non-chelated compounds			
1) Control	2.25	2.51	--	2.38
2) 7 L/ha	2.75	2.00	--	2.87
Increase	0.50 (22 %)	0.40 (19 %)	--	0.49 (21 %)

Source: El-Sayed *et al.*, 1997