

Cotton (*Gossypium spp.*)

French: Coton; Italian: Cottone; Spanish: Algodon; German: Baumwolle; Portuguese: Algodao

Crop data

Annual. Harvested part: seed, for fibre.

Important uses of by-products: cotton seed oil; cake, meal and hulls (for feeding); linters.

Cotton is a major world fibre crop. It is grown under a very broad range of climates, soils and cultural practices. For the most part, it is grown in tropical latitudes. However, it is cultivated as far north as 43° N in the USSR and 45° N in China. There are four separate domesticated species of cotton grown in various parts of the world which include *G. arboreum* L. (diploid), *G. herbaceum* L. (diploid), *G. hirsutum* L. (tetraploid) and *G. barbadense* L. (tetraploid). *G. arboreum* and *G. herbaceum* are commonly referred to as Old World diploids due to their ploidy condition and origins being traced to locations in the Old World. Both *G. hirsutum* and *G. barbadense* evolved in the New World and are referred to as allotetraploids. There are literally hundreds of varieties of these various domesticated species which have been developed for production around the world. *G. hirsutum* is the most extensively developed species and represents approx. 90 % of total world production.

Sown at an average soil temperature of at least 18 °C; between April 1 and May 25 (Georgia, USA), spring (China), early spring (March/Egypt), from May/June to August/September (India, North to South).

Sowing by dibbling or in rows, 18 - 24 kg/ha (Brazil), 25 - 40 kg/ha (USA), upto 50 - 150 kg/ha (Egypt).

Plant density (depending on spacing of rows and plants within rows) 55 000 plants/ha (India), 45 000 - 67 500 plants/ha (China/Yellow and Yangtze River) to 120 000 - 150 000 plants/ha (North China, short season), 60 000 - 90 000 plants/ha (USA), 55 000 - 125 000 plants/ha (Brazil) and from 100 000 (Egypt, traditional) to 168 000 plants/ha (intensive, recommended). Temperature: Mainly tropical, grown at temperatures 25 - 35 °C.

Adapted to semi-arid conditions; in Brazil nearly all the cotton area is unirrigated; in India 70 % is rainfed; in China and Egypt it is irrigated (10 - 12 irrigations at 15 day intervals), also in USA (e.g. water use in Arizona, desert Southwest, equivalent to 1 040 mm).

Preferably grown on light to medium soils, pH 6 - 8; highly sensitive to soil acidity and water or soil salinity:

Influence of water (EC^*_w) or soil (EC_e) salinity on yield potential of cotton					
	Yield potential, %				
	100	90	75	50	0
	ohm^{-1}				
EC_e	7.7	9.6	13	17	27
EC_w	5.1	6.4	8.4	12	18
* EC = electrical conductivity					
Source: Adapted from Ayers & Westcot, 1985					

Flowers with direct seeding 75 - 80 days (China) to 80 - 120 days (Egypt) after sowing.

Harvested 140-160 (China) to 210 days (Egypt) after sowing.

Nutrient demand/uptake/removal

Depends on variety and location under both irrigated and rainfed conditions. *G. arboreum* requires less nutrients than *G. hirsutum*; hybrids require more than single varieties; short compact variety types are more efficient users of nutrients than tall late varieties.

Nutrient uptake/removal - Macronutrients									
Country	Source	Variety	Yield of ginned cotton kg/ha	kg/ha					
				N	P ₂ O ₅	K ₂ O	MgO	CaO	S
Brazil	Malavolta, 1987	<i>G. hirsutum</i>	(2 500)**	156	36	151	40	168	64
China*	An Yang, 1985	<i>G. hirsutum</i>	1 421	183	64	156	-	-	-
	An Yang, 1985	"	1 115	153	53	112	93	204	-
	An Yang, 1985	"	941	128	45	90	-	-	-
USA	Mullins & Burmester, 1988	<i>G. hirsutum</i>	per 100 kg lint	19.9	5.2	18.4	-	-	-

* Nutrient uptake = All aerial parts plus part of roots - ** Seed cotton

Nutrient uptake/removal - Micronutrients								
Country	Source	Variety	Yield of ginned cotton kg/ha	g/ha				
				Fe	Mn	Zn	Cu	B
Brazil	Malavolta, 1987	<i>G. hirsutum</i>	(2 500)*	2 960	250	116	120	320
China	An Yang, 1985	<i>G. hirsutum</i>	1 115	5 000	254	397	71	205

* Seed cotton

Plant analysis data

Several analyses have been reported under different agroclimatic conditions and for different varieties. General sufficiency ranges for upland cotton (*G. hirsutum*) in the USA are given in the following tables:

Plant analysis data, sufficiency range - Macronutrients							
Country (Variety, time)	Sampling	% of dry matter					
		N	P	K	Mg	Ca	S
Brazil (Begin flowering)	Leaf next to fully develpd. flower	3.5-4.0	0.20-0.25	1.40-1.60	0.40-0.50	3.00-4.0	0.20-0.30
USA, Georgia (June or July)	Top mature leaves (20-30)	3.50-4.50	0.30-0.50	1.50-3.00	0.30-0.90	2.00-3.00	0.25-0.80

Plant analysis data, sufficiency range - Micronutrients						
Country (Variety, time)	Sampling	ppm dry matter				
		Fe	Mn	Zn	Cu	B
Brazil (Begin flowering)	Leaf next to fully develpd. Flower	60-80	20-40	10-15	30-40	20-30
USA, Georgia (June or July)	Top mature leaves (20-30)	50-250	25-300	20-200	5-25	20-80

Plant analysis data at different growth stages (India) - Macronutrients					
Variety	Growth stage	Plant part	% of dry matter		
			N	P	K
<i>G. arboreum</i>	Flower bud	Leaf	1.40	0.34	2.90
	stage (squaring)	Stem	0.42	0.18	1.70
		Leaf	1.30	0.29	2.80
	Flowering	Stem	0.26	0.13	1.30

	Harvesting	Leaf	1.08	0.56	2.70
		Stem	0.15	0.17	1.50
G. hirsutum	Flower bud	Leaf	2.67	0.41	2.10
	stage (squaring)	Stem	1.10	0.31	2.10
	Flowering	Leaf	2.30	0.40	1.98
		Stem	1.00	0.20	2.50
	Harvesting	Leaf	1.91	0.31	1.85
		Stem	0.77	0.17	1.90

Nitrate-N levels of the petioles at different growth stages in Western USA (Acala and other upland varieties) should be as follows:

Plant analysis data, petiole nitrate-N levels during growing season, USA (Variety: Acala, SJ-2)				
Range	ppm NO ₃ ⁻ N			
	First squares	First flowers	First bolls	First open bolls
Sufficient for growing season	18 000	12 500	7 000	3 500
Deficient before end of growing season	12 000	7 500	3 000	1 500

Source: Bassett & George, 1983.

Adequate concentration of NO ₃ ⁻ N*				
Variety	ppm NO ₃ ⁻ N			
	First squares	First flowers	First bolls	First open bolls
Pima	>10 000	>8 000	>4 000	>2 000
Delta Pine	>18 000	>14 000	>8 000	>4 000

* Contents of petioles from uppermost, fully developed leaves from upland and Pima cotton grown under irrigated conditions (Arizona, S.W. USA).
Source: Pennington & Tucker, 1984

Nutrient deficiency symptoms

N - lack of N reduces yield and quality; visible symptoms are light green plants, lower leaves yellow, drying to brownish colour.

P - deficient plants are short and small, growth is retarded, and maturity is postponed; typical symptoms include loss of chlorophyll and development of red discoloured leaves.

K - deficient plants are susceptible to stem blight leading to premature senescence; typical symptoms are bronzing and marginal necrosis of leaves adjacent to developing bolls; plants develop fully necrotic leaves and premature defoliation occurs.

Mg - typical symptoms are lower purplish red leaves with green veins.

S - deficient plants are dwarfed with green leaves.

Mn - deficient leaves are yellowish or reddish grey with green veins.

Zn - small leaves with interveinal chlorosis and shortened stems giving the plant a small bushy appearance; slow in development; leaves lose green colour and produce necrotic spots.

B - deficient plants will produce clittelums, and dieback of terminal buds which do not blossom and drop heavily in production; young leaves yellowish green, flower buds chlorotic.

Fertilizer recommendations

Due to the extensive variability in the conditions under which cotton is produced (soils, climate, varieties, species, cultural practices, etc.) it is very difficult to generalize recommendations for cotton fertility management.

N - increases height of plants, their boll-bearing capacity and seed weight, and improves seed cotton yield. Excess N - e.g. if cotton follows a good crop of soybeans - may result in rank growth, poor fruiting, delayed maturity, difficult defoliation and boll rot.

The N requirement of N is less for Asiatic cotton types than for American types, but it is greater for hybrids. The response to N is better in irrigated than in rainfed cotton. For better N response - as well as for other nutrients - proper weed control, insect and disease control is essential.

To obtain the highest efficiency from N, one-half (or one-third) should be given at the time of sowing, and the remainder split between (i) square formation and (ii) peak flowering and boll development. Split applications (side-dressing) will better meet the crop's requirements and reduce nitrate loss.

N given before or at planting can be broadcast together with P and K and incorporated into the soil; but placement at a depth of 5 cm below and 5 cm away from the plant has given a better yield (India) than broadcasting or simple drilling.

It is also common to apply part of the N as a foliar spray (1.5 - 2.0 % urea solution) in combination with insecticides at the time of peak flowering and the boll development stage. Foliar application has been found most beneficial on rainfed cotton.

P - improves root development, water use efficiency, the energy balance and the weight, oil and protein contents of the seed as well as fibre quality. The response to P (as well as to K) is normally better if it is given in form of NPK fertilizer (e.g. in India with N:P₂O₅:K₂O ratio 2:1:1 or 3:1:1), before or at planting, incorporated into the soil or placed 7.5 - 10 cm below the moist soil surface.

When not applied pre-planting, P (and K) should be given at the latest at thinning (in the bottom of the furrow before watering).

K - improves fibre fineness and strength, and results in early maturity of the crop. The response to K will always be better if it is applied with N and P at preplanting and incorporated into the soil. Only on sandy, permeable soils it is appropriate to give a split application of K, e.g. with a second dressing at the time of thinning.

Mg - if soil status is low apply 45 - 50 kg/ha MgO; where liming is recommended, dolomitic limestone may be used.

S - if the applied NPK fertilizer does not contain S, at least 12 - 15 kg/ha S should be given in addition (e.g. in ammonium sulphate).

Mn - on soils with pH above 5.6, application of 2.8 kg/ha elemental Mn is recommended.

Zn - soils are deficient when Zn (DTPA extraction) drops below 0.55 ppm; in this case 4.5 kg/ha of e.g. 36 % zinc sulphate should be given (possibly as foliar spray with insecticides).

B - where needed, apply 0.6 kg/ha B (if possible in two foliar applications at 0.3 kg/ha each, tankmixed with insecticide spray).

Liming - the crop is very sensitive to soil acidity. It has repeatedly shown a marked response to lime when applied to an acid soil, particularly if pH has dropped below approx. 5.5. For

lasting results, lime must be applied periodically. Enough should preferably be applied some months before planting; in an emergency it can also be applied shortly before planting.

It should be thoroughly mixed with the soil. Split application may be necessary where the soil is very acid and correspondingly large quantities of lime are recommended; the first application should be disced into the soil, followed by mouldboard ploughing; this can be followed by a second application and another discing. Most fields should however be limed before the soil becomes so acid that yields are reduced.

(Attention: no reduced tillage practices should be used in cotton planting unless the soil has been well limed to a depth of 20 cm.)

Preferred nutrient forms

N - may be given in ammonium, nitrate or amide form (ammonium nitrate, ammonium sulphate, urea or NP or NPK fertilizer) containing N in ammonium or ammonium nitrate form.

P - water-soluble, or water- and citrate-soluble form (e.g. superphosphate, ammonium phosphate or ammonium nitrate phosphate, NP or NPK).

K - normally as potassium chloride in NPK fertilizers; also, where sulphur is lacking, as potassium sulphate.

Present fertilizer practices

Brazil (Sao Paulo)

At planting: 10 kg/ha N, 30 kg/ha S plus P₂O₅ and K₂O (rates according to soil status, see below), applied in the furrows.

P and K rates at planting, according to soil analysis					
P(resin) µg/cm ³	P ₂ O ₅ kg/ha	Exchangeable K meq/100 cm ³	CEC meq/100 cm ³		
			0-4.0	4.1-8.0	> 8.0
			K ₂ O kg/ha		
0-6	100	< 0.007	60	60*	80*
7-15	80	0.008-0.15	60	60	60*
16-40	60	0.16-0.30	40	60	60
41-80	40	0.31-0.60	20	40	60
> 80	20	> 0.60	20	20	20

* 25 kg/ha K₂O sidedressed with N

When the crop is thinned, 15 - 50 kg/ha N (rate depending on soil organic matter) sidedressed, together with 25 kg/ha K₂O where required.

B is either applied at planting (0.5 - 1.5 kg/ha B) or as a sidedressing (1.2 - 1.5 kg/ha B).

Lime (usually as dolomitic limestone) is topdressed and incorporated (0 - 20 to 0 - 30 cm) at a rate to raise base saturation to 70 %.

China

Before sowing or transplanting 30 - 45 t/ha organic manure is given.

N - part applied as basal dressing, the rest as a topdressing at flowering.

P, K, B and Zn - generally given as basal dressing: (B and Zn also as foliar spray at flowering).

**On soils with adequate reserves of P and K according to soil analysis:
light soils, expected yield 900 kg/ha ginned cotton:**

Preplanting: 40 kg/ha N
Topdressing at square stages:
(45 - 55 days after sowing): 40 kg/ha N
(75 - 85 days after sowing): 65 kg/ha N

medium fertile soils, expected yield 1 067 kg/ha ginned cotton:

Preplanting: 53 kg/ha N
Topdressing at flowering
(75 - 85 days after sowing): 65 kg/ha N

fertile soils, expected yield 1 467 kg/ha ginned cotton:

Preplanting: 40 kg/ha N
Topdressing at flowering
(75 - 85 days after sowing): 50 kg/ha N

On soils with adequate reserves of K only, according to soil analysis; expected yield 1 164 kg/ha ginned cotton:

Preplanting: 50 kg/ha N, 87 kg/ha P₂O₅
Topdressing at flowering
(75 - 85 days after sowing): 61 kg/ha N

On soils needing N, P and K according to soil analysis; expected yield 1 275 kg/ha ginned cotton:

Preplanting: 50 kg/ha N, 78 kg/ha P₂O₅, 70 kg/ha K₂O
Topdressing at flowering
(75 - 85 days after sowing): 62 kg/ha N

B - where needed, is generally applied at a rate of 12 kg/ha borax as a basal dressing; as foliar spray, 0.1 - 0.2 % borax solution is applied 2 - 3 times at 15 days intervals.

Zn - where needed, is generally applied as a basal dressing of 22 kg/ha zinc sulphate (Zn SO₄.7 H₂O = 23 % Zn); it is also sprayed - from the square stage - as 0.1 - 0.2 % zinc sulphate solution.

Egypt

Where available well decomposed organic manure is applied and incorporated in the soil before planting.

Fertilizer rates (based on long term field experiments in the cotton belt):

- for provinces in the Nile Delta
N = 145 - 180 kg/ha (except for variety G77 receiving 160 - 200 kg/ha N)
P₂O₅ = 35 - 70 kg/ha

- for provinces in Middle and Upper Egypt
N = 160 - 200 kg/ha
P₂O₅ = 35 - 70 kg/ha

K may be added, where needed, at a rate of 55 - 60 kg/ha K₂O.

N is given in 2 split applications
(at thinning one month after planting, and one month later)

P and K - at preplanting or also at thinning.

India

Generally recommended N rate:

	kg/ha N	
	Irrigated	Rainfed
Traditional varieties	100	40 - 60
Hybrids	150 - 300	100 - 120

USA

N rate is used as a guide. Where cotton follows a good crop of soybeans N-rate is reduced by 20 - 30 kg/ha; where vegetative growth has been inadequate, N rate is increased by this amount.

Soil status	K				
	Very high	High	Medium	Low	Very Low
P	kg/ha N - P2O5 - K2O				
Very high	100-0-0	100-0-0	100-0-65	100-0-100	100-0-135
High	100-0-0	100-0-0	100-0-65	100-0-100	100-0-135
Medium	100-65-0	100-65-0	100-65-65	100-65-110	100-65-135
Low	100-110-0	100-110-0	100-110-55	100-110-110	100-135-135
Very low	100-135-0	100-135-0	100-135-65	100-135-135	100-155-155

Source: Coop. Ext. Service Clemson Univ., 1989

Present practice in Southeastern USA

N - a basic rate of 65 kg/ha N is recommended for "average" loamy sand soils; this may be modified recording to residual N from previous crop, the possibility of irrigation, and the growth of cotton in the field in previous years.

Fertilizer recommendations according to soil P and K status - Southeastern USA				
P status	K status			
	Low	Medium	High	Very high
	kg/ha N - P2O5 - K2O			
Low	65-110-110	65-110-55	65-110-0	65-110-0
Medium	65-55-110	65-55-55	65-55-0	65-55-0
High	65-0-110	65-0-55	65-0-0	65-0-0
Very High	65-0-110	65-0-55	65-0-0	65-0-0

P2O5 and K2O soil analysis results				
Rating	Coastal Plain		Piedmont, Mountain and Limestone Valley	
	kg/ha			
	P2O5	K2O	P2O5	K2O
Low	0- 30	0- 80	0-20	0-135
Medium	30- 65	80-190	20-45	135-280
High	65-110	190-310	45-85	280-450
Very High	>110	>310	>85	>450

On fields which have produced rank growth, the total N rate is reduced to 45 - 55 kg/ha. The petiole monitoring programme can help lower early season rates without yield reduction as a result of N deficiency. With weekly monitoring, N can be applied well before actual deficiencies may appear.

Desired pH = 6.0

50	55	85	115	140	170	200	200	200	200
70	25	55	85	120	150	180	200	200	200
90	0	20	55	90	130	165	200	200	200
110	0	0	20	60	100	140	180	200	200
130	0	0	0	20	65	100	150	195	200
150	0	0	0	0	25	75	120	165	200
170	0	0	0	0	0	35	85	130	180
190	0	0	0	0	0	0	45	95	145
210	0	0	0	0	0	0	10	60	110
230	0	0	0	0	0	0	0	25	75
250	0	0	0	0	0	0	0	0	50

* Soil nitrate levels (kg/ha NO₃⁻-N) are determined in the top 90 cm of soil after planting and converted into kg of soil-NO₃⁻ per hectare (multiply the NO₃⁻-N ppm concentration found in the top 90 cm of soil by 9.4 and then by the bulk density of the soil, e.g. 1.5 for clays to 1.7 for sands). This calculated amount of soil NO₃⁻-N is used along with the yield goal to estimate the fertilizer rate required to provide sufficient N for the projected yield.

Source: Zelinski, 1986

Western USA (Arizona)

Recommendations for P	
Soil test level* - ppm P	Fertilizer P rates - kg/ha P ₂ O ₅
< 5	30 - 55**
> 5	0 - 0

* NaHCO₃ extraction - ** Banded applications recommended.

Further reading

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