7.2 Vegetables Grown Under Tropical/ Subtropical Conditions

(see also 7.1 Vegetables Grown Under Temperate Conditions, page 273)

Fertilizer recommendations for most of the vegetables grown in the tropics currently follow a recipe approach, based on research conducted in temperate areas of the world. Little is thus still known concerning the true fertilizer requirements of vegetables in tropical areas. Proper recommendations should be based on soil test values which are adequately calibrated to the local soils, ambient conditions, and crop growth responses.

Information obtained from multiple sources should therefore be used with caution, based on a systematic analysis of several relevant biophysical factors. The recommendations given here relate to intensive monoculture production systems, with potential for high marketable yields.

7.2.1 Asparagus (*Asparagus officinalis* L.)

(see also 7.1.1, page 275)

Crop data

Perennial. Harvested part: young shoots. Direct seeded and crown transplanting. Plant density: 15 000 to 25 500 plants per ha. Preferably grown in muck and light sandy soils well supplied with organic matter and pH range of 6.7–7.5. Does not tolerate acid soils but grows well in slightly alkaline and saline soils.

Target marketable yields in intensive commercial production = 1.5–4 t/ha.

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Plant analysis data

Plant analysis data – Macronutrients (optimum fertility conditions)							
Plant part	Growth stage	% of dry matter					
		N	P	K	Mg	Ca	S
Fern	50 cm	2.4	0.2	1.9	0.4	0.4	0.1
Source: various							

Plant analysis data – Micronutrients (optimum fertility conditions)							
Plant part	Growth stage	ppm dry matter					
		Fe	Mn	Zn	Cu	B	Mo
Fern	50 cm	-	23	13	0	56	-
Source: various							

Fertilizer recommendations

P contributes to the improvement of spear quality, flavour, and texture, while K increases resistance to rust and helps maintain shoot quality. Mg is needed for carbohydrate storage. The crop also responds to B when soil supplies are deficient. Root inoculation with *Glomus fasciculatum* vesicular-arbuscular mycorrhizal fungus improves growth by improving P uptake and by decreasing the effects of Fusarium spp. diseases.

For the first year of establishment in the field apply all N, P and K before planting and field preparation. Annual treatments after field establishment should consist of split N applications, one-half before cutting begins and the remainder after harvesting has ended.

Present fertilizer practices

Senegal (Camberene)

During the first year of growth for field establishment in sandy soils of semi-arid areas, 15 t/ha organic manure and 40 kg/ha N, 180 kg/ha P_2O_5, and 90 kg/ha K_2O are broadcast before planting. Annually sidedress all organic manure, P and K before earthing up. The annual N applications are split in two, one-half applied after earthing up and the rest after harvest.

USA (California)

Before field preparation on mineral soils apply 110 kg/ha N, 130 kg/ha P_2O_5, and 130 kg/h K_2O; thereafter annually 110 kg/ha of N after the cutting season has ended.

Chile

In northern areas (for yields of 7–10 t/ha): in winter, 50 kg/ha N, 50 kg/ha P_2O_5 and 50 kg/ha K_2O and in summer a further 50 kg/ha N. In southern areas rates are doubled.

Further reading

KRARUP, A.; KRARUP, C.: Asparagus production in Chile. Acta Hort. 271, 253–256 (1990)

SIMS, W.L.; SOUTHER, F.D.; MULLEN, R.J.: Growing asparagus in California. Coop. Ext. Univ. Calif. Lf. 21447 (1988)

7.2.2 Beans (*Phaseolus vulgaris* L.)

(see also 7.1.6, page 281)

Crop data

Directly seeded. Harvested: 40–60 (bush) and 50–70 (pole) days after seeding. Plant density: 100 000 to 330 000 plants/ha (bush beans); 20 000–35 000 plants/ha (pole beans). Preferably grown in sandy loam, friable soils free of nematodes and fungus diseases.

The crop is adapted to a wide range of environmental conditions from sea-level to highlands. preferably with temperatures in range 20–25 °C.

Target marketable yields in intensive commercial production = 3.5–8.5 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients (optimum fertility conditions)					
Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
13	129	21	68	17	50
Source: various					

Plant analysis data

Plant analysis data – Macronutrients (optimum fertility conditions)							
Plant part	Growth stage	% of dry matter					
		N	P	K	Mg	Ca	S
Young mature leaf	Early flower	3.2	0.4	2.4	0.5	1.9	0.2
Source: various							

Plant analysis data – Micronutrients (optimum fertility conditions)							
Plant part	Growth stage	ppm dry matter					
		Fe	Mn	Zn	Cu	B	Mo
Young mature leaf	Early flower	137	92	23	11	26	1
Source: various							

Fertilizer recommendations

Both bush and pole types are very sensitive to salinity. Well decomposed organic manure should be used. Application of N early in growth is important in order to promote growth before effective atmospheric N fixation by nodule bacteria. The crop is sensitive to Mg deficiency (dolomitic lime to be applied).

Preferred nutrient forms

In loam soils the preferred N source is ammonium, to increase pod yields and N-fixing nodule formation.

Present fertilizer practices

Senegal (Camberene)

In light sandy soils in a semi-arid area apply 5 t/ha organic manure, 110 kg/ha N, 160 kg/ha P_2O_5, and 80 kg/ha K_2O. Before planting, broadcast all the organic manure, 40% of the P_2O_5 and 25% of the K_2O. At fifteen, thirty and forty days after planting, band 50, 25 and 25% of the N, 20% of the P_2O_5 and 25% of the K_2O.

Brazil (Minas Gerais)

General recommendations are, firstly, 60 kg/ha N, 200 kg/ha P_2O_5 and 90 kg/ha K_2O incorporated in the soil at planting and, secondly, 60 kg/ha N broadcast in two applications 15 and 30 days after planting.

Philippines (Los Baños)

Apply 100 kg/ha N, 200 kg/ha P_2O_5 and 100 kg/ha K_2O. All of the fertilizer is applied at planting in bands 8 cm to the side and 3 cm below the seed.

Further reading

MUNNS, D.N.; FOX, R.L.: Comparative lime requirements of tropical and temperate legumes. Plant Soil 46, 533–548 (1977)

PECK, N.H.; MACDONALD, G.E.; GARDNER, A.V.: Snap bean plant responses to sources and rates of nitrogen and potassium fertilizers. HortScience 24, 619–623 (1989)

7.2.3 Cabbage (*Brassica oleracea* L., Capitata group)

French: Chou; Italian: Cavolo; Spanish: Col; German: Kohl

Crop data

Biennial. Harvested part: Leafy head. Both direct seeded and transplanted. Harvested 70–120 days after sowing. Plant density: 28 700 to 40 000 plants per ha. Preferably grown in loamy sand. pH 6–6.5. Not tolerant of acid soils.

Adapted to cool (16–20 °C), moist climates. Generally irrigated. Target marketable yields in intensive commercial production = 20–30 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients (optimum fertility conditions)

Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
29	121	32	106	5	21

Source: various

Plant analysis data

Plant analysis data – Macronutrients (optimum fertility conditions)							
Plant part	Growth stage	% of dry matter					
		N	P	K	Mg	Ca	S
Wrapper leaf	Head	3.3	0.5	3.1	0.4	1.6	0.2
Source: various							

Plant analysis data – Micronutrients (optimum fertility conditions)							
Plant part	Growth stage	ppm dry matter					
		Fe	Mn	Zn	Cu	B	Mo
Wrapper leaf	Head	19	10	9	5	17	2
Source: various							

Fertilizer recommendations

Cabbage is a heavy feeder on fertilizer nutrients, except P. Heads will not form unless adequate N is given. Excessive N, on the other hand, may cause loose head formation and internal decay. The demand for P is greater during head formation. K deficiency can result in marginal necrosis and lower head quality, but an excess of K can cause the heads to open. The crop has a high S requirement and is sensitive to deficiencies of Mg and B.

Fertilizer applications are split, with part applied before planting. Ploughing-under of lime and compound fertilizer before planting is recommended. Use of a high analysis starter solution containing 0.75 kg nutrients per 100 litres is recommended when transplanting. The remainder of the crop's needs can then be met in one or two applications during the growing season.

The N-fixing bacteria *Azospirillum* spp., which are present in many tropical soils, were recently found to promote cabbage foliage growth.

Present fertilizer practices

Brazil (Minas Gerais)

General recommendations are, firstly, 60 kg/ha N, 120 kg/ha P_2O_5, and 180 kg/ha K_2O incorporated in the soil at planting and, secondly, 60 kg/ha N and 60 kg/ha K_2O broadcast in 3 applications 15 and 30 days after planting and during heading closure. For improved yields also incorporate 30 t/ha of organic matter into the soil two weeks or more before planting.

Philippines (Los Baños)

240 kg/ha N, 60 kg/ha P_2O_5 and 60 kg/ha K_2O, all the P_2O_5 and half the N and K_2O applied in bands along the rows at planting and the remaining N and K_2O sidedressed 8–10 cm deep one month after planting and watered immediately.

Senegal (Camberene)

On light sandy soil in a semi-arid area, 20 t/ha organic matter, 65 kg/ha N, 65 kg/ha P_2O_5, and 100 kg/ha K_2O. All the organic manure and P_2O_5 and one-third of the N and K_2O are broadcast before planting, one-third of the N and K_2O is sidedressed 20 days after planting, and the remaining third of the N and K_2O is sidedressed 40 days after planting.

India (Bangalore)

In sandy loams with pH 6.7: 150 kg/ha N, 80 kg/ha P_2O_5 and 40 kg/ha K_2O. All the P_2O_5 and K_2O and one-half of the N are applied before transplanting, and the remaining half of the N is applied 30 days after transplanting.

Further reading

GUPTA, A.: Effect of N and irrigation on cabbage production. Ind. J. Hort. Sci. 44, 241–244 (1987)

CSIZINSKY, A.A.: Nutrition of cole crops with the full-bed polyethylene mulch system in West-Central Florida. J. Plant Nutrition 10, 1489–1497 (1987)

7.2.4 Carrot (*Daucus carota* L.)

(see also 7.1.2, page 277)

Crop data

Directly seeded. Harvested four months after sowing. Plant density: 435 600 plants/ha. Preferably grown in loose, deep, well-drained soil. The crop is adapted to highland conditions in the tropics. Target marketable yields in intensive commercial production = 25–37 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients

Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
43	126	71	175	20	224

Source: various

Plant analysis data

Plant analysis data – Macronutrients

Plant part	Growth stage	% of dry matter				
		N	P	K	Mg	Ca
Young mature leaf	Midseason	3.8	0.5	4.0	0.3	1.6

Source: various

Plant analysis data – Micronutrients						
Plant part	Growth stage	ppm dry matter				
		Fe	Mn	Zn	Cu	B
Young mature leaf	Midseason	54	44	27	2	15
Source: various						

Fertilizer recommendations

Apply well decomposed organic matter to prevent forked root development. Excessive N may also be partly responsible for splitting or forked roots; heavy N treatments also promote foliage growth at the expense of root growth. Fertilizer should be applied at least 7 days before sowing, as the crop is susceptible to salt injury. Carrots respond well to B and to lime and Mg applications, as well as to N, P and K. N and K are applied before root enlargement, about 30 days after germination.

Present fertilizer practices

Senegal (Camberene)

On light sandy soils in semi-arid conditions apply 20t/ha of organic manure, 60 kg/ha N, 60 kg/ha P_2O_5 and 120 kg/ha K_2O. All organic manure and P_2O_5 and 20% of N and K_2O broadcast before planting; 40% of N and K_2O sidedressed 30 and 60 days after planting.

Brazil (Minas Gerais)

General recommendations are, firstly, 40 kg/ha N, 320 kg/ha P_2O_5 and 240 kg/ha K_2O incorporated in the soil before planting and, secondly, 80 kg/ha N and 40 kg/ha K_2O broadcasted in 2 applications 15 and 30 days after planting.

Philippines (Los Baños)

A broadcast application of 500–600 kg/ha of a 10–25–25 mixture is recommended, or in K deficient soils 1000–1 200 kg/ha 5–10–16.

Further reading

BIENZ, D.R.: Carrot splitting and second growth in Central Washington as influenced by spacing, time of sidedressing and other cultural practices. Proc. Amer. Soc. Hort. Sci. 86, 406–410 (1965)

7.2.5 Cucumber (*Cucumis sativus* L.)

(see also 7.1.5, page 280)

Crop data

Annual. Harvested part: Fruit. Directly seeded. Flowers 35–45 days after planting. Harvested: 45–55 days after planting. Plant density: 33 000 to 54 450 plants/ha. Preferably grown in well drained, non saline soils. Adapted to a wide-range of soils, but will produce early in sandy soils. Generally irrigated.

Target marketable yields in intensive commercial production: 13–30 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal (outdoor) – Macronutrients

Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
20	39	27	70	10	35

Source: various

Plant analysis data

Plant analysis data – Macronutrients

Plant part	Growth stage	% of dry matter					
		N	P	K	Mg	Ca	S
Young mature leaf	Fruit set	3.3	0.4	2.8	0.4	1.8	0.3

Source: various

Plant analysis data – Micronutrients						
Plant part	Growth stage	ppm dry matter				
		Fe	Mn	Zn	Cu	B
Young mature leaf	Fruit set	108	60	23	8	25
Source: various						

Fertilizer recommendations

Cucumbers are sensitive to Mg deficiency and respond to Mn and Cu applications.

Present fertilizer practices

Senegal (Camberene)

On light sandy soils in a semi-arid area apply 20 t/ha of organic manure, 130 kg/ha N, 95 kg/ha P_2O_5, and 200 kg/ha K_2O. Before planting broadcast all the organic manure and P_2O_5 and one-third of N and K_2O. At 30, and again at 50 days after planting apply one-third of the N and K_2O.

Brazil (Minas Gerais)

General recommendations are, firstly, 50 kg/ha N, 200 kg/ha P_2O_5 and 150 kg/ha K_2O incorporated in the soil at planting and, secondly, 50 kg/ha N and 50 kg/ha K_2O broadcast in two applications 15 and 30 days after transplanting. Greater yields are achieved by incorporating 20 t/ha organic matter two weeks or more before planting.

Philippines

In the dry season 120 kg/ha N, 120 kg/ha P_2O_5 and 120 kg/ha K_2O. Band one-third at planting. When the vines have reached about 1 m in length, sidedress a second one-third. Sidedress the remaining one-third when the first fruit is about the size of an egg.

India (Assam)

In sandy loam soils with pH 6.5 and soil boron content of 0.58 ppm, apply 80 kg/ha N, 45 kg/ha P_2O_5, 85 kg/ha K_2O and a 0.25% $Na_2B_4O_7 \cdot 10\,H_2O$ solution. Apply all the N, P_2O_5 and K_2O at planting. Spray the 0.25%

boron solution at the six leaf stage and at the flower bud initiation stage.

Further reading

HOCHMUTH, G. (ed.): Cucumber production guide for Florida. Florida Coop. Ext. Serv. Circ. 101E (1988)

MAURYA, K.R.: Effect of nitrogen and boron on sex ratio, yield, protein and ascorbic acid content of cucumber (*Cucumis sativus* L.). Indian J. Hort. 44, 239–240 (1987)

7.2.6 Eggplant [Aubergine] (*Solanum melongena* L.)

French: Aubergine; Spanish: Berenjena; Italian: Melanzana; German: Aubergine

Crop data

The crop is well adapted to the tropics. Optimum temperature for seed germination is in the range of 21–24° C and for growth 21–29° C. The most satisfactory environments are in lowland coastal areas with relatively little temperature variation. Temperature extremes can diminish the activity of root systems and interfere with plant nutrition. The crop develops a strong taproot with a branched root system that does not spread widely but responds positively to well drained soils of medium texture that are moderately deep. Good aeration is essential.

World production averages 14 t/ha. Experimental plots have yielded more than 90 t/ha and some commercial growers produce 74 t/ha but 30 t/ha should be considered an acceptable yield.

Nutrient demand/uptake/removal

The harvest extends over a long period of time in the tropics and the crop produces many fruits. As a result it requires fertilizers in large quantities especially nutrients that are easily released from the soil. In general its nutrition resembles that of tomato.

Nutrient uptake/removal – Macronutrients

Plant part	kg/40 t crop					
	N	P_2O_5	K_2O	MgO	CaO	S
Fruit	75	27	108	12	4	5
Total plant	207	46	340	-	-	15

Source: Paterson, 1989

The figures given for S are not derived from actual data but are estimates based on typical N:S ratios in plants. The amount of S required in fertilizer is generally about 10% of the N requirement minus the S supplied in rainfall and irrigation water and that taken up from the soil.

Plant analysis data

The table demonstrates the generally high concentration of nutrients in vegetative tissues especially N and K (for S, see remarks above).

Plant analysis data – Macronutrients (good plant nutrition and fertilizer practices)

Plant part/ conditions of growth	% of dry matter					
	N	P	K	Mg	Ca	S
Leaves*: well fertilized and limed; recently matured						
- not mulched	4.9	0.45	4.6	0.65	1.6	0.4
- mulched	5.2	0.6	5.0	0.55	1.3	-
5th leaf, 60 days**	2.73	0.42	3.9	-	-	-
Fruit***	2.1	0.31	3.0	0.23	0.12	-

* Paterson, 1989; ** Subbiah et al., 1987; *** Tindall, H. D., 1983; Paterson, 1989; Mortensen & Bullard; n.d.; Valenzuela, 1991

Plant analysis data – Micronutrients (good plant nutrition and fertilizer practices)

Plant part	ppm dry matter				
	Fe	Mn	Zn	Cu	B
Leaves: well fertilized and limed; recently matured					
- not mulched	250	70	-	11	30
- mulched	300	100	-	14	75

Source: Paterson, 1989

Fertilizer recommendations

Fertilizer practices
(recommended rates of fertilizer application for acceptable yields)

Geographical area	Nutrient use recommended kg/ha			
	N	P_2O_5	K_2O	Other
USA, East Coast 1)	200	185	190	Lime
Japan 2)	245	345	250	
Tropics/subtropics 3)	145	45	85	1 200 tree ash Lime
Brazil, Sao Paulo 4)	240	405 ± 200	240 ± 80	Lime (upto 70% base saturation)
Brazil 5)	200	365±90	145±50	
Hawaii 6)	200	640	120	10 Zn: Lime
Puerto Rico 7)	400	205	240	

1) Sandy soils, temperate and subtropical climates.
2) General recommendation; soils generally influenced by volcanic ash.
3) For 39.5 t/ha crop. N and K mostly supplied in wood ash.
4) Recommendations are for soils with moderately high P sorption capacity, of medium P and K status. 20% of N applied before planting, remainder in 4 equal applications 10, 25, 40 and 55 days after planting. P all applied before planting; K two-thirds before planting and remainder in 4 applications with the N.
For low or high soil P, add or subtract 200 kg P_2O_5 before plantings. For low or high soil K, add or subtract 80 kg K_2O before planting.
5) Recommendations based on general experience rather than substantial research.
6) The P requirement was such as would give 0.3 mg P/l soil solution. For soils in which iron and aluminium oxides dominate, typical P fertilizer requirements to attain 0.3 mg/l are in the range 690 - 2 750 kg/ha P_2O_5. Soil was high in non-exchangeable K.
7) The high application rate of fertilizer N seems to indicate a fertilizer efficiency of 50% with a very small contribution from the soil. The rate of P fertilizer employed was not sufficient to match the high requirement for maximum production in this high P-sorbing Oxisol.

The table is a summary statement of fertilizer either used in experimental plantings or being recommended in several areas. They are not all in the tropics. The recommended rate for N (except in Puerto Rico) is around 200 kg/ha. The fertilizer requirement depends more on soil properties than on plant uptake. On sandy soils (USA, East Coast) the recommendation is 185 kg/ha P_2O_5; for moderately high P absorbing soils of Brazil the requirement is twice as great; for very high iron content (basalt) soils of Hawaii 3 to 4 times as great; and for soils developed on weathered volcanic ash it will be even greater. Virtually all recommendations emphasize the need for relatively high base saturation/low aluminum saturation, pH 6–7 (lime or wood ash applicaton).

Further reading

FUSAGRI: Tomate, pimentón, aji y berenjena. Fundación Servicio Para el Agricultor; Serie Petroleo y Ag. No. 3, Caracas, Venezuela (1983)

PATERSON, J.W.: Eggplants. In: PLUCKNETT, D.L.; SPRAGUE, H.B. (eds.): Detecting mineral nutrient deficiencies in tropical and temperate crops. Westview, Boulder, CO, USA (1989)

VALENZUELA, H.: Eggplant production guidelines. Dept. of Horticulture, Univ. of Hawaii, Honolulu, Hawaii, USA (1991)

7.2.7 Lettuce (*Lactuca sativa* L.)

(see also 7.1.7, page 282)

Crop data

Annual. Harvested part: leaf. Usually transplanted in cooler or highland areas. Harvested: 70 (early) to 85 (late) days after planting. Plant density: 33 000 to 60 000 plants/ha. Grows well in well-drained organic or mineral soils with pH 6–6.5. Not tolerant of acid conditions. The crop is adapted to cool and dry environments. Target marketable yields in intensive commercial production: 30–34 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients

Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
18	68	21	130	8	20

Source: various

Plant analysis data

Plant analysis data – Macronutrients (optimum fertility conditions)							
Plant part	Growth stage	% of dry matter					
		N	P	K	Mg	Ca	S
Young mature leaf	Head	2.8	0.48	4.2	0.32	0.92	0.1
Source: various							

Plant analysis data – Micronutrients (optimum fertility conditions)							
Plant part	Growth stage	ppm of dry matter					
		Fe	Mn	Zn	Cu	B	Mo
Young mature leaf	Head	128	51	38	8	19	0.03
Source: various							

Fertilizer recommendations

Adequate fertilizer levels are needed to hasten development, improve quality and reduce bolting in bolting-prone cultivars. The P requirement of lettuce is high in comparison with most vegetable crops. Best results are obtained if the cultivated volume of soil solution is brought to 0.2–0.4 mg/l P. If the P fertilizer rate is below optimum, efficiency is increased when banded in strips 8 cm wide and 5 cm below the seeds. Banding N together with P may also help to improve yields and the efficiency of fertilizer use.

Present fertilizer practices

USA (Florida)

Apply starter fertilizer to transplants. On mineral irrigated soils apply 120 kg/ha N, 160 kg/ha P_2O_5, and 280 kg/ha K_2O. At planting broadcast in the bed or band all the P_2O_5 and one-quarter of the N and K_2O. The remainder of the N and K_2O is given in split dressings early in the growing season.

Senegal (Camberene)

In a light sandy soil in a semi-arid area apply 5 t/ha of organic manure, 125 kg/ha N, 180 kg/ha P_2O_5, and 280 kg/ha K_2O. Before planting broadcast all the organic manure, 40% of the P_2O_5 and 25% of the N and K_2O. At 30 days after planting apply 40% of the P_2O_5 and 25% of the N and K_2O. At 50 days after planting band 25% of N and K_2O and the remaining 20% of the P_2O_5. At 75 days after planting apply the remaining 25% of the N and K_2O.

Brazil (Minas Gerais)

General recommendations are, firstly, 30 kg/ha N, 120 kg/ha P_2O_5 and 90 kg/ha K_2O incorporated in the soil at planting and, secondly, 60 kg/ha N broadcast in three applications 15 and 30 days after planting and during heading closure. An alternative is to apply 50 t/ha organic matter incorporated into the soil two or more weeks before planting.

Further reading

GUZMAN, V.L.; SANCHEZ, C.A.; BEVERLY, R.B.: Soil and foliar Ca effects on diseases and disorders which affect the quality of lettuce. Proc. Interamer. Soc. Trop. Hort. 31, 10–20 (1987)

SANCHEZ, C.A.; SWANSON, S.; PORTER, P.S.: Banding to improve fertilizer use efficiency of lettuce. J. Amer. Soc. Hort. Sci. 115, 581–584 (1990)

7.2.8 Okra (*Abelmoschus esculentus* [L.] Moench.)

French: Gombo; Spanish: Ocra; Italian: Gombo; German: Okra

Crop data

This is an important vegetable in tropical and subtropical areas. In the tender stage it is very nutritious and the season of availability for use is long. Young leaves and tender pods are eaten. The crop is cultivated either alone or in mixed culture with other crops. It is one of the most important vegetables in India, and in Nigeria alone it occupies 1.5 million hectares.

It requires a temperature of at least 16 °C for germination. Temperatures of 20 to 30 °C are appropriate for production. The crop will do well on soils ranging from sand to clay if both internal and surface drainage are good and soil fertility is maintained. Although okra is tolerant to some drought stress, supplementary irrigation is necessary for good production during extended drought.

Plant population densities from 16 000 to > 100 000 plants per hectare may give ever-increasing yields if all growth factors are abundantly supplied. However 40 000 plants/ha will produce near maximum yields if the plants are well spaced.

Although the yield potential is high (30–40 t/ha have been reported). actual yields are usually low because improved methods of production are exceptional rather than the rule and because many areas where the crop is grown are subject to extremes of weather which make yield prospects uncertain.

Nutrient demand/uptake/removal

Nutrient uptake/removal* – Macronutrients

Plant part /yield	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
Pods. 20 t/ha	79	32	89	15	29
Total plant**	200	73	156	45	38

* Based on data of Majanbu et al.. 1986; Ahmad & Tullock-Reid. 1968; and FAO.
** Assumed that pods represented 45% of total dry weight and that composition of vegetative parts was equal to leaves composition at 15 weeks after harvest.

Plant analysis data

The table gives the nutrient concentration in leaves and pods in approximate 20 t of harvested product.

Plant analysis data* – Macronutrients

Plant part	% of dry matter				
	N	P	K	Mg	Ca
Leaves 15 weeks	4.1	0.35	1.9	0.62	3.2
Pods 8 weeks	3.3	0.60	3.1	0.38	0.7**

N-fertilizer application = 100 kg/ha N
* Based on data of Majanbu et al.. 1986: Ahmad & Tullock-Reid. 1968: and FAO.
** FAO. 1968; assumed pods 12% dry matter.

Fertilizer recommendations

Reliable general recommendations concerning practices cannot be made for two reasons; (1) environmental conditions, including soil factors, are so varied that generalizations will seldom if ever apply precisely, and (2) quality research upon which to base such generalizations is almost totally lacking. As a gross generalization it may be said that the requirement is similar to that of cotton.

The table below presents a few examples of fresh pod yields and leaf composition associated with various yield levels. Footnotes to the table suggests the conditions where these recommendations may apply. For example, recommendations in Brazil are based on soils of medium nutrient status. For soils low in P and K the recommendation is increased by 50%, whereas for soils high in P and K recommendations are reduced by 50%.

Generally, adjustments are necessary for fertilizer use efficiency and nutrient contributions from the soil, manure, residual fertilizers etc. As a first approximation, the efficiency of N fertilizer use is 50% and many soils will deliver approximately 80 kg/ha N. Thus for a 20 t okra crop, the estimated N fertilizer requirement would be (200–80) / 0.5 = 240 kg/ha N, which was the N level employed for estimated maximum yield in South India (Bangalore). The P is applied at planting, together with 25% of the N and 60% of the K, followed by two applications of N and K_2O approximately 20 and 40 days after seedling emergence.

Approximate okra yields (green pods), and N, P and K concentrations in leaves associated with various fertilizer rates

Yield level (tons/ha)	Leaf composition (% of dry matter)			Fertilizer rate (kg/ha)		
	N	P	K	N	P_2O_5	K_2O
	South India (Bangalore) 1)					
100% predicted	4.0	0.31	2.6	240	172	288
80% actual (6.5)	3.35	0.31	2.3	240	172	144
75% (5.1)	3.3	0.29	2.25	120	0	144
50% (4.1)	2.85	0.27	1.75	60	0	36
25% (2.0)	<2.7	-	-	0	0	0

contd.

Approximate okra yields (green pods), and N, P and K concentrations in leaves associated with various fertilizer rates (ctd.)

Yield level (tons/ha)	Leaf composition (% of dry matter)			Fertilizer rate (kg/ha)		
	N	P	K	N	P_2O_5	K_2O
	Trinidad 2)					
100% (16.5)	5.1	0.40	2.5	112	385	300
	Sao Paulo, Brazil 3)					
General recommendation for soils of medium P and K status	-	-	-	80	202	140
	Northern Nigeria (Samaru) 4)					
100% (6.2)	4.13	0.35	1.88	100	30	40
	Southeast USA (Georgia and Florida) 5)					
General recommendation for soils very low in P and K	-	-	-	120	160–275	60–149

1) Data based on a graphic reexamination of results presented by Kumar & Devarajura, 1988; using a boundary-line approach with some extrapolation.
2) Based on data by Ahmad and Tullock-Reid, 1968; with some obvious corrections. The soil is micaceous but with only 0.13 meq/100 g exchangeable K; thus K fixation accounts for high K fertilizer requirement.
3) Extracted from Van Raij et al., 1985; recommendation based on a soil of medium extractable P and K status but relatively high in P sorption capacity.
4) Extracted from data by Majanbu et al., 1985 & 1986. Soils averaged 0.2 meq exchangeable K and P sorption was low. Low P fertilizer rate was adequate but K fertilizer rate was insufficient for high yields, hence the low leaf K.
5) Composite fertilizer recommendations Hochmuth & Hanlon, 1989; Woodruff, 1927. The range represents greater P sorption by Georgia soils and greater K leaching by Florida sands.

Further reading

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MAJANBU, I.S.; OGUNBLA, V.B.; AHMED, M.K.: Response of two okra varieties to fertilizer: growth and nutrient concentrations as influenced by nitrogen and phosphorus application. Fertilizer Res. 8, 297–306 (1986)

7.2.9 Onion (*Allium cepa* L.)

(see also 7.1.9, page 284)

Crop data

Usually transplanted in the tropics. Harvested 90–150 days after planting. Plant density: 66 000 to 500 000 plants/ha. Grown in soils ranging from light sandy to organic with a pH range of 5.8–6.5 Adapted to cool weather (15–20 °C) and low humidity.

Target marketable yields in intensive commercial production: 30–45 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients					
Yield t/ha	t/ha				
	N	P_2O_5	K_2O	MgO	CaO
41	102	41	112	17	29
Source: various					

Plant analysis data

Plant analysis data – Macronutrients (optimum fertility conditions)						
Plant part	Growth stage	% of dry matter				
		N	P	K	Mg	Ca
Young mature leaf	Mid season	3.1	0.33	3.3	0.27	0.5
Source: various						

Plant analysis data – Micronutrients (optimum fertility conditions)						
Plant part	Growth stage	ppm dry matter				
		Fe	Mn	Zn	Cu	B
Young mature	Mid season	10	27	7	0.73	9
Source: various						

Fertilizer recommendations

The unbranched root system is very inefficient in P uptake unless the root is mycorrhizal. Cu deficiency is common in peaty and acid soils; acid soils should be limed, since the crop does not tolerate acidity well. Mn deficiency may occur in alkaline soils.

All fertilizer should be applied close to the surface to be within reach of the shallow root system. A complex fertilizer, rich in P_2O_5 (e.g. 12–24–12) will improve bulb enlargement and yields. Even when mineral fertilizers are used, additional application of organic manure may enhance yields, quality and bulb size.

Present fertilizer practices

Senegal (Camberene)

In a light sandy soil in a semi-arid area apply 10 t/ha of organic matter, 55 kg/ha N, 125 kg/ha P_2O_5, and 140 kg/ha K_2O. Broadcast all the organic manure (well-decomposed) and three-quarters of the N, P_2O_5 and K_2O before planting, and band the remainder 35 days after planting.

Philippines (Los Baños)

Apply 120 kg/ha N, 240 kg/ha P_2O_5, and 120 kg/ha K_2O in the dry season. At planting apply all the P_2O_5 and K_2O and half the N as a basal dressing. The remaining half of N is sidedressed when bulbing is initiated. Sidedress about 10 cm deep and 8 cm away from the roots.

Pakistan (Baluchistan Province)

Apply 120 kg/ha N, 80 kg/ha P_2O_5 and 80 kg/ha K_2O. All of the P_2O_5 and K_2O and half the N are applied at transplanting, and the remaining N 4 weeks later.

Nigeria (Nsukka)

In acid ultisoils apply 2 t/ha CaO at least two weeks before transplanting. At twenty days after transplanting apply 75 kg/ha N, 70 kg/ha P_2O_5, and 180 kg/ha K_2O. At 35 days after transplanting apply a further 75 kg/ha of N.

Further reading

ASIEGBU, J.E.: Response of onion to lime and fertilizer N in a tropical ultisol. Trop. Agric. 66, 161–166 (1989)

GAMIELY, S. et al.: Onion plant growth, bulb quality, and water uptake following ammonium and nitrate nutrition. HortScience 26, 1061–1063 (1991)

SAIMBHI, M.S.; RANDHAWA, K.S.: Influence of N, P and K on the yield and processing quality of onion bulbs. Vegetable Sci. 10(2); 73–76 (1983)

7.2.10 Peppers (*Capsicum annuum* L. var. *grossum*)

(see also 7.1.11, page 287)

Crop data

Transplanted or direct seeded. Harvested: 65–80 days after transplanting. The roots thrive with good soil aeration. The crop is therefore preferably grown in sandy loams and loams with good drainage, with pH between 6–6.8. The crop is adapted to warm conditions. Generally irrigated.

Target marketable yields in intensive commercial production: 11–25 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients					
Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
21	70	16	92	18	67
Source: various					

Plant analysis data

Plant analysis data – Macronutrients (optimum fertility conditions)							
Plant part	Growth stage	% of dry matter					
		N	P	K	Mg	Ca	S
Young mature leaf	Early fruiting	3.7	0.3	3.4	0.4	1.0	0.2
Source: various							

Plant analysis data – Micronutrients (optimum fertility conditions)						
Plant part	Growth stage	ppm dry matter				
		Fe	Mn	Zn	Cu	B
Young mature leaf	Early fruiting	45	33	26	4	23
Source: various						

Fertilizer recommendations

The greatest absorption of nutrients occurs in the first 8 to 14 weeks of growth and again after the first fruit removal. Therefore, high N levels are required by the plant early in the growing season with supplemental applications after the fruit initiation stage. Improved N use efficiency and greater yields are achieved when N is applied under polyethylene mulches and with 12 weekly N applications in a drip irrigation system. At least 50% of the total fertilizer N should be NO_3-N.

For optimum P placement, band 5–8 cm deep in the rows. Blossom-end rot may result from Ca deficiency which may be corrected with foliar sprays of calcium chloride or calcium nitrate. The crop is also sensitive to Mg deficiency and has a low salt tolerance, but root inoculation with vesicular-arbuscular mycorrhizal fungi may improve growth under salt stress conditions.

Present fertilizer practices.

Senegal (Cambarene)

In a light soil in a semi-arid area apply 10 t/ha organic manure, 140 kg/ha N, 100 kg/ha P_2O_5, and 200 kg/ha K_2O. At planting, basal applications of all the organic manure, dolomitic limestone if required, 60% of the P_2O_5 and 15% of the N and K_2O. The balance of the N and K_2O is applied in localized top dressings at 3-week intervals, beginning 15 days after planting. The balance of the P_2O_5 is applied before flowering.

Brazil (Minas Gerais)

General recommendations are. firstly, 60 kg/ha N. 240 kg/ha P_2O_5 and 180 kg/ha K_2O incorporated in the soil at planting and, secondly, 240 kg/ha N and 50 kg/ha K_2O broadcast in two applications 15 and 30 days after planting. Greater yields are obtained by incorporating into the soil 20 t/ha organic matter two or more weeks before planting.

India (Bangalore)

Applications on sandy loams in moderately fertilized soils are 150 kg/ha N, 80 kg/ha P_2O_5 and 40 kg/ha K_2O. Broadcast all the P_2O_5 and K_2O at planting time together with 50 kg/ha N. The remaining N is applied in equal split doses at 30 and 60 days after planting.

Further reading

MARTI, H.R.; MILLS, H.A.: Nutrient uptake and yield of sweet pepper as affected by stage of development and N form. J. Plant Nutrition 14, 1165–1175 (1991)

LOCASIO, S.J.; FISKELL, J.G.A.: Pepper response to sulphur-coated urea, mulch and nitrogen rate. Proc. Fl. State Hort. Soc. 92, 112–115 (1979)

RIVERA, E.; IRIZARRY, H.: Effect of fertilization with phosphorus, sulphur and micronutrients on yields of peppers, growing on alkaline soil. J. Agric. Univ. Puerto Rico 73, 1–4 (1984)

SHUKLA, V.; SRINIVAS, K.; PRABHAKAR, B.S.: Response of bell pepper to N, P and K fertilization. Indian J. Hort. 44, 81–84 (1987)

7.2.11 Plantain (*Musa accuminata* × *M. balbislana* [AAB group])

French: Plantain; Spanish: Plátano; German: Plantane, Kochbanane

Crop data

Plantains (cooking banana) are closely related to the familiar dessert banana. In some respects they are more important than dessert banana because they are a staple diet in Southeast Asia, the Pacific Islands, Tropical America and Tropical Africa. The Cameroons, for example, produce taro, cassava and banana (including plantain) in approximately equal quantities, about 600 000 t each per year.

In some respects plantain seems to differ in nutrient requirements from dessert banana. The two crops also seem to differ in the way they respond to intensive management; and dessert bananas are often more productive through many successive crops, whereas successive yields of intensively managed plantains often decline rapidly.

Nutrient demand/uptake/removal

The following table is based on very limited data.

Nutrient uptake/removal – Macronutrients

Production level	kg/ha					
	N	P_2O_5	K_2O	MgO	CaO	S
Near maximum	250	46	702	100	252	24
Intermediate (75%)	148	30	420	66	154	14
Low (50%)	73	16	180	33	91	7

Source: Vicente-Chandler & Figurella, 1962; Del Valle et al., 1978; Fox et al., 1979

Further data on contents of nutrients are given with "Fertilizer recommendations".

Plant analysis data

Plant analysis data – Macronutrients						
Production level	% of dry matter (No. 3 leaf)					
	N	P	K	Mg	Ca	S
Near maximum	3.4	0.19	3.5	0.25	0.7	0.26
Intermediate (75%)	2.7	0.16	2.8	0.21	0.6	0.20
Low (50%)	2.0	0.14	1.8	0.15	0.5	0.10
Source: Vicente-Chandler & Figurella, 1962; Del Valle et al., 1978; Fox et al., 1979						

Further "plant analysis data" is given with "Fertilizer recommendations".

Fertilizer recommendations

Plant nutrition problems may stem from a superficial and restricted root system – a problem of banana generally. However, reports frequently specify that the soil should be deep and fertile. Perhaps shallow rooting is as much a function of soil properties as it is of plant characteristics.

Fertilizer recommendations should be based on crop requirements for a particular expected yield, corrected for the ability of the environment to meet those requirements. But two nutrients, N and K, are deficient for plantain growing in most soils. The quantity of N a soil can deliver to plantain can be estimated from the N taken up in a similar situation by a crop such as continuously-grown, minimum-till maize. N uptake by plantain is approx. 8 kg/t of fruit produced. Thus a yield of 30 t represents 250 kg of N removed (table nutrient uptake/removal) The deficit, uptake minus soil N delivered, should be supplied as fertilizer or manure, with allowance made for the inefficiency of the fertilizer and/or manure application.

The efficiency of N in the tropics is often approx. 50%. In Hawaii (clay soil) estimates of N recovery in banana at harvest, in relation to N applied, were about 65%. Probably much of the N was lost as volatilized ammonia resulting from spreading the fertilizer (urea) on dry ground and trash.

Dessert bananas, and probably plantain too, develop an effective mycorrhiza. The fungus-root association decreased the required concentration of P in soil solution from 0.1 mg/l to 0.05 mg/l. This is less than the required concentration for many vegetable crops and perhaps more than the requirement for maize. Such dilute solutions do not necessarily indicate low fertilizer requirements. Highly weathered, fine-textured soils of the tropics will typically require 100 to > 200 mg/kg P in soil to attain a sufficient P level for plantain. Such rates of phosphate are seldom used even in experiments. Thus reported fertilizer requirements are frequently low.

P percentage in plantain fruit is low and so also is the quantity of P contained in the fruit. P fertilizer required is more a matter of soil reactions with P than it is of crop need. Estimates of fertilizer requirements on a global scale demonstrate that Acrisols. Ferralsols and Andosols – important soils in the tropics – are high P-sorbing soils: the weighted mean P sorption is 900 kg/ha P_2O_5 to attain 0.02 mg P/l in solution. This is a little low for maximum plantain production.

Plantain is rich in K; a 30 t crop contains approx. 720 kg/ha K_2O of which 240 kg is removed in the fruit. Much of the remaining 480 kg should be available for a ratoon crop.

The requirement for S in plantain is approx. 7% of the N requirement. However, S is taken up more sluggishly than N, and therefore should be supplied at approx. 10% of the amount of N.

The following table is an example of estimated fertilizer requirements for plantain (plant crop) and the type of information needed to make reasonable estimates for specific locations. This example assumes yields of approximately 35 t/ha, typical fertilizer efficiencies for weathered soils, and low soil fertility. The table can be modified to suit local conditions and yield expectations by substituting more appropriate values for soil-supplied nutrients and fertilizer efficiencies. Such modifications depend on the amount of leaching relative to expectation (based on rainfall-evaporation data, probability of N loss by NH_3 volatilization and denitrification, P and K sorption by the soil, S accretion via rainfall, etc.) The estimated N and K requirements are similar to the average fertilizer rates used in experiments that produced acceptable yields (average 34 t fruits/ha).

Estimated fertilizer requirements

Plant crop	N	P_2O_5	K_2O	MgO	S
Effective amounts from soil and rainfall (kg/ha)	60*	18**	216***	20	10
Total uptake by crop yielding 35 t/ha (kg/ha)	250	46	702	100	24
Balance to be obtained from fertilizer (kg/ha)	190	28	702	80	14
Assumed fertilizer use efficiency (%)	50	10	75	75	75
Amount to be provided in fertilizer (kg/ha)	380	280	648	107	19

Remark: Based on reasonable expectations of nutrient supplying power of wheathered soils, fertilizer efficiencies associated with moderate leaching, and plant uptake of nutrients associated with acceptable production of 35 t/ha of fruit.

* Assume 0.15% N, 4% mineralization rate and 50% efficiency.

** Assume 10 t dry matter that is 0.1% P and that this can be produced with no P fertilizer.

*** Assume 0.15 meq exchangeable K/100 g soil which is 75% available.

Predicting fertilizer requirements for a ratoon crop is more uncertain than for a plant crop because of residual fertilizer effects and the efficiency of nutrient recovery from plant crop residues, which are difficult to evaluate. Soil contributions will usually decrease with time and residual fertilizer effects will increase if fertilizer is added in excess of crop removal. An evaluation of these residual effects requires estimates of nutrients removed in the fruit and long-term (residual) efficiencies of fertilizers. The first can be calculated from yield and composition data; the second is more in the realm of speculation, or at best, an educated guess. Such uncertainties notwithstanding, predicted requirements for a ratoon crop producing 35 t/ha of fruit are about 165 kg/ha N, 115 kg/ha P_2O_5, 288 kg/ha K_2O, 40 kg/ha MgO and 25 kg/ha S.

These predictions are low in comparison with annual requirements (7-year average) for banana in Hawaii, but suitable data for ratoon plantain were not available for comparison. In the absence of specific data, local recommendations for dessert banana will be helpful.

Fertilizer requirements based on soil analysis have not been worked out for plantain as far, reference should be made to such worked out for banana.

Further reading

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IRIZARRY, H.F. et al.: Nutrient uptake of intensively managed plantain as related to stage of growth at two locations. J. Agric. Univ. Puerto Rico 65, 331–345 (1981)

7.2.12 Radish (*Raphanus sativus* L.)

French: Radis; Spanish: Rábano; Italian: Ravano; German: Rettich

Crop data

Annual. Harvested part: root. Directly seeded. Harvested: 22–30 days after planting. Plant density: 363 000 to 522 000 plants (average) to 1 250 000 (very intensive) plants/ha.

Preferably grown in a rich fertile soil free of stones and clods, to allow for rapid growth and smooth root growth. Sandy soils are preferred for early yields, pH 5.5–6.8. The crop is adapted to cool growing conditions.

Target marketable yields in intensive commercial production: 11–25 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients

Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
19	276	89	389	76	147

Source: various

Plant analysis data

Plant analysis data – Macronutrients							
Plant part	Growth stage	% of dry matter					
		N	P	K	Mg	Ca	S
Young mature leaf	20–30 days after planting	3.0	0.9	2.4	0.24	1.1	0.9
Source: various							

Plant analysis data – Micronutrients						
Plant part	Growth stage	ppm dry matter				
		Fe	Mn	Zn	Cu	B
Young mature leaf	20–30 days after planting	34	16	23	2	6
Source: various						

Fertilizer recommendations

Critical tissue P concentration in organic soils in Florida is 0.45%. In B deficient soils 10 kg/ha of borax will increase ascorbic acid content and yields. B toxicity (B > 0.1 mg/l) should be avoided.

Present fertilizer practices

USA (Florida)

On irrigated mineral soils apply 100 kg/ha N, 134 kg/ha P_2O_5 and 134 kg/ha K_2O. P and K should only be applied after soil analysis indicates deficiency. Broadcast all the P_2O_5 and half the N and K_2O at planting. Apply the remainder of the total N and K_2O, 15 days after planting. These rates should support three radish crops grown in succession.

Philippines (Los Baños)

Broadcast 60 kg/ha N, 90 kg/ha P_2O_5 and 90 kg/ha K_2O at planting. For radish, 300 to 400 kg/ha 10–25–25 mixture is recommended.

Brazil (Minas Gerais)

General recommendations are, firstly, 30 kg/ha N, 120 kg/ha P_2O_5 and 90 kg/ha K_2O incorporated in the soil at planting and, secondly, 40 kg/ha N broadcast in two applications 10 and 20 days after planting. If available, incorporate 20 t/ha of organic matter into the soil two weeks or more before planting.

India (North Bihar)

In a sandy loam soil with pH 8.5 broadcast at planting 15 t/ha organic manure, 50 kg/ha N, 40 kg/ha P_2O_5, and 80 kg/ha K_2O. If B deficiency occurs apply 10 kg/ha borax with the initial fertilizer package.

Further reading

MAURYA, K.R.; SINGH, B.K.: Effect of boron on growth, yield, protein and ascorbic acid content of radish. Indian J. Hort. 42, 281–283 (1985)

SANCHEZ, C.A., LOCKHART, M.; PORTER, P.S.: Response of radish to phosphorus and potassium fertilization on histosols. HortScience 26, 30–32 (1991)

7.2.13 Spinach (*Spinacia oleracea* L.)

(see also 7.1.12, page 288)

Crop data

Direct seeded. Harvested: 37–45 days after planting. Plant density: 72 500 to 653 500 plants/ha. Preferably grown in sandy loams but can be grown in a variety of soils with pH between 6 and 7. The crop is adapted to cool growing conditions.

Target marketable yields in intensive commercial production: 9–17 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients

Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
21	131	34	226	42	41

Source: various

Plant analysis data

Plant analysis data – Macronutrients (optimum fertility conditions)

Plant part	Growth stage	% of dry matter				
		N	P	K	Mg	Ca
Young mature leaf	40 days after planting; harvesting	2.6	0.3	4.7	1.0	1.0

Source: various

Plant analysis data – Micronutrients (optimum fertility conditions)

Plant part	Growth stage	ppm dry matter					
		Fe	Mn	Zn	Cu	B	Mo
Young mature leaf	40 days after planting; harvesting	189	36	37	4	19	1

Source: various

Fertilizer recommendations

Spinach has a moderate tolerance to salinity, but it is very sensitive to acidity. N demand is great just before harvest because of the flush in growth. When present in the rhizosphere, the N-fixing bacteria *Azospirillum* spp. promote the growth of this crop. It has a relatively high demand for B. In B-deficient soils broadcast 10 kg/ha borax with the initial fertilizer application.

Present fertilizer practices

USA (Florida)

For spinach grown on irrigated mineral soils apply: 90 kg/ha N, 120 kg/ha P_2O_5, and 120 kg/ha K_2O. At planting broadcast all the P_2O_5 and one-quarter of the N and K_2O. The remainder of the N and K_2O is sidedressed in split dressings at 20 and 40 days after planting.

USA (North Carolina)

In sandy and sandy loam soils broadcast 130 kg/ha N, 95 kg/ha P_2O_5, and 160 kg/ha K_2O before planting. Follow up with split applications of 50 kg/ha N. soon after planting.

Brazil (Minas Gerais)

Apply, firstly, 60 kg/ha N, 200 kg/ha P_2O_5 and 90 kg/ha K_2O incorporated in the soil at planting and, secondly, 60 kg/ha N broadcast in two applications, 15 and 30 days after planting.

Further reading

MARKOVIC, B.; LAZIC, B.; DJUROVKA, M.: Effect of increasing nitrogen doses on yield and quality of spinach. Acta Hort. 220, 297–302 (1987)

SANDERS, D.C.: Spinach. N.C. Coop. Ext. Serv. Leaflet No. 17 (1990)

7.2.14 Sweet Corn (*Zea mays* L. *convar. saccharata* Koern.)

French: Mais sucré; Spanish: Maiz dulce; Italian: Mais dolce; German: Zuckermais

Crop data

In the tropics field maize is more commonly grown as a vegetable than sweet corn, because most sweet corn varieties have been developed for long days in northern latitudes. However, sweet corn hybrids suitable for the tropics are now available (including several from Hawaii).

The crop can be grown in a wide variety of soils if they are naturally fertile or can be made fertile with appropriate fertilizers and/or organic manure. Optimum mean day temperatures are around 25 °C. Temperatures in excess of 35 °C can severely damage pollination, especially if accompanied with moisture stress from just before silk development extending through pollination. For crops grown in bright daylight conditions, an acceptable plant density is 60 000 per ha. Density should be less when extended periods of cloudy weather can be expected after full canopy development.

Nutrient demand/uptake/removal

The following table shows the generally high nutrient requirements for high yields of sweet corn; only Ca is low compared with many other crops. The requirements for nutrient quantity (and concentration) removed in a crop are similar to field maize. N and K contents are specially high, which explains the high fertilizer requirements.

Nutrient uptake/removal – Macro- and micronutrients (Zn)

Yield	kg/ha						
	N	P_2O_5	K_2O	MgO	CaO	S	Zn
20 t fresh weight	208	60	228	25	42	14	0.21

Source: Fox, 1973; Daigger & Fox, 1971; and others

Plant analysis data

Plant analysis data – Macro- and micronutrients (Zn) (good plant nutrition and fertilizer practices)

Crop status	% of dry matter						
	N	P	K	Mg	Ca	S	Zn
Concentration* near maximum yield	2.7	0.26	2.25	0.15	0.56	0.24	0.0024

* Data are means of several sources including Chapman, 1966; Lorenz & Maynard, 3rd ed; Fox et al., 1964; Daigger & Fox, 1971; Fox, 1973. If data specifically for sweet corn were not available, data from field maize in Hawaii (Rashid & Fox, 1992) or from field maize grown on a highly weathered soil in Georgia, USA (Hargrove, 1985) were used to construct the data. In most cases extrapolation from lower to a higher yield was necessary.

Fertilizer recommendations

Fertilizer used/recommended							
Area or soil conditions	Source	kg/ha					
		N	P_2O_5	K_2O	S*	Zn**
Brazil (General)						
- Sao Paulo	Van Raij et al., 1985	75	50	41	20	5
- Minas Gerais	Lopes, 1989	60	80	50	-	-
Florida, leached mineral soils, irrigated	Hochmuth & Hanlon, 1989	90	121	120	-	-
Hawaii (General) low organic matter, otherwise fertile	Nakagawa, 1957	80	101	96	-	-
- Maximum yield	Fox, 1973	220	101	96	10	10
Production Guidelines (General)	Valenzuela, 1991	103	96	110	-	-

* Apply with the N at about 10% of the rate.
** Apply infrequently, only when needed, to Zn deficient soils.

The N fertilizer requirement for maximum yields, as given for Hawaii (and it is the same in Nebraska, USA) is 220 kg/ha N. This is almost identical with N uptake given for an excellent (20 t/ha) crop. Any decrease in the rate of N fertilizer applied will diminish yields in a linear manner. This suggests that the usual fertilizer N recommendation is much below the optimum level. N should be given as a split application, one-quarter to one-half either before or at planting; and, depending upon the likelihood of N leaching and the visual appearance of the crop, the remainder in one or two applications up to approximately 40 days after germination.

Many soils will provide a substantial portion of the P required, but in the humid tropics most soils will not supply P in adequate concentration, especially at the seedling stage. Thus, an application of P near the seed is usually beneficial for early seedling vigour. The above recommendation for Sao Paulo, Brazil is for a soil of medium resin-extractable P status (7 to 15 mg/l P). The recommendation is doubled for soils with 0–6 mg/l and halved for soils with > 40 mg/l. The Florida recommendation is based on soils very low in P. Florida soils generally have low P absorbing capacities.

K is taken up in large quantities. Soils, however, even in the humid tropics, usually supply a substantial part of the K requirement. How much, can usually be estimated by soil analysis. The Brazil recommendation assumes a soil of medium exchangeable K status (1.6 meq/l). If exchangeable K exceeds 3 meq/l the recommendation is decreased by one half and if < 0.07, the recommendation is doubled. K is usually applied before or at planting except when leaching is severe as in the case of sandy soils or highly weathered soils which have little cation exchange capacitiy and little weatherable K minerals. In such cases the fertilizer K requirement approaches the amount of K removed in the crop; and the fertilizer is applied in split dressings like N.

The crop is among those most sensitive to Zn deficiency. Calcareous and strongly alkaline soils of the semi-arid tropics are suspect, as are also the highly weathered soils of the humid tropics. Eroded soils and low organic matter soils are at greatest risk. Zn uptake is very low: thus the effects of a substantial Zn application of 10 kg/ha Zn may persist for several years.

S deficiency is a greater problem than is generally recognized in the tropics. The crop is susceptible especially in the young growth stages. Many subsoils of the humid tropics contain much absorbed sulphate but it may be difficultly available or positionally unavailable. Rainwater contains sulphate. If the S concentration is <1 mg/l, deficiency can be expected. If S deficiency is confirmed, apply S at 5 to 10% of the N requirement.

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7.2.15 Tomato (*Lycopersicon esculentum* Mill.)

(see also 7.1.13, page 289)

Crop data

Transplanted 35 to 50 days after seeding. Harvested 60 to 90 days after transplanting. Plant density: 12 150 to 36 900 plants/ha. Preferably grown in sandy soils for an early harvest but adapted to clay soils, pH 6–6.5. Adapted to 20–24 °C temperatures and at least a 115-day growing season. In the tropics tomatoes are normally grown in the highlands or in the cooler season.

Target marketable yields in intensive commercial production: 27–37 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients					
Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
24	177	46	319	43	129
Source: various					

Plant analysis data

Plant analysis data – Macronutrients (optimum fertility conditions)							
Plant part	Growth stage	% of dry matter					
		N	P	K	Mg	Ca	S
Young mature leaf	1/2 fruit	2.7	0.5	2.9	0.4	1.2	0.3
Source: various							

Plant analysis data – Micronutrients (optimum fertility conditions)							
Plant part	Growth stage	ppm dry matter					
		Fe	Mn	Zn	Cu	B	Mo
Young mature leaf	1/2 fruit	119	76	24	7	25	0.16
Source: various							

Fertilizer recommendations

N requirements are moderate during foliage growth until fruit set. P is very important for vigorous growth and fruit production. Near maximum yield is attained at approx. 0.2 mg P/l soil solution. Root inoculation with *Glomus intraradices* vesicular-arbuscular mycorrhizal fungi may improve growth through improved P uptake and decreased *Fusarium oxysporum* disease incidence.

K is required for fruit set and enlargement. Important growth stages for nutrient uptake include seedling establishment when maximum nutrient efficiency uptake occurs, and early fruiting when the maximum rates of K accumulation take place. Tomato should be supplied with Mg in soils deficient in this nutrient. Ca deficiencies may cause "blossom-end rot" or apical necrosis.

Fertilizer applications through a drip irrigation system may improve the efficiency of N uptake.

Present fertilizer practices.

Senegal (Camberene)

In a light sandy soil in semi-arid conditions apply 20 t/ha organic matter, 70 kg/ha N, 200 kg/ha P_2O_5, and 240 kg/ha K_2O distributed in the following manner: All organic matter and one-fifth of the N, P_2O_5 and K_2O broadcast before planting, followed by four equal sidedressings of N, P_2O_5 and K_2O at 20-day intervals beginning 15 days after planting.

For intensive tomato production under irrigation in sandy soil apply 190 kg/ha N, 225 ha P_2O_5, and 300 kg/ha K_2O. One-fifth of the N, P_2O_5 and K_2O is broadcast before planting, and the remainder in four equal dressings at 15-day intervals beginning 15 days after planting.

Philippines

Fertilizer requirements are 96 kg/ha N, 192 kg/ha P_2O_5, and 96 kg/ha K_2O. A basal dressing of all the P_2O_5 and one-half the N and K_2O is placed 8 cm below and slightly to the side of the seedling root crown. The remaining N and K_2O is sidedressed 1 month after transplanting. If planting in furrows, the fertilizer is applied in the furrows and covered with soil.

Pakistan (Baluchistan Province)

Fertilizer recommendations are 150 kg/ha N, 100 kg/ha P_2O_5, and 50 kg/ha K_2O. Apply all the P_2O_5 and one-half the N and K_2O

before transplanting. The remainder of the N and K_2O is applied at 6–8 weeks after transplanting.

Venezuela (States of Lara, Aragua, Falcon, Nueva Esparta and Trujillo)

Sidedress 800 kg/ha of 12–24–12 fertilizer 15–20 days after planting.

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7.2.16 Watermelon (*Citrullus lanatus* [Thunb.] Matsum. et Nakai)

(see also 7.1.14, page 291)

Crop data

Annual. Harvested part: Fruit. Flowers about 80 days after planting. Harvested about 95 days after planting. Plant densitiy: 4 500 to 9 100 plants/ha. Preferably grown in sandy or sandy loam soils. Watermelons grown in heavy soils are subject to fruit cracking. Tolerant of acid soils. Adapted to a low ambient humidity.

Target marketable yields in intensive commercial production: 15–30 t/ha.

Nutrient demand/uptake/removal

Nutrient uptake/removal – Macronutrients					
Yield t/ha	kg/ha				
	N	P_2O_5	K_2O	MgO	CaO
15	56	16	100	25	98
Source: various					

Plant analysis data

Plant analysis data – Macronutrients (optimum fertility conditions)							
Plant part	Growth stage	% of dry matter					
		N	P	K	Mg	Ca	S
Young mature leaf	Mid season	3.6	0.48	2.7	0.5	1.3	0.1
Source: various							

Plant analysis data – Micronutrients (optimum fertility conditions)						
Plant part	Growth stage	ppm dry matter				
		Fe	Mn	Zn	Cu	B
Young mature leaf	Mid season	33	30	15	4	15
Source: various						

Fertilizer recommendations

N or Mg deficiency will reduce fruit-set. Dolomitic limestone should be applied to offset Mg or Ca deficiencies. Pre-plant broadcast applications are recommended in preference to band-applied preplant fertilizer to prevent seedling salt injury. Cu deficiencies in organic soils may drastically reduce yields.

Present fertilizer practices

Senegal (Camberene)

In a light sandy soil in a semi-arid area apply 10 t/ha of organic manure, 60 kg/ha N, 60 kg/ha P_2O_5 and 120 kg/ha K_2O in the following manner: All organic matter and one-third of the N, P_2O_5 and K_2O broadcast before planting, another third sidedressed when the runners start to grow, and the remainder during the fruit enlargement stage.

Brazil (Minas Gerais)

Apply, firstly, 40 kg/ha N, 160 kg/ P_2O_5, and 90 kg/ha K_2O incorporated in the soil at planting and, secondly, 100 kg/ha N broadcast in two equal dressings 15 and 30 days after transplanting. Alternatively, incorporate 5 t/ha organic matter into the soil two or more weeks before transplanting.

Philippines

In the dry season apply 120 kg/ha N, 120 kg/h P_2O_5, and 120 kg/ha K_2O. Band one third at planting, sidedress the second third when the vines have reached about 1 m in length, and the remaining third when the first fruit is about the size of an egg.

Hawaii

Apply 224 kg/ha N, 600 kg/ha P_2O_5, and 220 kg/ha K_2O. Apply half the fertilizer at planting and the rest four weeks after planting. If the soils are low in Mg apply 170 kg/ha of magnesium sulphate.

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