

LAND EVALUATION

PART III

CROP REQUIREMENTS

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GENERAL INTRODUCTION

In this part we inform the user on crop requirements with regard to climate, landscape and soil conditions for a wide range of crops commonly cultivated in the tropical and sub-tropical regions. In addition we have summarized some specific parameters required for the calculation of the potential climatic yield; this includes the crop coefficients (Kc) at different crop development stages, yield response factors (Ky) at different crop growth periods, information on water utilization efficiency for harvested yield (Ey), leaf area index (LAI) and harvest index (Hi), as well as on the moisture content of the harvested product (Mp).

The crop requirements are summarized in separate tables for climate and soil conditions. The structure of the tables is according to what has been suggested in Part I. For each characteristic they indicate four limitation levels with corresponding land classes and rating values for those who wish to use the parametric approach.

For certain crops the tables have been elaborated on the basis of available literature data and technical reports; for other crops they have been adapted to specific site conditions using regional experience. We should realize that production functions which may work adequately in one region may be unreliable in another. Therefore these tables have to be considered as a guideline so that the limitation levels for the different characteristics should be critically reviewed and possibly adapted to local conditions and sometimes to varieties of the same crop.

As outlined in Part II, a qualitative evaluation implies a matching of the site conditions, available in the land resources inventory, with the crop requirements given in the tables. The matching procedure requires application of the following guidelines :

TOPOGRAPHY

Use slope classes as given in the land resources inventory and adapt the limitation levels to these classes.

If other topographic features, such as "gilgai", are present, include them in the evaluation flow chart.

WETNESS

- Flooding

For rice we use the flood classes as defined in Part II (page 236, table 101).

For all other crops, we use the general flood classes as defined in Part I (page 83). If detailed information on floods is available we may use flood classes set up for specific crops as defined in Part I (pages 84 and 85).

- Drainage

The excessive drainage class is not used in the table as to avoid interaction with coarse textured soils. Soils with excessive drainage are considered as well drained.

PHYSICAL SOIL CHARACTERISTICS

- Texture - structure

Textural-structural classes used are according to the following sequence :

Cm	: massive clay
SiCm	: massive silty clay
C+60,v	: very fine clay, vertisol structure
C+60,s	: very fine clay, blocky structure
C-60,v	: clay, vertisol structure
C-60,s	: clay, blocky structure
SiCs	: silty clay, blocky structure
Co	: clay, oxisol structure
SiCL	: silty clay loam
CL	: clay loam
Si	: silt
SiL	: silt loam
SC	: sandy clay
L	: loam
SCL	: sandy clay loam
SL	: sandy loam
Lfs	: loamy fine sand
LS	: loamy sand
Lcs	: loamy coarse sand
fs	: fine sand
S	: sand
cs	: coarse sand

CS : coarse sand

If not specifically mentioned as for rice, profiles with heterogeneous texture require a recalculation of the texture using depth weighting factors (Part I, page 68) to a depth of 100 cm for annual crops, 150 cm for perennial crops or up to a lithic contact.

- Coarse fragments

When coarse fragments are present in the surface 25 cm and their content decreases with depth, the mean content will be used in the evaluation.

In all other cases we use the recalculated coarse fragment content, using weighting factors up to 100 cm for annuals, 150 cm for perennials or up to an impermeable layer.

- Calcium carbonate and gypsum

If the mean lime (gypsum) content of the surface 25 cm decreases with depth the evaluation takes into account these upper 25 cm.

In other cases the recalculated lime (gypsum) content, using the depth weighting factors, is used.

SOIL FERTILITY CHARACTERISTICS

- Apparent CEC

The apparent CEC, calculated by the following formula : (total mineral CEC x 100)/% clay, can be considered as an expression of the weathering stage and is therefore only useful in the tropics.

For profiles developed in a uniform soil material use the apparent CEC of the B horizon (at a depth of 50 cm); if no B horizon is present use the value at 50 cm depth or just above a lithic contact.

For profiles with rejuvenated topsoil, as a result of volcanic ash deposits or an alluvial cover, use a recalculated value up to 75 cm depth by applying weighting factors. For the correction of organic matter, use 2.6 cmol(+) for 1% organic carbon (matter)

(0.52 for 1% org carbon)

- Base saturation, sum of basic cations and pH

In order to avoid interaction, the user should consider only the most severe limitation or the lowest rating attributed to one of these three characteristics.

Base saturation is still given in the tables because this characteristic can be inferred from the soil classification names, when universal classification systems are used. Use recalculated values using depth weighting factors over the rooting zone.

For the sum of basic cations (Ca + Mg + K) and pH, use the weighted average of the topsoil (0-25 cm).

For soils under natural vegetation we should add to the sum of basic cations the estimated amount immobilized in the vegetation; tropical rainforest : 2 to 3 cmol(+) kg⁻¹, secondary forest more than 15 years old : 1 to 2 cmol(+) kg⁻¹, savannah : 0.5 to 1.5 cmol(+) kg⁻¹ and miombo woodland : 1 to 1.5 cmol(+) kg⁻¹.

- Organic carbon

Use the weighted average of the topsoil (0-25 cm).

SALINITY AND ALKALINITY

If the values of the E.S.P. or the ECe decrease with depth compared to mean values of the surface 25 cm, the evaluation takes into account the upper 25 cm.

In all other cases, recalculated values considering the depth weighting factors, to a depth of 100 cm are used.

In the crop requirement tables some numbers are associated with certain characteristics; they have the following meaning :

For topography

- (1) Irrigated agriculture, basin furrow irrigation.
- (2) High level of management with full mechanization.
- (3) Low level of management animal traction or handwork.

For drainage

- (4) Medium and fine textured soils.
- (5) Coarse textured soils (sandy families).

For organic carbon

- (6) Kaolinitic materials.
- (7) Non kaolinitic, non-calcareous materials.
- (8) Calcareous materials.

These tables are a basis for a qualitative evaluation using the methods described in Part II. When yield data, with information on optimal and marginal yields, are available a quantitative evaluation can be realized (Part II, page 156).

An alternative approach of a quantitative evaluation, developed by FAO, suggests in a first phase a climatic evaluation using yield data calculated from climatic characteristics. In this case the yields are deducted from the calculated net biomass production corrected for the water deficit of a soil profile with standard storage capacity and taking into account yield reductions due to other climatic hazards such as : hail, storm, deceases due to exceptional climatic conditions, etc.... This climatic potential yield expressed in percentage of a standard yield is used as a basis for the climatic evaluation.

Yield reductions estimated for soil limitations are further applied to achieve the final yield per land unit. FAO considers downgradings for the soil group taking into account characteristics which can be deducted from the subgroup name; further downgradings are considered for texture, slope and the different phases represented on their map.

CROP REQUIREMENTS

ALFALFA (Medicago sativa)

1. CLIMATE

To enable a proper growth the average daily temperature should be greater than 5 °C. The adequate temperature range for growth is 10 - 40 °C, the optimum temperature range being 24 - 26 °C. Frost can damage the crop.

Alfalfa is grown in areas with an annual precipitation between 400 - 2700 mm.

A low air humidity is desirable. A maximum of sunshine is required. No wind hazard.

2. SOIL

Medium soil textures, such as sandy loam to clay loam, are preferred.

Since the maximum rooting depth of alfalfa exceeds 3.00 m, deep and well drained soils are most suitable. The crop is sensitive to waterlogging.

pH range : 5.2 - 8.5, optimum pH: 6.0 - 8.0

Salinity : no yield reduction at an electrical conductivity (EC) of < 2 dS/m; the yield reduction is 10% at 3.4; 25% at 5.4; 50% at 8.8; 100% at 16 dS/m.

Sodicity : 50% yield reduction is observed at an exchangeable sodium percentage (ESP) of 35.

Micronutrients

Copper : high response to application.

Boron : high requirements ; more than 0.5 ppm in soil, tolerant of high concentrations.

Manganese : no, or low, response to application.

Magnesium : tolerant of deficiency.

Molybdenum : medium response to application.

Aluminium : sensitive to toxicity.

Nutrients

Available P requirements (ppm, Olsen) : < 4 deficient,
> 8 sufficient.

Nutrient removal (kg/ha/growing cycle) to produce 80 ton/ha of green alfalfa:

N	:	320
P ₂ O ₅	:	60
K ₂ O	:	180

Fertilizer application (kg/ha/growing cycle) to produce 80 ton/ha of green Alfalfa.

	min.	max.
N	:	0 - 40
P ₂ O ₅	:	125 - 150
K ₂ O	:	90 - 120

3. YIELDS

Rainfed

Good commercial yield of a green crop : 53 - 60 ton/ha.

Irrigated

Good commercial yield of green crop : 80 - 100 ton/ha.

Good commercial yield of hay : 15 ton/ha.

CLIMATIC REQUIREMENTS - ALFALFA (growing cycle 100-365 days)

	Climatic class, degree of limitation and rating scale					
Climatic Characteristics	S1		S2	S3	N1	N2
	0	1	2	3	4	0
	100	95	85	60	40	25
Length of growing period (days) P > 1/2 PET	365-120	120-100	100-80	80-70	-	< 70
Precipitation of growing cycle (mm)	1100-1200 1100-1000	1200-1400 1000-800	1400-1600 800-600	> 1600 600-400	-	< 400
Mean temp. of the growing cycle (°C)	25-24 25-26	24-20 26-28	20-15 28-32	15-10 32-40	-	< 10 > 40
Relative humidity growing cycle (%)	40-50 40-30	50-75 30-24	75-90 24-20	> 90 < 20	-	-

LANDSCAPE AND SOIL REQUIREMENTS - ALFALFA

	Class, degree of limitation and rating scale					
Land Characteristics	S1		S2	S3	N1	N2
	0	1	2	3	4	0
	100	95	85	60	40	25
Topography (t)						
Slope (%)	(1) 0-1	1-2	2-4	4-6	-	> 6
	(2) 0-2	2-4	4-8	8-16	-	> 16
	(3) 0-4	4-8	8-16	16-30	-	> 30
Wetness (w)						
Flooding	Fo	-	-	F1	-	F2+
Drainage	(4) good	moderate	imperfect	poor and aeric	poor but drainable	poor not drainable
	(5) imperfect	moderate	good			
Physical soil Characteristics(s)						
Texture/struct.	SL,SCL,SC, L,CL,SiCL	C<60s,Co, SiCs	C<60v,LS, C>60s,Lfs	C>60v,fs, S,LcS	-	Cm,SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 100	100-75	75-50	50-20	-	> 20
CaCo ₃ (%)	0-6	6-15	15-25	25-35	-	> 35
Gypsum (%)	0-2	2-4	4-10	10-20	-	> 20
Soil fertility Characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol (+)/kg soil)	> 8	8-5	5-3.5	3.5-2	< 2	-
PH H ₂ O	7.4-7.0	7.0-6.0	6-5.5	5.5-5.2	< 5.2	-
	7.4-7.8	7.8-8.0	8-8.2	8.2-8.5	-	> 8.5
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
E _{ce} (dS/m)	0-3	3-5	5-9	9-12	-	> 12
ESP (%)	0-8	8-20	20-35	35-50	-	> 50

ARABICA COFFEE (*Coffea arabica*)

1. CLIMATE

The minimum temperature for the growth of arabica coffee is 10 °C, though the absolute minimum is the frost limit. The maximum temperature is 30 °C. The mean optimum temperature for growth is 15 - 24 °C. High and low temperatures can be mitigated by mulching and shading. Excessive temperatures cause die back, force rapid growth and early bearing.

Arabica coffee is produced in areas with a precipitation in the range of 800 - 2500 mm/year. The precipitation is optimum between 1400 - 1600 mm/year, but the distribution is more important than the total. A well distributed rainfall with a drier period of 2 to 3 months for the initiation of flower buds is best.

Arabica coffee is grown at sea-level in the subtropics and at altitude in the tropics.

Periods of mist and low clouds are beneficial.

Strong or cold winds are detrimental; banana wind breaks constitute an efficient protection.

2. SOIL

Deep, slightly acid, friable, permeable, well drained, fertile clay to clay loam soils, with a 'reasonable' humus content are most suitable. The roots have a high oxygen requirement, therefore poorly drained and massive heavy clay soils should be avoided.

Subsoil moisture must be present at all times, but the topsoil must be drier for some part of the year to initiate flower buds through moisture stress.

Sandy soils are satisfactory if underlain by a subsoil with a higher clay content.

Adverse soil structure, low moisture-holding capacity, and low base status are often offset by the use of a grass mulch.

pH range : 5.2 - 7.8, optimum pH: 5.6 - 6.6

Salinity : no yield reduction at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 50% at 1; 100% at 7 dS/m.

Moderate erosion hazard.

Nutrients

A high organic matter content is preferred.

N requirements are lower for shaded coffee. The most important nutrients are N and K, secondly P.

The calcium requirement is fairly high. Mg deficiency lowers the quality of the production.

Nutrient removal (kg/ha/growing cycle) for high production:

N	: 135
P ₂ O ₅	: 35
K ₂ O	: 145

Mineral deficiency symptoms

Boron	: young leaves malformed, narrow leathery leaves, short weak branches, fan branching.
Calcium	: convex cupping of leaves and corky growth on veins.
Iron	: white color between green veins on leaf; remedy is to acidify soils with ammonium sulfate.
Magnesium	: 'herring-bone' pattern on older leaves. High concentrations of K will often cause Mg deficiencies, particularly when heavily mulched.
Manganese	: olive-green terminal leaves, dark-green leaves below, mature leaves with yellow mottles.
Nitrogen	: general yellowing of whole leaf.
Phosphorus	: blue-green color of older leaves and reddish autumn tints.
Potash	: brown scorching of entire leaf margin.
Sulphur	: causes excessive N intake.
Zinc	: shortened internodes, production of small deformed narrow leaves.

Mineral toxicity symptoms

Manganese : excessive uptake of Mn occurs under influence of low pH; remedy by applying lime to increase the pH.

3. YIELDS

Rainfed

Good commercial yield
(clean green hulled beans) : 1.5 - 3.0 ton/ha
Good smallholder yield : 0.5 - 1.2 ton/ha

CLIMATIC REQUIREMENTS - ARABICA COFFEE

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitat. (mm)	1500-1600	1600-1800	1800-2000	> 2000	-	-
	1500-1400	1400-1200	1200-1000	1000-800	-	< 800
Length dry season (months:P<1/2 PET)	2.5-3	3-4	4-5	5-6	-	> 6
	2.5-2	2-1	1-0	-	-	-
Mean annual max. temp. (°C)	25-26	26-28	28-30	30-32	-	> 32
	25-24	24-22	22-20	20-18	-	< 18
Mean daily min. temp. of coldest month (°C)	15-17	17-19	19-21	21-23	-	> 23
	15-14	14-10	10-7	7-4	-	< 4
Mean annual temp. (°C)	19-18	18-16	16-15	15-14	-	< 14
	19-20	20-22	22-24	24-26	-	> 26
Mean rel.humidity dryest month (%)	55-60	60-70	70-80	80-90	-	> 90
	55-50	50-40	40-30	30-20	-	< 20
n/N of 5 dryest months	> 0.65	0.65-0.5	0.5-0	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - ARABICA COFFEE

Land Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1	1-2	2-4	4-6	-	> 6
	(2) 0-2	2-4	4-8	8-16	-	> 16
	(3) 0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo good;	Fo good;	Fo moderate	Fo imperf.	-	F1+
Drainage	groundwa. > 150 cm	groundwa. 100-150 cm			poor but drainab	poor not drainab
Physical soil characteristics (s)						
Texture/struct.	C<60s, Co, SiCL, CL	C>60s, SC, L	SCL	SL, LfS	-	Cm, SiCm C>60v, LS, LcS, cS, fs
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 200	200-150	150-100	100-50	-	< 50
CaCO ₃ (%)	0	0-1	1-2	2-5	-	> 5
Gypsum (%)	0	0-0.5	0.5-2	2-3	-	> 3
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 80	80-50	50-35	35-20	< 20	-
Sum of basic cations (cmol(+)/kg soil)	> 6.5	6.5-4	4-2.8	2.8-1.6	< 1.6	-
pH H ₂ O	6.0-5.8	5.8-5.6	5.6-5.4	5.4-5.2	< 5.2	-
	6.0-6.2	6.2-6.6	6.6-7.4	7.4-7.8	-	> 7.8
Organic carbon(%)	> 2.4	2.4-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-0.5	-	-	0.5-2	2-6	> 6
ESP (%)						

AVOCADO (*Persea americana*)

1. CLIMATE

The required mean temperature for growth is 18-26°C. Avocado is not tolerant to frost.

Avocado is grown in areas that receive a precipitation that is at least 750 mm/year. Alternating dry and wet seasons are desirable. Dry weather at flowering has little effect, unless it lasts too long when flowers drop and the crop may fail. Plenty of moisture is needed in the fruiting period.

High air humidity is desirable.

The wood is soft and brittle and susceptible to wind damage.

2. SOIL

Deep, medium to coarse soils are preferred; heavy soils with a tendency to waterlogging are not suitable. Sandy or loamy alluvial soils are desirable.

Avocado prefers well drained soils, with a water table at > 2.0 m. The crop is extremely sensitive to fluctuations in soil moisture. Excessive soil moisture and poor aeration around the roots leads to avocado rot.

Fertile soils are required.

pH range : 4.3 -8.3, optimum pH: 5.0 - 6.5

Salinity : Avocado is intolerant of saline conditions.
No yield reduction at an electrical conductivity (EC) of < 1.3 dS/m; the yield reduction is 10% at 1.8; 25% at 2.5; 50% at 3.7; 100% at 6 dS/m.

Sodicity : 50% yield reduction is observed at an exchangeable sodium percentage (ESP) of 15.

3. YIELDS

Rainfed

Good commercial yield : 2.0 - 2.5 ton/ha

CLIMATIC REQUIREMENTS - AVOCADO

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1	S2	S3	N1	N2	
	0 100	1 85	2 60	3 40	4 25	0
Annual precipitat. (mm)	1500-1400 1500-1600	1400-1200 1600-2000	1200-1000 >2000	1000-750 -	- -	< 750 -
Mean temp. of the growing cycle (°C)	22-24 22-20	24-26 20-18	26-30 18-15	>30 15-10	- -	- < 10
Mean min. temp of the coldest month (°C)	> 18	18-16	16-13	13-8	-	< 8
Length of the dry season (months)	2.5-2 2.5-3	2-1 3-4	< 1 4-5	- > 6	- -	- -

LANDSCAPE AND SOIL REQUIREMENTS - AVOCADO

Land Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - -	> 6 > 16 > 30
Wetness (w)						
Flooding	Fo	-	-	-	-	Fl+
Drainage	good water- table>2m	good water- table<2m	moder.	imperf.	poor but drainab	poor not drainab
Physical soil characteristics (s)						
Texture/struct.	SL,CL,LS L,SiCL	LcS,SCL, fS	SC,SiCs, S	C>60s, C<60v	-	Cm,SiCm C>60v
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 150	150-100	100-75	75-50	-	< 50
CaCO ₃ (%)	0	< 1	1-4	4-10	-	> 10
Gypsum (%)						
Soil fertility characteristics(f)						
Apparent CEC (cmol+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic ca- tions (cmol+)/kg soil)	> 4	4-2.8	2.8-1.6	< 1.6	-	-
pH H ₂ O	5.8-5.5 5.8-6.0	5.5-5.0 6.0-6.5	5.0-4.6 6.5-7.5	4.6-4.3 7.5-8.3	< 4.3	> 8.3
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-2	2-3	3-4	4-5	-	> 5
ESP (%)	0-5	5-10	10-15	15-20	-	> 20

BANANA (Musa spp.)

1. CLIMATE

The optimal mean monthly air temperature for the growth of banana is 25-28°C. A reduced growth is observed at temperatures < 22°C.

The lowest mean annual temperature for growth is 14°C. Plantation chilling occurs when the winter temperature falls below 10°C. 12 hours exposure to temperatures < 7°C generally causes chilling injury. High temperatures result in leaf and fruit scorch.

Small changes in altitude may have a significant effect on the period to shooting, e.g. in Martinique :

Altitude (m)	0 - 137	183 - 365	397 - 641
Months to shooting	6 - 7	9 - 10	11 - 13
approx. temp.drop (°C)	-	1	3

The optimal precipitation amounts to 1500 - 2500 mm/year. Well distributed rainfall is best, but bananas can equally be grown in areas with a pronounced dry season. Drought however lowers the quality of the fruit.

A high relative air humidity is desirable : > 60 % is preferred.

A maximum of sunshine required.

Wind damage represents a major source of loss in production, especially where the nematode *Radopholus similis* weakens the roots. A total loss occurs at wind speeds above 100 km/h.

2. SOIL

Freely drained, well-aerated, deep, fertile loamy soils are preferred, though bananas are produced on a wide range of soil types. The maximum rooting depth of the crop is 0.90 m. Mulching however leads to a reasonable production on sandy soils.

A high available water content (AWC) is needed in order to prevent possible damage due to moisture stress.

Roots do not tolerate waterlogging.

Erosion hazard: on sloping areas conservation practices are necessary.

pH range : 4.5 - 8.2, optimum pH: 5.6 - 7.5

Salinity : < 500 ppm salt in the soil ; no yield reduction at an electrical conductivity (EC) of < 1 dS/m;

Sodicity : no hazard at an exchangeable sodium percentage (ESP) below 4 ; 50 % yield reduction is observed at an ESP of 15.

Micronutrients

Zinc : deficiency associated with high levels of Truog acid-soluble phosphate. Deficiency at pH > 6. Available after P- fertilization.

Magnesium : deficiency at < 1 cmol(+)/kg soil. .

Nutrients

Banana requires soils of high fertility, with high N and K levels. A C/N ratio of the organic matter of < 20 is preferred.

	Adequate levels	Critical levels
N	1200 ppm	
P	50 - 100 ppm	20 ppm
K	300 - 350 ppm	150 ppm

Nutrient removal (kg/ha/growing cycle) to produce 25 ton/ha:

N	17 - 28
P ₂ O ₅	6 - 7
K ₂ O	56 - 78

Fertilizer application (kg/ha/growing cycle) to produce 30 ton/ha:

	min.	max.
N	50	90
P ₂ O ₅	60	100
K ₂ O	150	250

Cation balance: CaO/MgO/K₂O = 10/5/0.5

CaO > or = 2 x MgO

MgO/K₂O = 4 - 25 (> 25 = K deficiency).

Mineral deficiency symptoms

Calcium : yellow bands along leaf margins.

Iron : interveinal chlorosis on young leaves.

Magnesium : interveinal chlorosis with wavy leaf margins.

Manganese : spots on leaves and fruits, caused by high soil pH.

Nitrogen : slow growth, stunting, yellowish-green leaves.

Phosphorus: slow growth, caused by marginal scorching of leaves.

Potassium : marginal yellowing of leaves. Acute: leaves turn bright yellow. Nematode attack may accentuate K deficiency.

Zinc : produces bunched top effect.

3. YIELDS

Rainfed

Good commercial yield : 30 - 35 ton/ha.

Average farmer yield : 15 - 25 ton/ha (1500 trees).

Irrigated

Good commercial yield : 40 - 60 ton/ha.

Average farmer yield : 35 - 50 ton/ha.

CLIMATIC REQUIREMENTS - BANANA

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitat. (mm)	> 1800	1800-1500	1500-1250	1250-1000	-	< 1000
Length dry season (months : p<1/2PET)	0-1	1-3	3-4	4-6	-	> 6
Mean annual temp. (°C)	> 22	22-18	18-16	16-14	-	< 14
Average min. temp. coldest month (°C)	> 20	20-15	15-8	8-2	-	< 2
Absolute min. temp. coldest month (°C)	> 12	12-8	8-0	0 to -2	-	< -2

LANDSCAPE AND SOIL REQUIREMENTS - BANANA

Land Characteristics	Class, degree of limitation and rating scale.					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	F1	F2	-	F3+
Drainage	good	moder.	imperf.	poor and aeric	poor but drainab	poor not drainab
Physical soil characteristics (s)						
Texture/struct.	C<60s, Co, SiCs, SiCL, CL, SiL	C>60s, C<60v, SC, L	C>60v, SCL	SL, LfS, LS	-	Cm, SiCm fs, S, cS
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 100	100-75	75-50	50-25	-	< 25
CaCO ₃ (%)	0	< 5	5-10	10-15	-	> 15
Gypsum (%)	0	< 1	1-4	4-10	-	> 10
Soil fertility characteristics(f)						
Apparent CECclay (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg soil)	> 6.5	6.5-4	4-2.8	-	-	-
pH H ₂ O	6.4-5.8	5.8-5.6	5.6-5.2	5.2-4.5	< 4.5	-
	6.4-7.0	7.0-7.5	7.5-8.0	8.0-8.2	-	> 8.2
Organic carbon(%)	> 2.4	2.4-1.5	1.5-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-4	4-6	6-8	> 8
ESP (%)	0-2	2-4	4-8	8-12	12-16	> 16

BARLEY (*Hordeum vulgare*)

1. CLIMATE

Barley is produced in areas with an average temperature in the growing cycle of < 20°C. Chilling is required for flowering.

The precipitation should be well distributed in the growing cycle and amount to 300 - 1100 mm/growing cycle.

A low or medium relative air humidity is desirable. Hot dry winds after heading reduce the grain yield.

2. SOIL

The crop prefers deep (1.5-2.0 m), well drained and warm soils with medium soil textures. The maximum rooting depth of the crop is 1.50 m. Barley is intolerant of waterlogging. The water table should be at a depth of > 0.60 m.

pH range : 5.5 -8.5, optimum pH: 6.2 - 8.0

Salinity : no yield reduction at an electrical conductivity (EC) of < 8 dS/m; the yield reduction is 10% at 12; 25% at 16; 50% at 18; 100% at 28 dS/m.

Sodicity : 50% yield reduction at an exchangeable sodium percent age (ESP) of 35.

Micronutrients

Copper : high response to application.
Boron : 1-2 mg in soil solution.

3. YIELDS

Rainfed

Good commercial yield : 2 - 3 ton/ha.

Irrigated

Good commercial yield : 3 - 4 ton/ha.

CLIMATIC REQUIREMENTS - BARLEY (growing cycle 120-156 days)

Climatic Characteristics	Climatic class, degree of limitation and rating						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of growing cycle(mm)	650-400 650-900	400-300 900-1100	300-200 1100-1300	200-150 1300-1500	-	< 150 > 1500	
Monthly rainfall vegetat.stage (mm) (2nd month)	60-35 60-80	35-15 80-95	15-10 95-120	10-5 > 120	-	< 5 -	
Monthly rainfall flowering stage(mm) (3rd month)	60-45 60-70	45-20 70-90	20-10 90-120	10-0 > 120	-	-	
Mean temp. of the vegetative stage (2nd month) (°C)	10-8 10-12	8-6 12-18	6-4 18-24	4-2 24-28	-	< 2 > 28	
Mean temp. of the flowering stage (3rd month) (°C)	18-14 18-22	14-12 22-26	12-10 26-32	10-8 32-36	-	< 8 > 36	
Mean temp. of the ripening stage (4-5th month) (°C)	20-16 20-24	16-14 24-30	14-12 30-36	12-10 36-42	-	< 10 > 42	
Average daily min. temp. coldest month combined with average daily max. temp. coldest month (°C)	< 8	-	< 8 if < 21	8-13 if > 21	-	> 13	

LANDSCAPE AND SOIL REQUIREMENTS - BARLEY

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-8	8-12	12-16	-	> 16
(3)	0-4	4-8	8-16	16-24	24-30	> 30
Wetness (w)						
Flooding (4)	Fo good	- moderate	F1 imperf.	F2 poor and aeric	- poor but drainab	F3+ poor not drainab
Drainage (5)	imperfect	moderate	good			
Physical soil characteristics (s)						
Texture/struct.	C<60s,Co, SiCs,SiCL Si,SiL,CL	C<60v,SC C>60s,L	C>60v, SCL	SL,LfS	-	Cm,SiCm LcS,fS cS,S
Coarse fragm.(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 90	90-50	50-20	20-10	-	< 10
CaCO ₃ (%)	3-20	20-30	30-40	40-60	-	> 60
Gypsum (%)	0-3	3-5	5-10	10-20	-	> 20
Soil fertility characteristics(f)						
Apparent CEC (cmol+)/kg clay	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 60	80-50	50-35	< 35	-	-
Sum of basic cations (cmol+)/kg)	> 8	8-5	5-3.5	3.5-2	< 2	-
pH H ₂ O	7.2-7.0	7.0-6.2	6.2-5.8	5.8-5.5	< 5.5	-
	7.2-7.5	7.5-8.0	8.0-8.2	8.2-8.5	-	> 8.5
Organic carbon(%)						
(6)	> 2.0	2.0-1.2	1.2-0.8	< 0.8	-	-
(7)	> 1.2	1.2-0.8	0.8-0.4	< 0.4	-	-
(8)	> 0.6	0.6-0.4	< 0.4	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-8	8-12	12-16	16-20	20-25	> 25
ESP (%)	0-15	15-25	25-35	35-45	-	> 45

BEANS
(*Phaseolus vulgaris*)

1. CLIMATE

Beans are not grown in the lowland humid tropics. The common temperature range for beans is 18-30°C. The optimum temperature range is 15-20°C. The soil temperature for germination should be > 15°C. The crop is sensitive to temperatures above 30°C, especially at flowering and seed set. Beans are sensitive to frost; flowers are damaged at 5°C.

The total precipitation should be 400 - 500 mm/growing cycle. Moisture stress should be avoided in the flowering and setting periods. Dry weather is required at harvest. Excessive rain causes flower drop and diseases.

A medium to high relative air humidity is required, especially at flowering.

Strong winds may damage the crop. Dry winds affect the pollination and therefore the yield.

2. SOIL

Beans can be grown on soils with a texture ranging from loamy sand to (kaolinitic) clay; the optimal texture is loam to clay loam.

The minimum soil depth is 0.5 m. The optimum soil depth is > 0.75 m. The maximum rooting depth of beans is 1.00 - 1.50 m. Soils that show surface capping should be avoided.

Moderately well to well drained soils are most suitable. The crop is sensitive to waterlogging; surface water standing for only a few hours damages the crop.

pH range : 5.2 - 8.2, optimum pH: 6.0 - 7.0

Salinity : no yield reduction at an electrical conductivity (EC) of < 1 dS/m; the yield reduction is 10% at 1.5; 25% at 2.3; 50% at 3.6; 100% at 6.5 dS/m

Sodicity : 50% yield reduction at an exchangeable sodium

percentage (ESP) of 15.

Micronutrients

Copper : no or low response to application.
 Boron : less than 0.1 ppm required; sensitive to excess.
 Manganese : high response to application; sensitive to deficiency.
 Magnesium : tolerant of deficiency.
 Zinc : very responsive to spraying if soil is deficient.

Nutrients

Nutrient removal (kg/ha/growing cycle) to produce 1 ton/ha of dry beans:

N : 31
 P : 3.5
 K : 6.6

Fertilizer application (kg/ha/growing cycle) for high production:

	min.	max.
N :	20	40
P :	40	60
K :	50	120

3. YIELDS

Rainfed

dry beans

Good commercial yield: 1.0 - 1.5 ton dry beans/ha.
 Average farmer yield: 0.5 - 1.0 ton dry beans/ha.

Irrigated

	dry beans	green beans
Good commercial yield:	1.5 - 2.5	6 - 8 ton/ha
Average farmer yield:	1.0 - 1.5	

4. ROTATIONS

With maize, sweet potato, cotton, wheat, onion, sorghum, potato.

CLIMATIC REQUIREMENTS - BEANS (green: growing cycle 60-90 days, dry: 90-120 days)

Climatic Characteristics	Climatic class, limitation and rating scale.					
	S1		S2		S3	
	0	1	2	3	N1	N2
	100	95	85	60	40	25
Precipitation of growing cycle (mm)	450-500 450-400	500-600 400-350	600-1000 350-300	>1000 300-250	-	< 250
Mean temp. of the growing cycle (°C)	18-20 18-15	20-24 15-12	24-27 12-10	27-30 10-8	-	> 30 < 8
Mean min.temp. of growing cycle (°C)	13-15 13-10	15-20 10-7	20-25 7-5	> 25 < 5	-	-
Relative humidity of devel.stage(%)	55-50 55-60	50-42 60-75	42-36 75-90	36-30 > 90	-	< 30 -
Relative humid. of maturation stage(%)	40-30 40-50	30-24 50-75	24-20 75-90	< 20 > 90	-	-
n/N develop.stage	0.55-0.5 0.55-0.6	0.5-0.35 0.6-0.75	< 0.35 > 0.75	-	-	-
n/N maturation stage	> 0.7	0.7-0.5	< 0.5	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - BEANS

Land Characteristics		Class, degree of limitation and rating scale					
		S1	S2	S3	N1	N2	
		0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)							
Slope (%)	(1)	0-1	1-2	2-4	4-6	-	> 6
	(2)	0-2	2-4	4-8	8-16	-	> 16
	(3)	0-4	4-8	8-16	16-30	-	> 30
Wetness (w)							
Flooding		Fo	-	-	F1	-	F2+
Drainage	(4)	good	moder.	imperf.	poor	poor	poor
	(5)	imperf.	moder.	good	and aeric	but drainab	not drainab.
Physical soil characteristics (s)							
Texture/struct.		C<60s,Co, SiCs,SiCL, CL,Si,SiL	C>60s,SC C<60v, L,SCL	C>60v,SL LFS,LS, S	LcS,fs, S	-	Cm,SiCm, cS
Coarse fragm(vol%)		0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)		> 100	100-75	75-50	50-20	-	< 20
CaCO ₃ (%)		0-6	6-12	12-20	20-25	-	> 25
Gypsum (%)		0-0.1	0.1-0.5	0.5-1	1-3	-	> 3
Soil fertility characteristics(f)							
Apparent CEC (cmol+)/kg clay)		> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)		> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol+)/kg soil)		> 5	5-3.5	3.5-2	< 2	-	-
pH H ₂ O		6.5-6.0	6.0-5.6	5.6-5.4	5.4-5.2	< 5.2	-
		6.5-7.0	7.0-7.6	7.6-8.0	8-8.2	-	> 8.2
Organic carbon(%)		> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)							
ECE (dS/m)		0	0-1	1-1.5	1.5-2	-	> 2
ESP (%)		0-2	2-5	5-8	8-12	-	> 12

CABBAGE (Brassica oleracea)

1. CLIMATE

Germination of cabbage is observed in the temperature range of 5 - 37°C. The optimum temperature for germination is 28°C. The temperature range for growth is 5 - 35°C. The temperature range for optimal growth is 15 - 20°C or an average monthly maximum of 24°C. A difference between day and night temperature of 11°C is optimal. Most varieties tolerate up to - 6°C. Long periods with temperatures of < 5°C however are harmful.

The total precipitation should be at least 250 - 300 mm/growing cycle, and is optimal at 400 - 500 mm/growing cycle .

A high relative air humidity is desirable: 60 - 90% . Below 60 % wilting occurs.

2. SOIL

Cabbage is grown on soils with a wide range of textures, but loam is preferred. Lighter soils are suitable if the rainfall is high.

The soil depth should be at least 0.20 m; the optimum soil depth is > 0.60 m.

Well aerated, moderately well to well drained soils are preferred.

pH range : 5.5 - 8.2, optimum pH: 6.2 - 7.5

Salinity : no yield reduction at an electrical conductivity (EC) of < 1.8 dS/m; the yield reduction is 10% at 2.8; 25% at 4.4; 50% at 7.0; 100% at 12 dS/m

Sodicity : 50% yield reduction at an exchangeable sodium percent age (ESP) of 20.

Micronutrients

Copper : medium response to application.
Boron : high requirements : more than 0.5 ppm in soil;

tolerant of high concentrations.
Manganese : sensitive to deficiency.
Molybdenum : sensitive to deficiency.

Nutrients

Moderate to high, well decomposed organic matter is beneficial.

Fertilizer application (kg/ha/growing cycle) to produce 20 ton/ha:

N : 150
P₂O₅ : 115
K₂O : 240

3. YIELDS

Rainfed

Good commercial yield : 35 - 50 ton/ha.
Average farmer yield : 10 - 20 ton/ha.

Irrigated

Good commercial yield : 60 - 80 ton/ha.
Average farmer yield : 20 - 40 ton/ha.

CLIMATIC REQUIREMENTS - CABBAGE (growing cycle 100-150 days)

Climatic Characteristics	Climatic class, limitation and rating.						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of growing cycle (mm)	450-400 450-500	400-350 500-800	350-300 800-1000	300-250 > 1000	-	< 250	
Mean temp. of the growing cycle (°C)	18-20 18-15	20-24 15-13	24-30 13-10	30-35 10-5	-	> 35 < 5	
Mean temp at germination(°C)	28-25 28-30	25-20 30-32	20-15 32-35	15-5 35-37	-	< 5 > 37	
Temp. difference day/night (°C)	11-10 11-12	10-8 12-14	8-4 14-16	4-2 16-18	-	< 2 > 18	
Relative humidity of growing cycle	80-75 80-85	75-65 85-90	65-60 90-95	60-50 > 95	-	< 50 -	

LANDSCAPE AND SOIL REQUIREMENTS - CABBAGE

Land Characteristics	Class, degree of limitation and rating scale.						
	0 100	S1 95	1 85	S2 60	S3 40	N1 25	N2 0
Topography (t)							
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - -	> 6 > 16 > 30	
Wetness (w)							
Flooding	Fo	-	-	-	-	F1+	
Drainage	(4) good (5) imperf.	moderate moderate	imperf. good	poor and aeric	poor but drainab	poor not drainab	
Physical soil characteristics (s)							
Texture/struct.	L, SCL	SiC, Sl, SC,C<60s	LS,LfS, fS,C>60s	C>60v, S	-	Cm,SiCm	
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55	
Soil depth (cm)	> 75	75-60	60-50	50-20	-	< 20	
CaCO ₃ (%)	0-6	6-15	15-25	25-35	-	> 35	
Gypsum (%)	0-2	2-4	4-10	10-20	-	> 20	
Soil fertility characteristics(f)							
Apparent CEC (cmol+)/kg clay	> 24	24-16	< 16(-)	< 16(+)	-	-	
Base saturation(%)	> 50	50-35	35-20	< 20	-	-	
Sum of basic cations (cmol+)/kg soil	> 5	5-3.5	3.5-2	< 2	-	-	
pH H ₂ O	6.8-6.2	6.2-6.0	6.0-5.8	5.8-5.5	< 5.5	-	
	6.8-7.5	7.5-7.8	7.8-8.0	8.0-8.2	-	> 8.2	
Organic carbon(%)	> 1.5	1.5-0.8	< 0.8	-	-	-	
Salinity and Alkalinity (n)							
ECe (dS/m)	0-3	3-4.5	4.5-7	7-10	-	> 10	
ESP (%)	0-8	8-15	15-20	20-25	-	> 25	

CARROTS
(*Daucus carota*)

1. CLIMATE

Germination of carrots is observed at temperatures between 4 and 35°C. The optimum temperature range for germination is 6 - 28°C.

The temperature range for growth is 4 - 35°C. The optimum temperature range for growth is 16 - 22°C.

Young seedlings are easily killed if the temperature is too high.

High temperatures result in poor flavour and pale short roots. Too low temperatures may induce flowering in some varieties.

The precipitation should be approximately 300 - 350 mm/growing cycle.

High relative air humidity may induce diseases.

2. SOIL

Sandy to loamy soils are preferred. Clayey soils are not suitable. The soils should be well drained and at least 0.60 m deep. The optimum soil depth is > 0.90 m.

pH range : 5.2 - 8.2, optimum pH: 6.0 - 7.0

Salinity : no yield reduction at an electrical conductivity (EC) of < 1 dS/m; the yield reduction is 10% at 1.5; 25% at 2.5; 50% at 4.5; 100% at 8 dS/m

Sodicity : 50% yield reduction at an exchangeable sodium percent age (ESP) of 35.

Micronutrients

Copper : high response to application.

Boron : 0.1 - 0.5 ppm required in the soil; tolerant of high concentrations and sensitive to deficiency.

Manganese : medium response to application.

Nutrients

The soil fertility should be high; the organic matter content however should only be moderately high.

3. YIELDS

Rainfed

Good commercial yield : 18 - 20 ton/ha.

Irrigated

Good commercial yield : 30 - 38 ton/ha.

CLIMATIC REQUIREMENTS - CARROTS (growing cycle 100-150 days)

Climatic Characteristics	Climatic class, degree of limitation and rating						
	0 100	S1 95	1 85	S2 2 60	S3 3 40	N1 4 25	N2 0
Precipitation of growing cycle (mm)	325-300 325-350	300-250 350-400	250-200 400-600	200-150 600-1000	- -	< 150 > 1000	
Mean temp. of the growing cycle (°C)	19-18 19-20	18-16 20-22	16-13 22-28	13-4 28-35	- -	< 4 > 35	
Mean temp. at germination (°C)	17-7 17-26	7-6 26-28	6-5 28-30	5-4 30-35	- -	< 4 > 35	
Relative humidity growing cycle (%)	60-70 60-50	70-80 50-40	80-90 40-20	> 90 < 20	- -	- -	

LANDSCAPE AND SOIL REQUIREMENTS - CARROTS

Land Characteristics	Class, degree of limitation and rating scale.						
	0 100	S1 95	1 85	S2 2 60	S3 3 40	N1 4 25	N2 0
Topography (t)							
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50	
Wetness (w)							
Flooding	Fo	-	-	-	-	F1+	
Drainage	(4) good (5) imperf.	moder. moder.	imperf. good	poor and aeric	poor but drainab	poor not drainab	
Physical soil characteristics (s)							
Texture/struct.	L,SL,LfS	LS,SCL, SiCL	SiCs,SC, S,fS,LcS	C<60v,Co C>60s	-	Cm,SiCm C>60v	
Coarse fragm.(vol%)	0-3	3-15	15-35	35-55	-	> 55	
Soil depth (cm)	> 100	100-90	90-75	75-60	-	< 60	
CaCO ₃ (%)	0-3	3-5	5-10	10-20	-	> 20	
Gypsum (%)	0-1	1-2	2-3	3-5	-	> 5	
Soil fertility characteristics(f)							
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-	
Base saturation(%)	> 50	50-35	35-20	< 20	-	-	
Sum of basic cations (cmol(+)/kg soil)	> 4	4-2.8	2.8-1.6	< 1.6	-	-	
pH H ₂ O	6.3-6.2 6.3-6.4	6.2-6.0 6.4-7.0	6.0-5.7 7.0-7.6	5.7-5.2 7.6-8.2	< 5.2 -	- > 8.2	
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-	
Salinity and Alkalinity (n)							
ECe (dS/m)	0-1	1-1.5	1.5-4.5	4.5-7	-	> 7	
ESP (%)	0-10	10-20	20-35	35-50	-	> 50	

CASHEW (*Anacardium occidentale*)

1. CLIMATE

For the cultivation of cashew hot conditions are preferred. The temperature range for growth is 12 - 32°C; the optimum temperature is 24 - 30°C. Frost can damage the crop.

Cashew is a drought resistant crop. Dry weather is required at peak flowering and at harvesting. In the absense of dry weather black nuts are formed and rot occurs. The required precipitation ranges from 500 - 3800 mm/year.

The relative air humidity should be at least 20 - 25 %.

2. SOIL

Deep, light to medium soil textures are preferred. Cashew can nevertheless be grown on a wide range of soils, from pure sands to laterites as long as they are well drained. Shallow soils or heavy clay soils are unsuitable.

pH range : 4.5-8.5, optimum pH: 5.5 - 7.0

Salinity : no yield reduction is observed at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 10% at 1.0; 25% at 2.0; 50% at 3.0; 100% at 6 dS/m.

3. YIELDS

Rainfed

Good commercial yield : 3 ton/ha.

CLIMATIC REQUIREMENTS - CASHEW

CLIMATIC REQUIREMENTS - CASHEN						
Climatic Characteristics	Climatic class, limitation and rating scale					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitat. (mm)	1800-1600 1800-2000	1600-1200 2000-3000	1200-800 3000-3800	800-500 > 3800	-	< 500
Length dry season (months: P<1/2 PET)	2.5-3 2.5-2	3-4 2-0	4-5 -	5-6 -	-	> 6
Mean annual temp. (°C)	> 25	25-22	22-20	< 20	-	-
Mean min. temp. of coldest month (°C)	> 13	13-10	10-8	8-4	-	< 4

LANDSCAPE AND SOIL REQUIREMENTS - CASHEW

Land Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding (4)	Fo good	- moderate	- imperf.+	- imperf.+	- poor	F1+ poor
Drainage (5)	moderate	good	fluct. groundw.	permanent high groundw.	but drainab	not drainab
Physical soil characteristics (s)						
Texture/struct.	C<60s,SiC Co,SiCL, CL,SiL,SC	C>60s,L C<60v, LfS,SCL	C>60v,fS LcS	S,cS	-	Cm,SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 150	150-100	100-50	50-25	-	< 25
CaCO ₃ (%)						
Gypsum (%)						
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	any	-	-	-	-	-
Base saturation(%)	> 35	35-20	< 20	-	-	-
Sum of basic cations (cmol(+)/kg soil)	> 2.8	2.8-1.6	< 1.6	-	-	-
pH H ₂ O	6.0-5.5	5.5-5.2	5.2-4.8	4.8-4.5	< 4.5	-
Organic carbon(%)	6.0-7.0	7.0-7.5	7.5-8.0	8.0-8.5	-	> 8.5
	> 1.5	1.5-0.8	< 0.8	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-3	3-4	-	> 4
ESP (%)	0-15					> 15

CASSAVA (Manihot esculenta)

1. CLIMATE

The temperature range for growth is 12 - 35°C. At less than 15°C there is a premature leaf shedding and slow growth. Too low temperatures and frost damage and kill the crop.

The required total precipitation ranges from 500 - 5000 mm/year. The optimum amount of rainfall is 1400 - 1800 mm/year. Cassava can survive a prolonged period of drought during the growing season but not at the time of planting.

2. SOIL

Sandy loam to (kaolinitic) clay textured soils are suitable for cassava growing. Loam to sandy clay loam textured soils are most suitable.

The soil depth should be at least 0.50 m; the optimum soil depth is > 1.00 m.

Moderately well to somewhat excessively drained soils are preferred. Cassava is sensitive to waterlogging. No flooding should occur.

Medium erosion hazard.

pH range : 4.5 - 8.2, optimum pH: 5.2 - 7.0
liming is required at pH values < 5.0

Salinity : no yield reduction is observed at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 10% at 1 ; 25% at 2 ; 50% at 3 ; 100% at 7 dS/m.

Nutrients

Cassava can grow on poor soils . On very fertile soils the vegetative growth is very luxuriant at the expense of the roots.

Nutrient removal (kg/ha/growing cycle) to produce 20 ton roots/ha

N : 125
P₂O₅ : 30
K₂O : 150

Fertilizer application (kg/ha/growing cycle) to produce 80 ton roots/ha.

	min.	max.
N	50	90
P ₂ O ₅	60	75
K ₂ O	80	120

3. YIELDS

Rainfed

High yielding cultivars :	> 50 ton/ha.	} fresh weight of tubers
Good commercial yield :	30 - 40 ton/ha.	
Average farmer yield :	5 - 15 ton/ha.	

Irrigated

Good commercial yield : 35 - 50 ton/ha.
Average farmer yield : 25 - 30 ton/ha.

CLIMATIC REQUIREMENTS - CASSAVA

Climatic Characteristics	Climatic class, degree of limitation and rating						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Annual precipitat. (mm)	1600-1400 1600-1800	1400-1000 1800-2400	1000-600 > 2400	600-500 -	-	-	< 500
Length dry season (months P < 1/2PET)	3.5-4 3.5-3	4-5 3-1	5-6 < 1	6-7	-	-	> 7
Mean annual temp. (°C)	23-20 23-26	20-18 26-30	18-16 > 30	16-12	-	-	< 12
Absolute min. temp. of coldest month (°C)	> 16	16-10	10-2	+2 to -2	-	-	< -2
Mean min. temp. of growing cycle (°C)	17-16 17-18	16-12 18-24	12-9 > 24	9-7 -	-	-	< 7
n/N of the 5 dryest months	> 0.7	0.7-0.55	< 0.55	-	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - CASSAVA

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 80	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	-	-	F1+
Drainage	good	-	moderate	imperf.	poor but drainab	poor not drainab
Physical soil characteristics (s)						
Texture/struct.	L,SCL	SL,C<60s, SiC,Co,CL SiCL,SC	C>60s,LfS C<60v,LcS LS,fs	C<60v, S,cS	-	Cm,SiCm
Coarse fragm.(vol%) surface	0-1	1-3	3-15	15-35	-	> 35
depth	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 125	125-100	100-75	75-50	-	< 50
CaCO ₃ (%)	0-0.5	0.5-1	1-5	5-10	-	> 10
Gypsum (%)	0-0.1	0.1-0.2	0.2-1	1-2	-	> 2
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 16	any	-	-	-	-
Base saturation(%)	> 35	35-20	< 20	-	-	-
Sum of basic cations (cmol(+)/kg soil)	> 3.5	3.5-2	< 2	-	-	-
pH H ₂ O	6.0-5.5	5.5-5.2	5.2-4.8	4.8-4.5	< 4.5	-
Organic carbon (%)	6.0-6.5	6.5-7.0	7.0-7.6	7.6-8.2	-	> 8.2
	> 1.5	1.5-0.8	< 0.8	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-3	3-4	4-6	> 6
ESP (%)						

CASTOR BEANS (*Ricinus communis*)

1. CLIMATE

The best temperature range for planting castor beans is 20 - 37 °C; the optimum planting temperature is 35°C. At germination the soil temperature should be in the range of 10 - 20°C; optimum germination is obtained at temperatures between 15°C and 20 °C.

The temperature range for growth is 16 - 32°C. The growth of castor beans is optimal at 24 - 30°C.

The seeds get badly affected if, at flowering, the air temperature rises above 40°C. The result is even worse if high temperatures are combined with moisture stress. The crop is sensitive to cold. A temperature of - 2 °C for 4 hours kills the crop.

A total precipitation between 500 mm and 1800 mm/growing cycle is required by the crop. The optimal total precipitation is 700 - 1400 mm/ growing cycle.

Though castor beans are resistant to drought, at least 5 months of rainy season a year are needed. No heavy rains should occur during flowering.

The optimum relative air humidity is 30-50 %.

2. SOIL

Castor beans can grow on extremely coarse textured (gravel) to fine textured (silty clay) soils. Nevertheless a sandy loam to loam texture is preferred. The soils should be deep (> 1.5 m) and have no compact layers.

Preference is given to well drained soils. The crop is intolerant of waterlogging.

pH range: 5.0 - 7.5, optimum pH: 6.0 - 7.0

Salinity: no yield reduction at an electrical conductivity (EC) of < 1 dS/m; the yield reduction is 10% at 2; 25% at 4; 50% at 6; 100% at 10 dS/m.

Sodicity: 50% yield reduction at an exchangeable sodium percentage (ESP) of 20.

Nutrients

Castor beans require moderately fertile soils and are considered to be a soil exhausting crop.

3. YIELDS

Rainfed

Good commercial yield of seeds : 2 ton/ha.

Irrigated

Good commercial yield of seeds : 3 ton/ha.

CLIMATIC REQUIREMENTS - CASTOR BEANS (growing cycle 180-200 days)

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1	1	S2	S3	N1	N2
	0 100	95	85	60	40	25
Precipitation of growing cycle (mm)	1000-1200 1000-800	1200-1400 800-700	1400-1800 700-600	> 1800 600-500	- -	- < 500
Mean temp. of the growing cycle (°C)	27-28 27-26	28-30 26-24	30-32 24-20	> 32 20-16	- -	- < 16
Mean temp. of the initial stage (°C)	17-18 17-16	18-20 16-14	> 20 14-12	- 12-10	- -	- < 10
Relative humidity of maturation stage (%)	40-30 40-50	30-24 50-75	24-20 75-90	< 20 > 90	- -	- -

LANDSCAPE AND SOIL REQUIREMENTS - CASTOR BEANS

Land Characteristics		Class, degree of limitation and rating scale					
		S1		S2	S3	N1	N2
		0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)							
Slope (%)	(1)	0-1	1-2	2-4	4-6	-	> 6
	(2)	0-2	2-4	4-8	8-16	-	> 16
	(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)							
Flooding	Fo	-	-	-	-	-	F1+
Drainage	(4) good	moder.	imperf.	poor	poor	poor	poor
	(5) imperf.	moder.	good	and aeric	but drainab	not drainab	
Physical soil characteristics (s)							
Texture/struct.	L,SL	SCL,SiCL LFS,CL	C<60v,SiC C>60s,LS	C>60v,fs S,LcS	-	Cm,SiCm	
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55	
Soil depth (cm)	>150	150-100	100-75	75-50	-	< 50	
CaCO ₃ (%)							
Gypsum (%)							
Soil fertility characteristics(f)							
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-	
Base saturation(%)	> 50	50-35	35-20	< 20	-	-	
Sum of basic cations (cmol(+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-	
pH H ₂ O	6.5-6.2	6.2-6.0	6.0-5.5	5.5-5.0	< 5.0	-	
	6.5-6.8	6.8-7.0	7.0-7.2	7.2-7.5	-	> 7.5	
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-	
Salinity and Alkalinity (n)							
ECe (dS/m)	0-2	2-4	4-6	6-8	-	> 8	
ESP (%)	0-8	8-15	15-20	20-25	-	> 25	

CHICKPEA (*Cicer arietinum*)

1. CLIMATE

Chickpea has a growing cycle of 4 - 6 months. The crop performs best at air temperatures between 20 -25°C. Though a cool and dry climate is preferred, the crop is not frost tolerant. Cool nights with dew are necessary.

Chickpea does not tolerate heavy rains and is drought resistant. The crop is not suited to the wet hot tropics where it often fails to flower.

High insolation is preferred.

2. SOILS

Well-drained clayey soils with a high available water content are most suitable for chickpea growing. On Vertisols the crop is sown at the end of the rainy season.

pH range: 5.2 - 8.2; optimum pH : 6.0 - 7.6

Sodicity: 50 % yield reduction is observed at an ESP of 15.

CaCO₃ content: optimal 0 - 25 % (range 0 - 50 %).

Gypsum content: optimal 0 - 0.3 % (range 0 - 15 %).

Nutrients

Generally the crop shows no response to fertilizers. Only on P-deficient soils a response to P-applications is observed. Very fertile soils favor an excessive vegetative growth.

3. YIELD

Rainfed

Yield under good management : 1.5 ton/ha.
Average farmer yield : 0.7 ton/ha.

Irrigated

Average yield : 1.0 - 1.5 ton/ha.

CLIMATIC REQUIREMENTS - CHICKPEA (growing cycle 120-160 days)

Climatic Characteristics	Class, degree of limitation and rating scale					
	0 100	S1 95	1 85	S2 2 60	S3 3 40	N1 4 25 N2 0
Precipitation of growing cycle	> 300	300-250	250-150	150-50	-	< 50
Precipitation of the 3rd month	60-75 60-50	75-150 < 50	> 150 -	- -	- -	- -
Precipitation of the 4th month	< 60	60-120	> 120	-	-	-
Mean temp. of the growing cycle (°C)	20-21 20-18	21-23 18-16	23-25 16-14	25-28 14-12	- -	> 28 < 12

LANDSCAPE AND SOIL REQUIREMENTS - CHICKPEA

Land Characteristics	Class, degree of limitation and rating scale					
	S1		S2	S3	N1	N2
	0	1	2	3	4	0
	100	95	85	60	40	25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	F1	-	F2+
Drainage (4)	good	moder.	imperf.	poor and aeric	poor but drainab	poor not drainab
(5)	imperf.	moder.	good			
Physical soil characteristics (s)						
Texture/struct.	CL, SiL	SiCL,L, SCL,SC	Cs, SL, SiCs	LS,fS,Co SiCm	-	Cm,cS
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	>100	100-75	75-50	50-30	-	< 30
CaCO ₃ (%)	0-10	10-25	25-35	35-50	-	> 50
Gypsum (%)	0-0.1	0.1-0.3	0.3-3	3-15	-	> 15
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 80	80-50	50-35	< 35	-	-
Sum of basic cations (cmol(+)/kg soil)	> 8	8-5	5-3.5	3.5-2	< 2	-
pH H ₂ O	6.8-6.5	6.5-6.0	6.0-5.6	5.6-5.2	< 5.2	-
	6.8-7.0	7.0-7.6	7.6-8.0	8.0-8.2	-	> 8.2
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-3	3-6	-	> 6
ESP (%)	0-5	5-8	10-12	12-15	-	> 15

CITRUS
(Citrus spp.)

1. CLIMATE

Citrus spp. are mostly grown in subtropical countries below 600 m of altitude. On the equator, citrus does well below 1830 m. Citrus spp. perform well in the temperature range of 13 - 39 °C, but prefer an air temperature of 22 - 30 °C. Grapefruit can withstand long hot periods better than other citrus spp.. Flowers and young fruits are sensitive to frost.

The required average total precipitation is > 800 mm/year, unless the crop is irrigated. Citrus spp are intolerant of high air humidity, but mandarins can tolerate wetter conditions.

Strong winds may damage the crop.

2. SOIL

Since the maximum rooting depth of citrus spp. extends to 1.0-2.0 m and since the roots have a high oxygen requirement, deep, well drained (well aerated) and light soils are preferred. The most suited soil texture is sand to loam. Citrus spp. can be grown on poor sandy soils with extreme low fertility; in some cases as many as 12 essential elements (N,P,K,Mg,Ca,S,Mn,Cu,Zn,B,Fe,Mb) have to be applied for normal growth.

The crop is sensitive to waterlogging.

pH range: 5.0 - 8.2, optimum pH: 5.5 - 7.6.

Salinity: no yield reduction at an electrical conductivity (EC) of < 1.7 dS/m; the yield reduction is 10% at 2.3; 25% at 3.3; 50% at 4.8; 100% at 8 dS/m.

Sodicity : 50% yield reduction at an exchangeable sodium percentage (ESP) of 15.

Micronutrients

Boron : sensitive to excess

An excess of P can cause a micronutrient deficiency and impair N use.

Nutrients

As Mg is a weak competitor against Ca and K, dolomitic limestone should be used for liming acid soils.

An excess of Ca or K leads to Mg deficiency.

Nutrient removal (kg/ha/growing cycle) to produce 15 ton/ha of fruit:

N	:	100
P ₂ O ₅	:	25
K ₂ O	:	145

Fertilizer application (kg/ha/growing cycle) to produce 15 ton/ha of fruit:

		min.	max.

N	:	100	- 150
P ₂ O ₅	:	60	- 100
K ₂ O	:	100	- 200

Mineral deficiency symptoms

Boron : watery spots, dull, brownish-green leaves which tend to curl; small, hard, lumpy fruits, often with gummy discolorations in pith.

Copper : die-back with blisters on young branches, leaves and fruit.

Iron : interveinal chlorosis, the veins remaining green.

Phosphate : reduced growth with dull-green foliage.

Magnesium : leaves turn yellow; cured by epsom salts (MgSO₄).

Nitrogen : pale green-yellowish leaves, stunted shoots.

Zinc : mottling and reduction in leave size.

3. YIELDS

Rainfed

Good commercial yield of oranges : 25 - 40 ton/ha.

Irrigated

Good commercial yield of oranges : 25 - 40 ton/ha.
grapefruit : 40 - 60 ton/ha.
lemon : 30 - 45 ton/ha.
mandarine : 30 - 33 ton/ha.

CLIMATIC REQUIREMENTS - CITRUS

Climatic Characteristics	Climatic class, limitation and rating scale.					
		S1	S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitat. (mm)	2300-3000 2300-1500	> 3000 1500-1200	1200-1000	1000-800	-	< 800
Number of dry months (P < 1/2PET)	2.5-3 2.5-2	3-4 2-0	4-5 -	5-6 -	- -	> 6 -
Mean annual temp.(°C)	26-30 26-22	30-33 22-19	33-36 19-16	36-39 16-13	- -	> 39 < 13
No. of months with mean temp.> 38 °C	0-1	1-2	2-4	4-6	-	> 6
No. of months with mean temp. < 13°C	0-1	1-2	2-4	4-6	-	> 6
Absol. min. t° (°C)						
- lemon	> -1	-1→-2	-2→-6	-6→-9		<-9
- grapefruit	> -3	-3→-4	-4→-7.5	-7.5-9.5		<-9.5
- oranges	>-3.5	-3.5→-4	-4→-7.5	-7.5-9.5		<-9.5
- mandarines	>-4.5	-4.5→-5.5	-5.5→-8.5	-8.5→-12		<-12
Mean temp. in the 2 months aft.harvest (°C)	13-10 13-15	10-8 15-18	8-6 18-20	6-4 20-25	- -	< 4 > 25
Mean temp. of the flowering stage(°C)	> 15	15-10	10-5	5 to -5	-	< -5
Relative humidity in coldest month if frost (%)	< 30	30-60	60-90	> 90	-	-
Relative humidity at ripening stage (%)	45-60 45-30	60-70 < 30	70-90 -	> 90 -	- -	- -
Relative humidity at flowering (%)	75-70 75-80	70-50 80-90	< 50 > 90	- -	- -	- -

LANDSCAPE AND SOIL REQUIREMENTS - CITRUS

Land Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50
Wetness (w)						
Flooding	Po	-	-	-	-	F1+
Drainage	good, groundw. >150cm	good, groundw. 100-150 cm	moderate	imperf.	poor but drainab	poor not drainab
Physical soil characteristics (s)						
Texture/struct.	SL,SiL, L,SiCL, CL,Si	SCL,LS, LFS	C<60s, SC,S,fS, SiCs,Co	C<60v, C>60s	-	Cm,SiCm C>60v
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 200	200-150	150-100	100-75	-	< 75
CaCO ₃ (%)	0-3	3-5	5-10	10-25	-	> 25
Gypsum (%)	0-1	1-2	2-3	3-5	-	> 5
Soil fertility characteristics(f)						
Apparent CEC (cmol+)/kg clay)	> 16	< 16(-)	< 16(+)	-	-	-
Base saturation(%)	> 35	35-20	< 20	-	-	-
Sum of basic cations (cmol+)/kg soil)	> 3.5	3.5-2	< 2	-	-	-
pH H ₂ O	6.5-5.8 6.5-7.0	5.8-5.5 7.0-7.6	5.5-5.2 7.6-8.0	5.2-5.0 8.0-8.2	< 5.0 -	> 8.2 -
Organic carbon(%)	> 1.5	1.5-0.8	< 0.8	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-2	2-3	3-4	4-6	-	> 6
ESP (%)	0-4	4-8	8-12	12-15	-	> 15

COCOA
(*Theobroma cacao*)

1. CLIMATE

The mean air temperature should not fall below 15°C, nor rise above 30°C. The diurnal temperature range may not exceed 9°C. Since cocoa is a crop that has evolved in a forest environment shade trees are necessary, especially for young trees.

The annual total precipitation should be 1600 - 2500 mm, well distributed throughout the year and no marked dry season should occur.

The relative air humidity should be around 80 %, without important fluctuations. Excessive humidity is not directly harmful, but may enhance pests and diseases. High wind velocities may cause excessive damage.

2. SOIL

Since adequate soil aeration is absolutely essential, the total pore space should be around 66 %; the non-capillary pore space should be more than 10 %. If the annual total precipitation exceeds 3750 mm, the soils need to be very permeable.

Though the roots extend to a depth of 2.0 m, 80 % of the roots are concentrated in upper 0.15 m of the soil.

pH range: 5.0 - 8.2, optimum pH: 6.0 - 7.0
no soil layer within 1.0 m of the surface may have a pH value < 4 or > 8.

salinity: no yield reduction at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 10% at 1; 50% at 2; 100% at 3 dS/m

Micronutrients

Boron : > 0.2 ppm of hot-water-soluble boron in soil is required for proper growth; cocoa is tolerant of high B concentrations.

A high pH causes malformation of the leaves due to a lack of available Fe, Zn and Cu.

Nutrients

The ratio (K+Na)/(Mg+Ca) should be near 1/50 to obtain a good crop growth. The organic matter content is optimal at levels above 3 %.

Optimum level of exchangeable cations:

Ca	> 8	cmol(+)/kg soil
Mg	> 2	cmol(+)/kg soil
K	> 0.24	cmol(+)/kg soil

Optimum base saturation: > 35 % in the subsurface layers.

Optimum CEC in the surface soil: > 12 cmol(+)/kg soil
Optimum CEC in the subsoil : > 5 cmol(+)/kg soil

Nutrient removal (kg/ha/growing cycle) to produce 1 ton of beans/ha:

N	:	20 - 25
P ₂ O ₅	:	10
K ₂ O	:	15

Fertilizer application (kg/ha/growing cycle) to produce 1 ton of beans/ha:

	min.	max.
N	35	60
P ₂ O ₅	25	50
K ₂ O	55	75

Mineral deficiency and toxicity symptoms

Aluminium : on very acid soils: pale interveinal region near the tip of older leaves.
Iron : at a pH > 7 and in the presence of free CaCO₃ : dark green veins with pale green between.
Magnesium : on acid soils: old leaves turn pale green.
Manganese : on very acid soils: younger leaves with irregular pale areas.
Nitrogen : small leaves, pale yellowish color.
Phosphorus : mature leaves are paler towards tip and margin.
Potash : older leaves appear pale yellow between veins.

Phosphorus : mature leaves are paler towards tip and margin.
Potash : older leaves appear pale yellow between veins.
Zinc : at high pH or when soil compaction occurs, causing lack of aeration; leaves are narrow and malformed.

Note: young leaves are naturally pale reddish brown.

3. YIELDS

Rainfed

Good commercial yield of dried beans : 1.5 - 2.5 ton/ha.
Smallholder yield : 0.8 - 1.5 ton/ha.

CLIMATIC REQUIREMENTS - COCOA

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	0 25
Annual precipitat. (mm)	1900-1800 1900-2000	1800-1600 2000-2500	1600-1400 2500-3500	1400-1200 3500-4400	- -	< 1200 > 4400
Length dry season (months P < 1/2PET)	0-1	1-2	2-3	3-4	-	> 4
Mean annual temp. (°C)	26-25 26-28	25-23 28-29	23-22 29-30	22-21 -	- -	< 21 > 30
Mean annual max. temp. (°C)	< 28	28-30	> 30	-	-	-
Mean annual min. temp. (°C)	> 20	20-15	15-13	13-10	-	< 10
Relative humidity dryest month (%)						
	55-45	45-40	40-35	35-30	< 30	-
(2)	55-60	60-65	65-75	75-85	> 85	-
(3)	50-45	45-40	40-35	35-30	< 30	-
	50-55	55-60	60-65	65-75	> 75	-

LANDSCAPE AND SOIL REQUIREMENTS - COCOA

Land Characteristics	Class, degree of limitation and rating scale.						
	S1		S2	S3	N1	N2	0
	0	1	2	3	4		
	100	95	85	60	40	25	
Topography (t)							
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6	
(2)	0-2	2-4	4-8	8-16	-	> 16	
(3)	0-4	4-8	8-16	16-30	30-50	> 50	
Wetness (w)							
Flooding	Fo	-	-	F1	-	F2+	
Drainage	good: groundw. > 150cm	good: groundw. 100-150 cm	moderate	imperf.	poor	very poor	
Physical soil characteristics (s)							
Texture/struct.	C<60s,Co SiCL,CL SiL	C>60s,L, SC	SCL, C<60v	C>60v, LfS,SL	-	Cm,SiCm LS,LcS, fS,S,cS	
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55	
Soil depth (cm)	> 200	200-150	150-100	100-50	-	< 50	
CaCO ₃ (%)	0	0-1	1-5	5-10	-	> 10	
Gypsum (%)	0	0-0.5	0.5-2	2-3	-	> 3	
Soil fertility characteristics(f)							
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-	
Base saturation(%)	> 50	50-35	35-20	< 20	-	-	
Sum of basic cations (cmol(+)/kg soil)	> 6.5	6.5-4	4-2.8	2.8-1.6	< 1.6	-	
pH H ₂ O	6.4-6.2	6.2-6.0	6.0-5.5	5.5-5.0	< 5.0	-	
	6.4-6.6	6.6-7.0	7.0-7.6	7.6-8.2	-	> 8.2	
Organic carbon(%)	> 2.4	2.4-1.5	1.5-0.8	< 0.8	-	-	
Salinity and Alkalinity (n)							
ECe (dS/m)	0-0.5	0.5-1.1	1.1-1.8	1.8-2.2	-	> 2.2	
ESP (%)							

COCONUT
(*Cocos nucifera*)

1. CLIMATE

Coconut requires warm and sunny conditions, without too great a diurnal variation in temperature. The ideal mean annual temperature is approximately 29 °C. The crop does not flourish if the mean annual temperature falls below 20°C.

The annual total precipitation should exceed at least 1000 mm and be well distributed over the year. For optimal conditions the annual rainfall should go beyond 1600 mm/year. Coconut tolerates up to 3800 mm/year, provided the soil drainage is good.

Drought reduces the number of nuts. Therefore the dry season should take less than 3 months.

The optimal mean annual relative air humidity is at least 60% and above.

2. SOIL

Light to well structured heavier soil textures are preferred. Coconut does well on alluvial soils and sandy soils near the coast, where the ebb and flow of the ground water contributes to palm nourishment.

The required minimum soil depth is 0.5 m. Coconut requires well drained conditions.

pH range: 4.5 - 8.5, optimum pH: 5.2 - 7.5

Salinity: no yield reduction at an electrical conductivity (EC) of < 4 dS/m; the yield reduction is 10% at 8; 25% at 12; 50% at 16; 100% at 25 dS/m.

Nutrients

Fertilizer application (kg/ha/growing cycle) for high production :

N : 74
P₂O₅ : 30

K₂O : 137
CaO : 18
MgO : 32

3. YIELDS

Rainfed

Good commercial yield : 3.0 - 3.7 ton copra/ha.

CLIMATIC REQUIREMENTS - COCONUT

	Climatic class, degree of limitation and rating scale					
Climatic Characteristics	S1 0 1 100 95		S2 2 85	S3 3 60	N1 4 40	N2 25 0
Annual precipitat. (mm)	> 2000	2000-1600	1600-1250	1250-1000	-	< 1000
Length dry season (months) P<1/2 PET	0-1	1-2	2-3	3-4	-	> 4
Mean annual temp. (°C)	29-26 29-32	26-24 > 32	24-22 -	22-20 -	- -	< 20 -
Mean annual rel. humidity (%)	> 75	75-60	60-50	< 50	-	-

LANDSCAPE AND SOIL REQUIREMENTS - COCONUT

Land Characteristics		Class, degree of limitation and rating scale									
		S1		S2		S3		N1		N2	
		0	1	2	3	4					
		100	95	85	60	40	25	0			
Topography (t)											
Slope (%)	(1)	0-1	1-2	2-4	4-6	-	> 6				
	(2)	0-2	2-4	4-8	8-16	-	> 16				
	(3)	0-4	4-8	8-16	16-30	30-50	> 50				
Wetness (w)											
Flooding	Fo	-	-	F1	-	F2+					
Drainage	good	moderate	imperf. fluctuat groundw.	imperf. almost always high groundw.	poor, drainab	very poor, not drainab					
Physical soil characteristics (s)											
Texture/struct.	C<60s, Co, SiC, SiCL, CL, SiL, SC	C>60s, SL, L, SCL, SL, LfS, LS	LcS, fS, C<60v	S, cS, C>60v	-	Cm, SiCm					
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55					
Soil depth (cm)	> 100	100-75	75-50	50-25	-	< 25					
CaCO ₃ (%)											
Gypsum (%)											
Soil fertility characteristics(f)											
Apparent CEC (cmol(+)/kg clay)	any	-	-	-	-	-					
Base saturation(%)	> 35	35-20	< 20	-	-	-					
Sum of basic cations (cmol(+)/kg soil)	> 2.8	2.8-1.6	< 1.6	-	-	-					
pH H ₂ O	6.3-5.6	5.6-5.2	5.2-4.8	4.8-4.5	< 4.5	-					
	6.3-7.0	7.0-7.5	7.5-8.0	8.0-8.5	-	> 8.5					
Organic carbon(%)	> 1.5	1.5-0.8	< 0.8	-	-	-					
Salinity and Alkalinity (n)											
ECe (mmhos/cm)	0-8	8-12	12-16	16-20	20-25	> 25					
ESP (%)											

COTTON **(*Gossypium hirsutum*)**

1. CLIMATE

The air temperature range for cotton growing is 18 - 40°C, the optimum air temperature being 24 - 34°C. An air temperature of > 40°C may cause damage, depending on the moisture availability.

A mean annual air temperature of < 16°C causes slow growth and results in a poor fiber quality. The minimum temperature for germination is 15°C. Cotton is not tolerant to frost.

The required mean annual precipitation is 500 - 1000 mm. The optimum annual precipitation range is 900 - 1200 mm. The rainfall should be well distributed during the growing cycle. In the ideal conditions, 5 months with discontinuous rain follow planting. In the first 56 days the moisture demand is low as the leaves are small; excess water is even harmful. During the flowering period (70 - 95 days after planting) dry conditions are beneficial to prevent excess vegetative growth. The peak water demand follows at 95 - 115 days after planting, when the bolls swell. Rainfall during maturation is harmful as this results in split bolls, rot and discolored fiber. Dry conditions are necessary after 5 months.

A moderate relative air humidity (<65 %) is desirable at the ripening stage.

Prolonged periods of cloud cover from flowering onwards reduces the yield.

Abundance of hot days with much sunshine are required.

Hot or cold winds may affect the young seedlings. High wind velocities in the harvest period cause the bolls to be blown away and soils lint with dust.

2. SOIL

Ferruginous soils and freely drained alluvial soils are most suitable for cotton cropping. Vertisols are equally suitable if not waterlogged as a result of rains.

Cotton grows on soils with a large variety of textures, from loamy sands to montmorillonitic clays, though preference is

given to silt loam to clay soils.

The available soil depth should be at least 0.25 m. Optimal conditions are reached as the soil depth exceeds 1.0 m. The maximum rooting depth is 1.8 m.

Well drained soils are preferred. Flooding can be withstood for up to 2 days.

High erosion hazard.

pH range: 5.2 - 8.2, optimum pH: 6.0 - 7.6

Salinity: no yield reduction at an electrical conductivity (EC) of < 7.7 dS/m; the yield reduction is 10% at 9.6; 25% at 13; 50% at 17; 100% at 27 dS/m

Sodicity: 50% yield reduction at an exchangeable sodium percent age (ESP) of 35.

Micronutrients

Boron : the optimum level is 1 - 2 mg/l in soil solution.
Lithium : 25 % growth reduction at 25 ppm in soil.

Nutrients

A balanced supply of nutrients is important.
High soil fertility causes excessive vegetative growth.

Nutrient removal (kg/ha/growing cycle) to produce 2 ton seed/ha.

N	:	90
P ₂ O ₅	:	60
K ₂ O	:	135

3. YIELDS

Rainfed

Good commercial yield of seed : 1.5 - 2.0 ton/ha.
Average farmer yield : 1.0 - 1.5 ton/ha.

Irrigated

Good commercial yield of seed : 4.0 - 5.0 ton/ha.
Average farmer yield : 2.0 - 3.0 ton/ha.

CLIMATIC REQUIREMENTS - COTTON (growing cycle 150-180 days)

Climatic Characteristics	Climatic class, degree of limitation and rating						
	S1		S2		S3		N1 N2
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of growing cycle (mm)	1050-900 1050-1200	900-750 1200-1400	750-625 1400-1600	625-500 > 1600	-	< 500	-
Precipitation of vegetative stage (mm) (1st - 2nd month)	50-65 50-35	> 65 < 35	- -	- -	-	-	-
Precipitation of yield form. stage (mm) (5th month)	200-150 200-300	150-100 300-400	100-50 > 400	< 50 -	-	-	-
Precipitation of ripening stage (mm) (6th month)	< 25	25-50	50-75	75-100	-	> 100	-
Mean temp. of the growing cycle (°C)	> 26	26-24	24-22	22-20	-	< 20	-
Mean max. temp. of growing cycle (°C)	> 32	32-28	28-26	26-24	-	< 24	-
Average max. temp. warmest month (°C)	> 34	34-30	< 30	-	-	-	-
Mean temp. of the vegetative stage (°C) (1st + 2nd month)	> 30	30-25	25-20	< 20	-	-	-
Mean DAY temp. of flowering stage (°C) (3-4th month)	20-30	30-35	35-40	> 40 < 20	-	-	-
Mean NIGHT temp. of flowering stage (°C) (3-4th month)	12-18	18-22	22-27	> 27 < 12	-	-	-
Mean temp. of ripening stage (°C) (6th month)	> 26	26-24	24-22	22-20	-	< 20	-
Relative humid. of maturation stage (%)	< 50	50-65	65-75	75-80	-	> 80	-

DAY temp. = [Mean T. + Mean max. T.] / 2
NIGHT temp. = [Mean T. + Mean min. T.] / 2

LANDSCAPE AND SOIL REQUIREMENTS - COTTON

Land Characteristics		Class, degree of limitation and rating scale						
		S1		S2	S3	N1	N2	
		0 100	1 95	2 85	3 60	4 40	5 25	6 0
Topography (t)								
Slope (%)	(1)	0-1	1-2	2-4	4-6	-		> 6
	(2)	0-2	2-4	4-8	8-16	-		> 16
	(3)	0-4	4-8	8-16	16-30	30-50		> 50
Wetness (w)								
Flooding		Fo	-	-	F1	-		F2+
Drainage	(4)	good	-	moderate	imperf.	poor,		poor,
	(5)	imperfect	-	moderate	good	but drainab		not drainab
Physical soil characteristics (s)								
Texture/struct.		C<60s, SiC Co, SiCL, Si, SiL, CL	C<60v, SC C>60s, L	C>60v, SL SCL	FS, S, LS, LcS	-		Cm, SiCm cS
Coarse fragm(vol%)		0-3	3-15	15-35	35-55	-		> 55
Soil depth (cm)		> 100	100-75	75-50	50-25	-		< 25
CaCO ₃ (%)		0-10	10-20	20-30	30-40	-		> 40
Gypsum (%)		0-3	3-6	6-10	10-15	-		> 15
Soil fertility characteristics(f)								
Apparent CEC (cmol(+)/kg clay)		> 24	24-16	< 16(-)	< 16(+)	-		-
Base saturation(%)		> 80	80-50	50-35	< 35	-		-
Sum of basic ca- tions (cmol(+)/kg soil)		> 6.5	6.5-4	4-2.8	2.8-1.6	< 1.6		-
pH H ₂ O		6.7-6.4	6.4-6.0	6.0-5.6	5.6-5.2	< 5.2		-
		6.7-7.0	7.0-7.6	7.6-8.0	8.0-8.5	-		> 8.2
Organic carbon(%)								
	(6)	> 2.0	2-1.2	1.2-0.8	< 0.8	-		-
	(7)	> 1.2	1.2-0.8	< 0.8	-	-		-
	(8)	> 0.8	0.8-0.4	< 0.4	-	-		-
Salinity and Alkalinity (n)								
E _{Ce} (mmhos/cm)		0-8	8-10	10-12	12-16	16-22		> 22
ESP (%)		0-15	15-20	20-30	30-40	-		> 40

COWPEA
(*Vigna unguiculata*)

1. CLIMATE

Cowpea tolerates heat and requires higher air temperatures than maize. The required temperature range for growth is 16 - 35°C; the optimum temperature range is 20 - 30°C. The crop is not frost tolerant.

Cowpea performs well in regions with a precipitation of 300 - 900 mm/growing cycle. The crop can survive some drought during the growing season. Moisture stress has an effect on the vegetative growth, rather than on the seed production. Too much rainfall on the other hand results in insect pests and diseases.

2. SOIL

Soils with heavy textures are preferred. For optimal conditions the soil depth should be at least 0.60 m. Cowpea prefers well drained soils and is sensitive to waterlogging.

pH range : 5.0 - 8.2, optimum pH: 6.0 - 7.8

Salinity: no yield reduction at an electrical conductivity (EC) of < 1.3 dS/m; the yield reduction is 10% at 2 ; 25% at 3.1 ; 50% at 4.9 ; 100% at 9 dS/m

Nutrients

Cowpea needs a medium nutrient supply. The organic matter content however should be high. Nevertheless, cowpea is sometimes grown on very poor acid soils as an improver of fertility.

3. YIELDS

Rainfed

Good commercial yield : 1.0 - 1.3 ton seed/ha.

Irrigated

Good commercial yield : 2.0 - 3.0 ton seed/ha.

Plant (or) tuber (per hectare) : 0.25 t/ha (25) pH 5.8
 (or) tuber (per hectare) : 1.2 t/ha (12)

CLIMATIC REQUIREMENTS - COWPEA

Climatic Characteristics	Class, degree of limitation and rating scale						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of growing cycle (mm)	500-550	550-900	900-1300	> 1300	-	-	
	500-400	400-300	300-250	250-200	-	< 200	
Mean precipitation of 1st month (mm)	100-75	75-50	50-25	-	-	< 25	
	100-150	150-255	255-400	> 400	-	-	
Mean precipitation of 2nd month (mm)	150-125	125-100	100-75	75-50	-	< 50	
	150-175	175-255	255-400	> 400	-	-	
Mean precipitation of 3rd month (mm)	150-125	125-100	100-75	75-50	-	< 50	
	150-175	175-255	400-255	> 400	-	-	
Mean precipitation of 4th month (mm)	< 75	75-135	> 135	-	-	-	
Mean temp. of the growing cycle (°C)	24-26	26-30	30-32	32-35	-	> 35	
	24-22	22-20	20-18	18-16	-	< 16	
Mean temp. at germination (°C) (1st month)	22-25	25-30	30-32	32-35	-	> 35	
	22-18	18-17	17-16	16-15	-	< 15	
Mean min. temp. of coldest month (°C)	> 18	18-16	16-13	13-7	-	< 7	
Relative humidity at harvest (%)	< 60	60-80	80-90	> 90	-	-	

LANDSCAPE AND SOIL REQUIREMENTS - COWPEA

Land Characteristics	Class, degree of limitation and rating scale						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Topography (t)							
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6	
(2)	0-2	2-4	4-8	8-16	-	> 16	
(3)	0-4	4-8	8-16	16-30	30-50	> 50	
Wetness (w)							
Flooding	Fo	-	-	F1	-	F2+	
Drainage (4)	good	moder.	imperf.	poor and aeric	poor, but drainab	poor, not drainab	
(5)	imperf.	moder.	good				
Physical soil characteristics (s)							
Texture/struct.	SiCs, SiL	C>60s, SL	C>60v, SL	S, fs	-	Cm, SiCm	
	Co, C<60s	C<60v,	LfS, LS				
	SiCL, CL	SC, L, SCL					
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55	
Soil depth (cm)	> 75	75-60	60-50	50-20	-	< 20	
CaCO ₃ (%)	0-6	6-15	15-25	25-35	-	> 35	
Gypsum (%)	0-2	2-4	4-10	10-20	-	> 20	
Soil fertility characteristics(f)							
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-	
Base saturation(%)	> 50	50-35	35-20	< 20	-	-	
Sum of basic cations (cmol(+)/kg soil)	> 4	4-2.8	2.8-1.6	< 1.6	-	-	
pH H ₂ O	6.6-6.2	6.2-6.0	6.0-5.5	5.5-5.0	< 5.0	-	
	6.6-7.0	7.0-7.8	7.8-8.0	8.0-8.2	-	> 8.2	
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-	
Salinity and Alkalinity (n)							
ECe (dS/m)	0-2	2-3	3-5	5-7	-	> 7	
ESP (%)	0-8	8-15	15-20	20-25	-	> 25	

GREEN PEPPER (*Capsicum annum*)

1. CLIMATE

Germination takes place at temperatures of 15 - 34°C. The optimum germination temperature is 18 - 24°C. The required temperature range for growth is 14 - 28°C. Growth is optimal between 18 - 26°C.

The precipitation should be well distributed and reach 600 - 1200 mm/growing cycle. Heavy rain during flowering and fruiting is harmful.

The crop is sensitive to strong winds.

2. SOIL

Light, deep and well drained soils with an adequate water holding capacity are preferred. The maximum crop rooting depth is 1.0 m. The crop is sensitive to waterlogging.

pH range: 5.2 - 8.2, optimum pH: 6.0 - 7.6

Salinity: no yield reduction at an electrical conductivity (EC) of < 1.5 dS/m; the yield reduction is 10% at 2.2; 25% at 3.3; 50% at 5.1; 100% at 8.5 dS/m.

Sodicity: 50% yield reduction at an exchangeable sodium percent age (ESP) of 20.

Micronutrients

Boron : needs 1 - 2 mg/l in the soil solution.
Magnesium : sensitive to deficiency.

Nutrients

Fertilizer application (kg/ha/growing cycle) for high production.

	min.	max.
N :	100	- 170
P :	25	- 50
K :	50	- 100

3. YIELDS

Rainfed

Good commercial yield : 10 - 15 ton fresh fruit/ha.

Irrigated

Good commercial yield : 20 - 25 ton fresh fruit/ha.

CLIMATIC REQUIREMENTS - GREEN PEPPER (growing cycle 120-150 days)

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1		S2		S3	
	0	1	2	3	4	5
	100	95	85	60	40	25
Precipitation of growing cycle (mm)	800-900 800-700	900-1200 700-600	1200-1400 600-500	> 1400 500-400	-	- < 400
Mean temp. of the growing cycle (°C)	22-20 22-24	20-18 24-26	18-16 26-27	16-14 27-28	-	< 14 > 28
Mean min. temp at germination (°C)	21-20 21-22	20-18 22-24	18-16 24-30	16-15 30-34	-	< 15 > 34

LANDSCAPE AND SOIL REQUIREMENTS - GREEN PEPPER

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	100 0 95	85	60	40	25	0
Topography (t)						
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50
Wetness (w)						
Flooding	Fo	-	-	F1	-	F2+
Drainage	(4) good (5) imperf.	moderate moderate	imperf. good	poor and aeric	poor, but drainab	poor > not drainab
Physical soil characteristics (s)						
Texture/struct.	SCL,SL,L, SiCL	LES,SC, 6<60s, Sic	C<60v,LS C<60s,S	C>60v	-	Cm,SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 100	100-75	75-50	50-30	-	< 30
CaCO ₃ (%)	0-2	2-5	5-10	10-20	-	> 20
Gypsum (%)	0-1	1-2	2-3	3-5	-	> 5
Soil fertility characteristics(f)						
Apparent CEC (cmol+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-
pH H ₂ O	6.6-6.2 6.6-6.8	6.2-6.0 6.8-7.6	6.0-5.5 7.6-8.0	5.5-5.2 8.0-8.2	< 5.2 -	- > 8.2
Organic carbon(%)	> 1.5	1.5-0.8	< 0.8	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-2	2-3	3-5	5-7	-	> 7
ESP (%)	0-8	8-15	15-20	20-25	-	> 25

GROUNDNUTS (*Arachis hypogaea*)

1. CLIMATE

Groundnuts need hot and sunny conditions. Germination occurs in the temperature range of 10 - 38°C. Optimum conditions for germination are created by temperatures between 22 - 28°C. The crop does not mature if the night temperature falls below 10 °C. A yield decrease is observed at mean temperatures below 18 °C and above 30°C.

The minimum precipitation that is required in the growing cycle is 300 mm. Optimum conditions are reached with 400 - 1100 mm in the growing cycle. Moisture is most needed at peak flowering and pod filling stages. Dry weather is necessary at the harvest stage to prevent pod rotting.

The crop is sensitive to dry winds.

2. SOIL

For groundnut cropping sandy soils are preferred. A sandy loam to sandy clay loam texture is most suited. Heavy textures are only acceptable if the soil is permeable, well aerated and friable. Plastic clays and soils of a very firm consistence should be avoided.

The optimal soil depth is > 0.75 m. The maximum rooting depth of the crop is 1.80 m.

Groundnut cannot stand flooding.

pH range: 5.4 - 8.2, optimum pH: 6.0 - 7.5

Salinity: no yield reduction at an electrical conductivity (EC) of < 3.2 dS/m; the yield reduction is 10% at 3.5; 25% at 4.1; 50% at 4.9; 100% at 6.5 dS/m

Sodicity: 50 % yield reduction occurs at an ESP of 20 .

Nutrients

Ca supply is needed at fruit formation : 300 - 600 kg/ha

(if pH > 6.5 : gypsum , if pH < 6.5 : CaCO₃).

Nutrient removal (kg/ha/growing cycle) to produce 1 ton of unshelled nuts/ha:

N : 50
P₂O₅ : 15
K₂O : 15
CaO : 10

Fertilizer application (kg/ha/growing cycle) to produce 1 ton of unshelled nuts/ha:

	min.	max.
N	15	25 (starter)
P ₂ O ₅	50	100
K ₂ O	35	75

3. YIELDS

Rainfed

Good commercial yield : 2.0 - 3.0 ton unshelled nuts/ha.
Average farmer yield : 1.0 - 2.0 ton unshelled nuts/ha.
Tradit. smallholder yield : 0.5 ton unshelled nuts/ha.

Irrigated

Good commercial yield : 3.5 - 4.5 ton unshelled nuts/ha.
Average farmer yield : 1.5 - 2.0 ton unshelled nuts/ha.

CLIMATIC REQUIREMENTS - GROUNDNUTS (growing cycle 90-140 days)

Climatic Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Precipitation of growing cycle (mm)	700-500 700-900	500-400 900-1100	400-300 1100-1600	300-200 1600-1900	-	< 200 > 1900
Mean precipitation of 1st month (mm)	165-100 165-225	100-70 225-275	70-60 275-400	60-50 400-475	-	< 50 > 475
Mean precipitation of 2nd month (mm)	175-125 175-225	125-100 275-225	100-75 275-400	75-50 400-475	-	< 50 > 475
Mean precipitation of 3rd month (mm) (flowering)	175-125 175-225	125-100 225-275	100-75 275-400	75-50 400-475	-	< 50 > 475
Mean precipitation of 4th month (mm)	145-210 145-80	210-275 80-60	275-400 60-40	400-475 < 40	-	> 475 -
Mean temp. of the growing cycle (°C)	24-22 24-26	22-18 26-30	18-14 30-34	14-10 > 34	-	< 10
Mean max. temp. of growing cycle (°C)	35-36 35-34	36-38 34-15	38-40 -	40-42 < 15	-	> 42 -
Mean min. temp. of growing cycle (°C)	19-18 19-20	18-14 20-28	14-10 28-30	10-6 > 30	-	< 6
Relative humidity growing cycle (%)	60-70 60-50	70-80 < 50	> 80 -	- -	- -	- -

LANDSCAPE AND SOIL REQUIREMENTS - GROUNDNUTS

Land Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	-	-	F1+
Drainage (4)	good	-	moderate	imperf.	poor, drainab	poor, not drainab
(5)	imperf.	moder.	good			
Physical soil characteristics (s)						
Texture/struct.	L,SCL,SL	SiCl, SiL Co, Si, SC CL	C<60s, LfS, LS, SiCs	C>60v, C<60v, fs C>60s, S LcS	-	Cm, SiCm
Coarse fragm(vol%)	0-1	1-3	3-15	15-35	-	> 35
Soil depth (cm)	> 100	100-75	75-50	50-25	-	< 25
CaCO ₃ (%)	0-12	12-25	25-35	35-50	-	> 50
Gypsum (%)	0-2	2-4	4-10	10-20	-	> 15
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 16	< 16(-)	< 16(+)	-	-	-
Base saturation(%)	> 50	50-35	< 35	-	-	-
Sum of basic cations (cmol(+)/kg soil)	> 4	4-2.8	2.8-1.6	< 1.6	-	-
pH H ₂ O	6.8-6.5	6.5-6.0	6.0-5.6	5.6-5.4	< 5.4	-
Organic carbon(%)	6.8-7.0	7.0-7.5	7.5-8.0	8.0-8.2	-	> 8.2
(6)	> 2.0	2.0-1.2	1.2-0.8	< 0.8	-	-
(7)	> 1.2	1.2-0.8	0.8-0.5	< 0.5	-	-
(8)	> 0.8	0.8-0.4	< 0.4	-	-	-
Salinity and Alkalinity (n)						
Ece (dS/m)	0-2	2-4	4-6	6-8	8-12	> 12
ESP (%)	0-8	8-10	10-15	15-20	-	> 20

GUAVA
(*Psidium guajava*)

1. CLIMATE

The optimum temperature for the growth of guava is 20 - 28°C. Guava can however grow in a wide air temperature range and can tolerate very high temperatures. Frost damages the crop, though near-freezing conditions are tolerated. Guava is very drought resistant.

Guava grows in areas with a precipitation between 200 mm and 4200 mm/year. Though guava is very drought resistant, a constant supply of moisture is preferred.

The crop prefers a high relative air humidity.

2. SOIL

Guava grows on a wide range of soils. Both shallow and deep soils are suitable, as long as the roots have constantly access to moisture. Guava tolerates temporary waterlogging.

pH range: 4.5 - 8.2; optimal pH : 5.5 - 7.8.

Salinity: no yield reduction at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 10% at 1; 25% at 2; 50% at 3; 100% at 5 dS/m

Sodicity: 50 % yield reduction is observed at an ESP of 20 .

3. YIELDS

Rainfed

Good commercial yield : 60 - 80 kg/tree, 300 kg if grafted.

CLIMATIC REQUIREMENTS - GUAVA

Climatic Characteristics	Class, degree of limitation and rating scale.					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitation (mm)	> 2000	2000-1000	1000-500	500-200	-	< 200
Mean annual temp. (°C)	25-24 25-26	24-20 26-28	20-15 28-34	15-10 > 34	- -	< 10 -

LANDSCAPE AND SOIL REQUIREMENTS - GUAVA

Land Characteristics	Class, degree of limitation and rating scale.					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	F1	-	F2+
Drainage	good groundw. > 200 cm	good groundw. < 200 cm	moderate	imperf.	poor, but drainab	poor, not drainab
Physical soil characteristics (s)						
Texture/struct.	SiCs, SiCL C<60s, SiL Co, CL, Si	C>60s, SC C<60v, L	C>60v, SL SCL	LfS, LS, LcS, fS	-	Cm, SiCm S
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	-
Soil depth (cm)	> 100	100-50	50-30	30-10	-	> 55 < 10
CaCO ₃ (%)						
Gypsum (%)						
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg soil)	> 4	4-2.8	2.8-1.6	< 1.6	-	-
pH H ₂ O	6.8-5.8	5.8-5.5 6.8-7.8	5.5-5.2 7.8-8.0	5.2-4.5 8.0-8.2	< 4.5 -	> 8.2 -
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-3	3-4	-	> 4
ESP (%)	0-8	8-15	15-20	20-25	-	> 25

MAIZE (Zea mais)

1. CLIMATE

Maize shows tolerance to a wide range of environmental conditions, but the growing season must be frost-free. The optimum temperature for germination is 18 - 21°C; germination is reduced at 13°C and fails at temperatures below 10°C.

Maize grows in the temperature range of 14 - 40°C. The growth of the crop is optimal at temperatures between 18°C and 32°C. The mean minimum temperature should be in the range of 12 - 24 °C ; the mean maximum temperature should be in the range of 26 - 29°C.

Maize grows in regions that have a total annual precipitation between 500 and 5000 mm. An optimal water supply can be secured in regions that receive 1000 - 1500 mm/year or 500 - 1200 mm in the growing cycle. For short-season varieties however an adequate water supply is already secured with 300 mm/growing season.

Maize is most sensitive to moisture stress from the beginning of flowering until the end of grain formation (50 -100 days from planting).

Hail can do great damage.

No excessive air humidity and a good insolation are favorable.

2. SOIL

Maize grows on many types of soils. Well drained, well aerated, deep loam and silt loam soils with adequate organic matter are most suited for maize cropping. The maximum crop rooting depth is 2.0 m.

Sites with drainage impedance, as shown by mottling within 1.0 m from the surface, should be avoided. The watertable must occur at a depth below 0.75 m from the surface.

Maize cannot stand waterlogging in the first 5 weeks after sowing. From the 6th week onwards, waterlogging during 1 to 2 days may kill the crop.

On soils with a low moisture retention capacity, or in areas of low rainfall, a low plant density should be used. Yield

increases with planting density on irrigated plots, but the reverse may occur on rainfed plots.

pH range : 5.2 - 8.5, optimum pH: 5.8 - 7.8

Salinity: no yield reduction at an electrical conductivity (EC) of < 1.7 dS/m; the yield reduction is 10% at 2.5; 25% at 3.8; 50% at 5.9; 100% at 10 dS/m

Sodicity: 50 % yield reduction is observed at an ESP of 15 .

Nutrients

Nitrogen is the most important nutrient. Young maize has difficulty in taking up P from the less available phosphate forms in the soil. K removal is very high in maize harvested for silage: 200 - 300 kg K₂O/ha are removed at harvest time.

Nutrient removal (kg/ha/growing cycle) to produce 6.27 ton grain/ha:

N	:	165
P ₂ O ₅	:	55
K ₂ O	:	135

Fertilizer application (kg/ha/growing cycle) to produce 4 ton grain/ha :

	min.	max.
N	:	60 - 100
P ₂ O ₅	:	50 - 100
K ₂ O	:	30 - 60

Micronutrients

Boron : moderate tolerance; 1 - 2 mg/l in soil solution.
Magnesium : sensitive to deficiency.
Manganese : medium response.
Zinc : response to spraying if the soil is deficient.
Lithium : 25 % growth reduction at 70 ppm in soil.

Mineral deficiency symptoms

Magnesium : whitish or yellowish striping between leaf veins.
 Nitrogen : reduced vigor, a pale-green or yellowish color.
 Phosphorus: stunted growth, delayed ripening and purplish color.
 Potassium : small whitish-yellow spots on leaves.
 Zinc : chlorotic fading of the leaves with broad whitish areas.

3. YIELDS

Rainfed

Good commercial yield : 6.0 - 9.0 ton grain /ha.
 33.0 ton fodder/ha.

Tradit. smallholder yield : 0.5 - 1.5 ton grain/ha.

Irrigated

Good commercial yield : 6.0 - 9.0 ton grain /ha.
 80.0 ton fodder/ha.

CLIMATIC REQUIREMENTS - MAIZE (growing cycle 90-130 days)

Climatic Characteristics	Class, degree of limitation and rating scale						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of growing cycle (mm)	750-900 750-600	900-1200 600-500	1200-1600 500-400	> 1600 400-300	-	-	< 300
Precipitation of the 1st month (mm)	175-220 175-125	220-295 125-100	295-400 100-75	400-475 75-60	-	-	> 475 < 60
Precipitation of the 2nd month (mm)	200-235 200-175	235-310 175-150	310-400 150-120	400-475 120-70	-	-	> 475 < 70
Precipitation of the 3rd month (mm)	200-235 200-175	235-310 175-150	310-400 150-120	400-475 120-70	-	-	> 475 < 70
Precipitation of the 4th month (mm)	165-210 165-125	210-285 125-100	285-400 100-80	400-475 60-80	-	-	> 475 < 60
Mean temp. of the growing cycle (°C)	24-22 24-26	22-18 26-32	18-16 32-35	16-14 35-40	-	-	< 14 > 40
Mean min. temp. of growing cycle (°C)	17-16 17-18	16-12 18-24	12-9 24-28	9-7 28-30	-	-	< 7 > 30
Relative humidity of devel. stage (%) (2nd month)	65-50 65-80	50-42 > 80	42-36 -	36-30 -	-	-	< 30 -
Relative humidity maturation stage(%)	40-30 40-50	30-24 50-75	24-20 75-90	< 20 > 90	-	-	- -
n/N develop. stage (2nd month)	0.55-0.5 0.55-0.6	0.5-0.35 0.6-0.75	< 0.35 > 0.75	- -	-	-	- -
n/N maturation stage	> 0.7	0.7-0.5	< 0.5	-	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - MAIZE

Land Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	100	95	85	60	40	25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding (4)	Fo	-	-	F1	-	F2+
Drainage (5)	good	moderate	imperf.	poor and	poor, but	poor, not
	imperf.	moderate	good	aeric	drainab	drainab
Physical soil characteristics(s)						
Texture/struct.	C<60s, Co, SiC, SiCL, Si, SiL, CL	C<60v, SC, C>60s, L, SCL	C>60v, SL, LFS, LS	fS, S, LcS	-	Cm, SiCm, cS
Coarse frag. (vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 100	100-75	75-50	50-20	-	< 20
CaCO ₃ (%)	0-6	6-15	15-25	25-35	-	> 35
Gypsum (%)	0-2	2-4	4-10	10-20	-	> 20
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 80	80-50	50-35	35-20	< 20	-
Sum of basic cations (cmol(+)/kg soil)	> 8	8-5	5-3.5	3.5-2	< 2	-
pH H ₂ O	6.6-6.2	6.2-5.8	5.8-5.5	5.5-5.2	< 5.2	-
	6.6-7.0	7.0-7.8	7.8-8.2	8.2-8.5	-	> 8.5
Organic carbon(%) (6)	> 2.0	2.0-1.2	1.2-0.8	< 0.8	-	-
(7)	> 1.2	1.2-0.8	0.8-0.5	< 0.5	-	-
(8)	> 0.8	0.8-0.4	< 0.4	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-2	2-4	4-6	6-8	8-12	> 12
ESP (%)	0-8	8-15	15-20	20-25	-	> 25

MANGO
(*Mangifera indica*)

1. CLIMATE

Growth of mango trees is secured within the temperature range of 15 to 40°C. Growth is optimal between 22 and 28°C. The average minimum temperature should be > 16° C. Because flowers and young foliage are sensible to frost, young trees may be killed at temperatures below freezing point.

Mango grows in regions with a total precipitation between 250 and 6000 mm/year. The crop can withstand a 6 month dry period. Rain during flowering may depress the yields.

A moderate to high air humidity is required.

Strong winds can cause considerable damage, while dry and hot winds lower the fruit quality.

A high insolation is needed at maturation.

2. SOIL

Mango can grow on many types of soil. Moderately deep (>0.50 m) to deep, well drained (watertable at > 2.30 m from the surface) sandy loam to loam soils however provide the best environment for mango production.

pH range: 4.5 - 8.2, optimum pH: 5.5 - 7.8

Salinity: no yield reduction at an electrical conductivity (EC) of < 1 dS/m; the yield reduction is 10% at 2 ; 25% at 4 ; 50% at 6 ; 100% at 9 dS/m

Sodicity: 50 % yield reduction at an ESP of 20 .

Nutrients

High fertility favors vegetative growth over fruit formation.

3. YIELDS

Rainfed

Good commercial yield : 14 - 20 ton/ha or 100 kg/tree.

Irrigated

Good commercial yield : 30 - 40 ton/ha.

CLIMATIC REQUIREMENTS - MANGO

Climatic Characteristics	Class, degree of limitation and rating					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitation (mm)	> 2000	2000-1000	1000-500	500-250	-	< 250
Length of the dry season (months) (P < 1/2 PET)	4.5-5 4.5-4	5-6 4-3	6-7 3-2	7-8 2-1	-	> 8 < 1
Monthly precipitation during dry season (mm)	< 50	50-60	60-100	>100	-	-
Mean annual temp. (°C)	25-24 25-26	24-22 26-28	22-18 28-34	18-15 34-40	-	< 15 > 40
Mean min. temp. (°C) of coldest month	> 18	18-16	16-13	13-8	-	< 8
Annual relative humidity (%)	65-80 65-50	> 80 50-42	- 42-36	- 36-30	-	- < 30
n/N maturation stage	> 0.7	0.7-0.5	< 0.5	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - MANGO

Land Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50
Wetness (w)						
Flooding	Fo	-	-	-	-	F1+
Drainage	good groundw. > 200 cm	good groundw. < 200 cm	moderate	imperf.	poor, but drainab	poor, not drainab.
Physical soil characteristics (s)						
Texture/struct.	L, SiL, SL Si	SiCs, SCL LfS, SiCL CL, SC,	C<60s, fs, LcS	C>60s, S, C>60v	-	Cm, SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 150	150-100	100-75	75-50	-	< 50
CaCO ₃ (%)	0-3	3-5	5-10	10-25	-	> 25
Gypsum (%)	0-1	1-2	2-3	3-5	-	> 5
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 16	< 16(-)	< 16(+)	-	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg clay)	> 4	4-2.8	2.8-1.6	< 1.6	-	-
pH H ₂ O	6.4-6.0 6.4-6.8	6.0-5.5 6.8-7.8	5.5-5.0 7.8-8.0	5.0-4.5 8.0-8.2	< 4.5	> 8.2
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-2	2-4	4-6	6-8	-	> 8
ESP (%)	0-8	8-15	15-20	20-25	-	> 25

MILLETS (*Pennisetum Americanum*)

1. CLIMATE

Milletts grow and mature under conditions of low rainfall and soil fertility, with little or no attention. The temperature range for growth is 16 - 32°C.

The distribution of the rainfall throughout the growing season is more important than the total precipitation in that period. Milletts grow in regions that can secure a precipitation of 150 to 1350 mm/growing cycle. Optimum growth is observed in regions with 300 - 600 mm/growing cycle.

Though no dormancy facility is provided during drought, the crop is very drought resistant.

Water is most required at flowering. Heavy rain during flowering however interferes with fertilization and causes reduced yields.

At harvest, dry weather is required.

Wet conditions and a high air humidity may favour diseases. The air humidity should be medium or low.

2. SOIL

Milletts prefer loamy to clayey soils. Lighter and heavier textures can however be tolerated. The soil depth should be at least 0.50 m. Optimum conditions are met at depths > 2.00 m. Well drained and aerated soils are most suitable for millet cropping. Waterlogging is not tolerated.

The erosion hazard under millet cropping is high.

pH range: 5.2 - 8.2, optimum pH: 5.6 - 7.6

Salinity: no yield reduction at an electrical conductivity (EC) of < 1 dS/m; the yield reduction is 10% at 2 ; 25% at 4 ; 50% at 6 ; 100% at 12 dS/m

Sodicity: 50 % yield reduction is observed at and ESP of 35.

Nutrients

Milletts show a good response to N and K fertilizers. Millet is

not a demanding crop however and tolerates impoverished soils with a low organic matter content. Manuring is seldom practiced.

3. YIELDS

Rainfed

Good commercial yield : 2 - 4 ton grain /ha.

CLIMATIC REQUIREMENTS - MILLETS (growing cycle 70 - 105 days)

Climatic Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Precipitation of growing cycle (mm)	450-400 450-500	400-300 500-600	300-200 600-800	200-150 > 800	- -	< 150 -
Precipitation of 1st month (mm)	> 150	150-100	100-75	75-50	-	< 50
Precipitation of 2nd month (mm)	> 150	150-100	100-75	75-50	-	< 50
Precipitation of 3rd month (mm)	< 60	60-120	> 120	-	-	-
Mean temp. of the growing cycle (°C)	24-22 24-26 22-28	22-20 26-28 28-32	20-18 28-30 32-34	18-16 30-32 34-36	- -	< 16 > 32
Mean max. temp. of growing cycle (°C)	35-36 35-34	36-38 34-30	38-40 < 30	40-42 -	- -	> 42 -
Mean min. temp. of growing cycle (°C)	17-18 17-16	18-20 16-14	> 20 14-12	- 12-10	- -	< 10 -
Relative humidity at harvest (%)	55-60 55-50	60-65 50-0	65-70 -	70-85 -	- -	> 85 -

LANDSCAPE AND SOIL REQUIREMENTS - MILLETS

Land Characteristics	Class, degree of limitation and rating scale.					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	F0	-	F1	F2	-	F3+
Drainage (4)	good	moderate	imperf.	poor	-	F3+
(5)	imperfec	moderate	good	and aeric	poor, but drainab	poor, not drainab
Physical soil characteristics (s)						
Texture/struct.	C<60s, Co SiCL, L, SC, SiCs	C<60v, C>60s, SL SCL	C>60v, LS Lfs	Cm, SiCm LcS, fs, S	-	cS
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 90	90-50	50-20	20-10	-	< 10
CaCO ₃ (%)	0-10	10-25	25-35	35-50	-	> 50
Gypsum (%)	0-3	3-6	6-10	10-20	-	> 20
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 16	< 16(-)	< 16(+)	-	-	-
Base saturation(%)	> 50	50-35	35-15	< 15	-	-
Sum of basic cations (cmol(+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-
pH H ₂ O	6.5-6.0	6.0-5.6	5.6-5.4	5.4-5.2	< 5.2	-
Organic carbon(%) (6)	6.5-7.0	7.0-7.6	7.6-8.0	8.0-8.2	-	> 8.2
Salinity and Alkalinity (n)	> 0.8	0.8-0.4	< 0.4	-	-	-
Ece (dS/m)	0-2	2-4	4-6	6-8	8-12	> 12
ESP (%)	0-10	10-25	25-35	35-45	-	> 45

OIL PALM
(*Elaeis guineensis*)

1. CLIMATE

The optimum mean daily temperature for oil palm is 22 - 30°C. The mean minimum temperature should be at least 18°C.

Oil palm performs well in regions with a total annual precipitation of over 1700 mm, well distributed throughout the growing period, that have 2 or less consecutive dry months. Excessive rainfall decreases both the pollen density and the oil content of the mesocarp.

In order to get high yields the annual number of sunshine hours should exceed 1300 hours.

2. SOIL

Deep, permeable, well structured soils are most suitable for oil palm cropping. The required effective soil depth is > 1.00 m. The maximum rooting depth of oil palm is 2.00 m.

Oil palm is sensitive to waterlogging. A groundwater level at less than 0.90 m from the surface, lasting for more than 14 days should be avoided. If the land is flooded for over 1 week in 10 years, this land is considered not suitable.

Clay and clay loam textures are optimal for oil palm. Soils on alluvial deposits are preferred. Poorly drained soils with ironstone gravel, sandy coastal soils and deep (>0.50 m) peats are unsuitable.

The erosion hazard under oil palm is high.

pH range: 3.5 - 7.5, optimum pH: 5.0 - 6.5

Salinity: no yield reduction at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 10% at 1; 25% at 2; 50% at 3; 100% at 8 dS/m

Nutrients

K is the main nutrient that is required. N is needed for rapid

growth of young palms. P is best applied with K on some soils and the need for Mg is exhibited through its deficiency symptoms, often induced by K - manuring. Available P and exchangeable K should be high ($K > 0.5$ meq/100g)

Nutrient removal (kg/ha/growing cycle) to produce 15 ton fruit/ha

N : 90
 P_2O_5 : 20
 K_2O : 135
 CaO : 40

Mineral deficiency symptoms

Boron : 'little leaf' occurs in young oil palms and in older palms; 'hook leaf' is often prominent where a distinctive hook appears at the apex of one or more pinnae on an affected frond; 'White stripe' may be an early or mild symptom.

Magnesium : deep orange tints, known as orange frond, specific and well established. Symptoms only occur in unshaded parts of the pinnae.

Nitrogen : fronds become pale green, changing to pale or bright yellow as the chlorosis becomes more severe.

Phosphorus: only observed through foliar analyses.

Potassium : orange spotting and mid-crown yellowing of leaflet fronds leading to terminal and marginal necrosis.

3. YIELDS

Rainfed

Good commercial yield : 20 - 28 ton fruit /ha.
 4 - 6 ton oil /ha.

CLIMATIC REQUIREMENTS - OIL PALM

Climatic Characteristics	Climatic class, limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	0 25
Annual rainfall (mm)	> 2000	2000-1700	1700-1450	1450-1250	-	< 1250
Length dry season (months) $P < 1/2$ PET	0-1	1-2	2-3	3-4	-	> 4
Mean annual max. temp. ($^{\circ}C$)	> 29	29-27	27-24	24-22	-	< 22
Average daily min. temp. coldest month ($^{\circ}C$)	> 20	20-18	18-16	16-14	-	< 14
Mean annual temp. ($^{\circ}C$)	> 25	25-22	22-20	20-18	-	< 18
Annual n/N	> 0.75	0.75-0.45	< 0.45	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - OIL PALM

Land Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	Fo	F1	F2	-	F3+
Drainage (4)	moderate	good	imperf.	poor	poor,	poor,
(5)	imperf.	moderate	good	and aeric	but drainab	not drainab
Physical soil characteristics (s)						
Texture/struct.	C>60s, C<60s, SiCs	SiCL, Co CL, SC, L	SCL	SL, Lfs	-	Cm, SiCm, LS, LcS, fs, S, cS
Coarse fragm(vol%) in depth	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 150	150-100	100-50	50-25	-	< 25
CaCO ₃ (%)	0	0-1	1-5	5-10	-	> 10
Gypsum (%)	0	0-0.5	0.5-2	2-3	-	> 3
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 16	< 16(-)	< 16(+)	-	-	-
Base saturation(%)	> 35	35-20	< 20	-	-	-
Sum of basic cations (cmol(+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-
pH H ₂ O	5.8-5.5	5.5-5.0	5.0-4.2	4.2-3.5	< 3.5	-
	5.8-6.0	6.0-6.5	6.5-7.0	7.0-7.5	-	> 7.5
Organic carbon(%)	> 1.2	1.2-0.8	< 0.8	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-3	3-4	4-8	> 8
ESP (%)						

OLIVES
(*Olea europacae*)

1. CLIMATE

The temperature range for the growth of olive trees is 0 - 38 °C. Growth is however optimal at temperatures between 15 and 22 °C. Olive trees need a dormancy period of 2 months with an average temperature of < 10°C, otherwise flowering will be poor or will not occur at all. During that time temperatures as low as - 8°C can be tolerated, but it is best not to plant in areas where the temperature regularly falls below - 4°C.

Olive trees perform well in regions that receive a precipitation of 400 - 1000 mm/year. The optimal annual precipitation is however 500 - 800 mm.

2. SOIL

Loamy, deep, well drained and aerated, calcareous soils are preferred for growing olive trees. It is required that the watertable occurs at > 1.00 m from the surface. The maximum crop rooting depth is 1.80 m.

pH range : 5.0 - 8.5; optimal pH : 6.2 - 8.0.

Salinity: no yield reduction at an electrical conductivity (EC) of < 2.7 dS/m; the yield reduction is 10% at 3.8; 25% at 5.5 ; 50% at 8.4 ; 100% at 14 dS/m

Nutrients

Even poor soils can produce a reasonable crop.

Boron : 1 - 2 mg/l in the soil solution is required.

3. YIELDS

Rainfed

Good commercial yield : 3.0 - 4.0 ton/ha.
Average farmer yield : 2.0 - 2.5 ton/ha.

Irrigated

Good commercial yield : 7 - 10 ton/ha, 50 - 100 kg/tree.
Average farmer yield : 3 - 4 ton/ha.

CLIMATIC REQUIREMENTS - OLIVES (growing cycle 210-300 days)

Climatic Characteristics	Class, degree of limitation and rating scale					
	S1 0 100	1 95	S2 2 85	S3 3 60	N1 4 40	N2 5 25
Annual precipitation (mm)	650-500 650-800	500-400 800-1000	400-300 1000-1200	300-150 1200-1400	- -	< 150 > 1400
Monthly rainfall during the sclerification of stone (mm)						
- August (N hem.) February (S hem.)	> 45	45-20	< 20	-	-	-
- September (N hem.) March (S hem.)	> 30	30-15	< 15	-	-	-
Mean annual temp. (°C)	18-16 18-20	16-15 20-22	15-14 22-24	14-13 24-26	- -	< 13 > 26
Average absolute min. temp. of coldest month (°C)	-1 to -2 -1 to 0	-2 to -4 0-2	-4 to -6 2-4	-6 to -8 4-6	- -	< -8 > 6

LANDSCAPE AND SOIL REQUIREMENTS - OLIVES

Land Characteristics	Class, degree of limitation and rating scale					
	S1 0 100	1 95	S2 2 85	S3 3 60	N1 4 40	N2 5 25
Topography (t)						
Slope (%)	(1) 0-1 (2) 0-4 (3) 0-8	1-2 4-8 8-16	2-4 8-16 16-30	4-6 16-25 30-50	- - -	> 6 > 25 > 50
Wetness (w)						
Flooding Drainage	Fo good, groundw. > 150 cm	- good, groundw. 100-150 cm	- moderate	- imperf.	- poor, but drainab	F1+ poor, not drainab
Physical soil characteristics (s)						
Texture/struct.	L,SCL,SL	SC,SiL, SiCL,Si, CL,LfS, LS,Si	C<60s,LcS C>60s,FS	Cm,SiCm, cS	-	-
Coarse fragm(vol%)	0-15	15-35	35-55	55-75	-	> 75
Soil depth (cm)	> 150	150-120	120-100	100-80	-	< 80
CaCO ₃ (%)	any					
Gypsum (%)	0-10	10-15	15-20	20-25	-	> 25
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 80	80-50	50-35	< 35	-	-
Sum of basic cations (cmol(+)/kg soil)	> 8	8-5	5-3.5	3.5-2	< 2	-
pH H ₂ O	7.2-7.0 7.2-7.5	7.0-6.2 7.5-8.0	6.2-5.8 8.0-8.2	5.8-5.5 8.2-8.5	< 5.5 -	- > 8.5
Organic carbon(%)	> 1.5	1.5-0.8	0.8-0.4	< 0.4	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-8	8-12	12-16	16-20	20-25	> 25
ESP (%)	0-15	15-25	25-35	35-45	-	> 45

ONION (*Allium cepa*)

1. CLIMATE

Onions are not grown in the lowland humid tropics. Cool conditions with an adequate moisture supply are most suitable for the early growth of onion; warm and drier conditions are required at maturation, harvesting and curing.

Bulbing takes place more quickly at warm than at cool temperatures provided the minimum photoperiod for the cultivar has been reached. Long-day cultivars, developed in temperate countries, will not form bulbs in the shorter days of the tropics. Bolting with the production of inflorescences is induced by low temperatures.

Germination takes place in the temperature range of 2 - 35°C. Optimum conditions for germination are met at temperatures between 10 and 25°C. A high soil temperature kills the young seedlings.

The optimum temperature for growth is 16 - 22°C. Flowering and consequent low yields are observed at temperatures < 16°C. Early maturity and low yields occur at temperatures > 22°C.

The optimal precipitation for onion is 350 - 600 mm/growing cycle.

A low air humidity and low temperatures lead to flowering. Onion is sensitive to the daylength : 12 - 13 hours of daylength are required in the yield formation period.

2. SOIL

Onion grows on a wide variety of soils, provided they are well aerated and friable and as long as sufficient water can be retained. Fertile, loamy textured soils are most suitable. The maximum rooting depth of the crop is 0.50 m.

Onion can be successfully grown on peat soils. In Nigeria river levees are favorite sites, with the young crop benefiting from a high watertable, which recedes with maturity, permitting bulbing and easy harvest.

pH range: 5.5 - 8.2, optimum pH: 6.0 - 7.8.

Salinity: no yield reduction at an electrical conductivity (EC) of < 1.2 dS/m; the yield reduction is 10% at 1.8; 25% at 2.8; 50% at 4.3; 100% at 6 dS/m

Sodicity : 50% yield reduction at an exchangeable sodium percent age (ESP) of 35.

Micronutrients

Copper : high response to application.
Boron : needs 0.1 - 0.5 ppm in soil, tolerant of high concentrations.
Manganese : high response to application.
Molybdenum : high response to application.

Nutrients

An excess of N slows down the bulbing process. In order to meet the conditions for an optimal nutrient supply the soil organic matter content must be maintained at a high level.

Nutrient removal (kg/ha/growing cycle) to produce 20 ton/ha. (before + after transplanting)

N	:	60 + 40
P ₂ O ₅	:	170 + 0
K ₂ O	:	60 + 60

Fertilizer application (kg/ha/growing cycle) for high production.

	min.	max.
N	:	60 - 100
P ₂ O ₅	:	55 - 105
K ₂ O	:	55 - 95

3. YIELDS

Rainfed

Good commercial yield : 14 - 20 ton/ha.
Average farmer yield : 5 - 10 ton/ha.

Irrigated

Good commercial yield : 35 - 45 ton/ha.
Average farmer yield : 10 - 20 ton/ha.

CLIMATIC REQUIREMENTS - ONION (growing cycle 100-140 days + 30-35 days nursery)

Climatic Characteristics	Climatic class, degree of limitation and rating					
	0 100	S1 95	1 85	S2 80	S3 60	N1 40 N2 25
Precipitation of the growing cycle (mm)	450-500	500-600	600-800	800-1600	-	> 1600
	450-400	400-350	350-300	300-250	-	< 250
Mean temp. of the growing cycle (°C)	19-20	20-22	22-23	23-25	-	> 25
	19-18	18-16	16-13	13-10	-	< 10
Mean temp. at germination (°C)	18-15	15-10	10-5	5-2	-	< 2
	18-20	20-25	25-30	30-35	-	> 35
Daylength(h) during yield form. period	12.5-12	12-11	11-10	10-9	-	< 9
	12.5-13	13-14	14-15	15-16	-	> 16

LANDSCAPE AND SOIL REQUIREMENTS - ONION

Land Characteristics	Class, degree of limitation and rating scale					
	0 100	S1 95	1 85	S2 80	S3 60	N1 40 N2 25
Topography (t)						
Slope (%)	(1) 0-1	1-2	2-4	4-6	-	> 6
	(2) 0-2	2-4	4-8	8-16	-	> 16
	(3) 0-8	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	-	-	F1+
Drainage	(4) good, (5) imperf.	moder.	imperfect good	poor and aeric	poor, but drainab	poor, not drainab
Physical soil characteristics (s)						
Texture/struct.	L,SC, SCL	SiCs,Si, SL,SiCl, C<60s,Co	C<60v, C>60s,fs, LS,LfS	C>60v,S	-	Cm,SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 75	75-50	50-30	30-20	-	< 20
CaCO ₃ (%)	0-3	3-5	5-10	10-20	-	> 20
Gypsum (%)	0-1	1-2	2-3	3-5	-	> 5
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg soil)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
pH H ₂ O	6.7-6.2	6.2-6.0	6.0-5.8	5.8-5.5	< 5.5	-
	6.7-7.2	7.2-7.8	7.8-8.0	8.0-8.2	-	> 8.2
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-3	3-5	-	> 5
ESP (%)	0-10	10-20	20-35	35-50	-	> 50

PAPAYA (*Carica papaya*)

1. CLIMATE

Papaya can grow in regions that are characterized by air temperatures between 8 and 38°C. Low temperatures however result in a poorly flavoured fruit. Papaya is very sensitive to frost.

An annual precipitation of 600 - 2000 mm is adequate for growing papaya. The crop can stand drought during some period in the year.

A high air humidity favours fungi. Papaya prefers sunny days. The crop is damaged by wind, hail and blown sands.

2. SOIL

Papaya performs well on many soils, also on shallow ones. Heavy textured soils are not suitable though. A good drainage is required by the crop and waterlogging is not tolerated.

pH range: 5.0 - 6.6 optimum pH: 6.0 - 6.6

Salinity: no yield reduction at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 10% at 1; 25% at 2; 50% at 3; 100% at 6 dS/m.

Sodicity : 50% yield reduction at an exchangeable sodium percentage (ESP) of 20.

Nutrients

Papaya requires fertile soils.

3. YIELDS

Rainfed

Good commercial yield : 20 - 26 ton/ha, 30 - 54 kg/tree.

Irrigated

Good commercial yield : 40 ton/ha.

CLIMATIC REQUIREMENTS - PAPAYA

Climatic Characteristics	Climatic class, degree of limitation and rating					
	0	S1 1	S2 2	S3 3	N1 4	N2 0
	100	95	85	60	40	25
Annual precipitation (mm)	1500-1400 1500-1600	1400-1000 1600-2000	1000-800 > 2000	800-600 -	- -	< 600 -
Mean annual temp. (°C)	25-24 25-26	24-20 26-28	20-15 28-34	15-8 34-38	- -	< 8 > 38
Mean min. temp. of coldest month (°C)	> 18	18-16	16-13	13-8	-	< 8
Annual relative humidity (%)	40-50 40-30	50-80 30-24	80-90 24-20	> 90 < 20	- -	- -
Annual n/N	> 0.7	0.7-0.5	< 0.5	-	-	-

PEA (*Pisum sativum*)

LANDSCAPE AND SOIL REQUIREMENTS - PAPAYA

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-8	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50
Wetness (w)						
Flooding Drainage	Fo good, groundw. > 1.5 m	- good, groundw. 1-1.5 m	- moderate	- imperf.	- poor, but drainab	F1+ poor, not drainab
Physical soil characteristics (s)						
Texture/struct.	SL, L,CL, SiCL	SiCL,SCL Si,Lfs, LS,Co	SC,C<60s, SiCs,LcS	C<60v,S, C>60s	-	Cm,SiCm C>60v
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 100	100-60	60-30	30-10	-	< 10
CaCO ₃ (%)						
Gypsum (%)						
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg soil)	> 4	4-2.8	2.8-1.6	< 1.6	-	-
pH H ₂ O	6.3-6.2	6.2-6.0	6.0-5.5	5.5-5.0	-	< 5.0
Organic carbon(%)	6.3-6.4 > 2	6.4-6.6 2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-3	3-4	-	> 4
ESP (%)	0-8	8-15	15-20	20-25	-	> 25

1. CLIMATE

Germination of peas takes place in the temperature range of 5 - 30°C. Optimal conditions for germination are met at 23°C. Peas grow well at temperatures between 8 - 25°C, the optimum temperatures being 14 - 20°C. The optimum mean daily temperature is 17°C. Hot weather interferes with seed settling. Young plants can tolerate light frost.

The water supply for peas is optimal in regions that receive 350 - 600 mm/growing cycle. Moist soil conditions are essential throughout growing season, particularly after flowering.

High air humidity favors moulds.

2. SOIL

Peas grow on a wide variety of soils, as long as they are well aerated. The maximum crop rooting depth is 1.00- 1.50 m. Peas cannot tolerate waterlogging.

pH range: 5.5 - 8.2, optimum pH: 6.0 - 7.5

Salinity: no yield reduction at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 10% at 1.5; 25% at 2.3; 50% at 3.6; 100% at 6.5 dS/m

Sodicity: 50% yield reduction at an exchangeable sodium percentage (ESP) of 20 .

Micronutrients

Copper : no or low response to application.
Boron : < 0.1 ppm required in the soil.
Manganese : high response to application.
Magnesium : tolerant of deficiency.

Nutrients

The soil organic matter content should be high.

Fertilizer application (kg/ha/growing cycle) for high production:

	min.	max.
N :	20	40 (starter)
P ₂ O ₅ :	90	140
K ₂ O :	95	120

3. YIELDS

Rainfed

Good commercial yield : 1.4 - 1.6 ton fresh pods/ha.

Irrigated

Good commercial yield : 2.0 - 3.0 ton fresh pods/ha.
0.6 - 0.8 ton dry pods/ha.

4. ROTATIONS

With alfalfa, potatoes and sugar beet.

CLIMATIC REQUIREMENTS - PEA (growing cycle : fresh 65-100 days, dry 85-120 days)

Climatic Characteristics	Climatic class, degree of limitation and rating						
	S1	S2	S3	N1	N2		
	0 1	2	3	4	5	6	7
Precipitation of the growing cycle (mm)	450-500 450-400	500-600 400-350	600-800 350-300	800-1000 300-200	-	> 1000 < 200	
Mean temp. of the growing cycle (°C)	17-18 17-16	18-20 16-14	20-23 14-10	23-25 10-8	-	> 25 < 8	
Mean min. temp at germination (°C)	23-22 23-24	22-20 24-26	20-12 26-28	12-5 28-30	-	< 5 > 30	

LANDSCAPE AND SOIL REQUIREMENTS - PEA

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-8	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	F1	-	F2+
Drainage (4)	good,	moder.	imperf.	poor	poor,	poor,
(5)	imperf.	moder.	good	and aeric	but drainab	not drainab
Physical soil characteristics (s)						
Texture/struct.	C<60s, SiC,Co, SiL,CL, SiCL,Si	C>60s,L, C<60v,SC SCL	C>60v, SL,LS, LfS	LcS,fS, S	-	Cm,SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 100	100-75	75-60	60-40	-	< 40
CaCO ₃ (%)	0-6	6-15	15-25	25-35	-	> 35
Gypsum (%)	0-2	2-4	4-10	10-20	-	> 20
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg soil)	> 8	8-5	5-3.5	3.5-2	< 2	-
pH H ₂ O	6.6-6.2	6.2-6.0	6.0-5.8	5.8-5.5	< 5.5	-
	6.6-7.0	7.0-7.5	7.5-8.0	8.0-8.2	-	> 8.2
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1.5	1.5-2.5	2.5-3.5	3.5-6	-	> 6
ESP (%)	0-8	8-15	15-20	20-25	-	> 25

PINEAPPLE
(*Ananas comosus*)

1. CLIMATE

Pineapple grows in regions that offer temperatures between 16 and 35°C. Growth is optimal in the range of 20 - 26°C. A mean daily maximum and minimum temperature of respectively 30°C and 20°C are ideal. Too high and too low temperatures affect the quality and the sugar/acid content. The variety 'Queen' is more tolerant than the variety 'Cayenne'. Pineapple is damaged by frost.

In order to secure an adequate water supply a precipitation of more than 600 mm/growing cycle is required. 1000 mm to 1600 mm of rainfall in the growing cycle secures an optimal water supply. Pineapple is to some extent drought resistant.

Pineapple prefers a high air humidity.

2. SOIL

The most suitable soils for growing pineapple are moderately deep (0.5 - 1.0 m) to deep (>1.0 m), well drained, sandy clay loam or sandier soils. The maximum crop rooting depth is 1.00 m.

pH range: 4.0 - 7.8, optimum pH: 5.0 - 6.5

Salinity: no yield reduction at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 10% at 1; 25% at 2; 50% at 3; 100% at 6 dS/m.

Sodicity: 50% yield reduction at an exchangeable sodium percentage (ESP) of 15.

Nutrients

A high organic matter content in the soil is preferred.

Fertilizer application (kg/ha/growing cycle) for a high production:

	min.	max.
N	230	300
P ₂ O ₅	105	150
K ₂ O	130	265

3. YIELDS

Rainfed

Good commercial yield : 40 - 48 ton/ha.
Average farmer yield : 12 - 25 ton/ha.

Irrigated

Good commercial yield : 75 - 90 ton/ha.
Average farmer yield : 40 ton/ha.

CLIMATIC REQUIREMENTS - PINEAPPLE (growing cycle : 365 days)

Climatic Characteristics	Climatic class, degree of limitation and rating						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Annual precipitation (mm)	1300-1200 1300-1400	1200-1000 1400-1600	1000-800 1600-2000	800-600 > 2000	-	< 600	-
Mean annual temp. (°C)	23-22 23-24	22-20 24-26	20-18 26-30	18-16 30-35	-	< 16 > 35	-
Annual relative humidity (°C)	70-80 70-60	> 80 60-50	50-40	40-30	-	< 30	-

LANDSCAPE AND SOIL REQUIREMENTS - PINEAPPLE

Land Characteristics	Class, degree of limitation and rating scale						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Topography (t)							
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-8	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	- - 30-50	> 6 > 16 > 50
Wetness (w)							
Flooding	Fo	-	-	-	-	-	F1+
Drainage	(4) good, (5) imperf.	moder. moder.	imperf. good	poor and aeric	poor, but drainab	poor, not drainab	
Physical soil characteristics (s)							
Texture/struct.	SCL,L	SL,SiL, Si,SC	LS,LfS,Co C<60s,SiC	C>60v, C>60s,fS	-	-	Cm,SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	-	> 55
Soil depth (cm)	> 75	75-60	60-40	40-20	-	-	< 20
CaCO ₃ (%)	0-1	1-2	2-3	3-5	-	-	> 5
Gypsum (%)	0-1	1-2	2-3	3-5	-	-	> 5
Soil fertility characteristics(f)							
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-	-
Sum of basic cations (cmol(+)/kg soil)	> 4	4-2.8	2.8-1.6	< 1.6	-	-	-
pH H ₂ O	5.7-5.4 5.7-6.0	5.4-5.0 6.0-6.5	5.0-4.3 6.5-7.0	4.3-4.0 7.0-7.8	< 4.0	-	> 7.8
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-	-
Salinity and Alkalinity (n)							
ECe (dS/m)	0-1	1-2	2-3	3-4	-	-	> 4
ESP (%)	0-5	5-10	10-15	15-20	-	-	-

POTATO (*Solanum tuberosum*)

1. CLIMATE

The temperature range for the growth of potatoes is 8 - 30°C. The growth is optimal at temperatures between 16 - 20°C. The growth of tubers is inhibited at temperatures below 10°C and above 27°C. The optimal soil temperature for tuber formation is 15 - 18°C. Night air temperatures below 15°C and generally cool weather favor tuber formation. High soil temperatures at planting cause the seeds to rot and lead to poor emergence. The crop is damaged by frost.

A precipitation of 300 - 700 mm/growing cycle is required. Excessive rainfall causes diseases. Hot and dry weather may cause wilting, even when sufficient soil moisture is available.

2. SOIL

Potatoes can grow on soils that have a fine sandy to (kaolinitic) clay texture, though loam to silty clay loam soils are preferred.

Heavy clays cause a poor emergence, poorly shaped tubers and harvesting problems. The soils must be well structured and freely workable. Suitable soils are well drained and aerated and moderately deep (0.5 - 1.0 m) to deep (> 1.0 m). The maximum crop rooting depth is 0.60 m.

Potatoes do not tolerate flooding. Slightly acid soils reduce the risk of scab.

Soils that are cropped with potatoes are exhibited to a medium erosion hazard.

pH range: 4.8 - 8.2, optimum pH: 5.6 - 7.0

Salinity: no yield reduction at an electrical conductivity (EC) of < 1.7 dS/m; the yield reduction is 10% at 2.5; 25% at 3.8; 50% at 6; 100% at 10 dS/m.

Sodicity: 50% yield reduction at an exchangeable sodium percentage (ESP) of 35.

Micronutrients

Copper : no or low response to application.
Boron : < 0.1 ppm required in the soil.
Manganese : high response to application.

Nutrients

Potatoes require a moderate to high soil fertility. The use of chloride fertilizers should be avoided. The organic matter content of the soil should be as high as possible.

Nutrient removal (kg/ha/growing cycle) to produce 25 ton/ha.

N	:	115
P ₂ O ₅	:	45
K ₂ O	:	200
Ca	:	70

Fertilizer application (kg/ha/growing cycle) to produce 25 ton/ha.

	min.	max.
N	50	100
P ₂ O ₅	50	100
K ₂ O	75	150

3. YIELDS

Rainfed

Good commercial yield : 25 - 28 ton/ha.

Irrigated

Good commercial yield : 25 - 35 ton/ha.

4. ROTATIONS

Rotations are essential due to nematode infestation. Potatoes may only be planted on the same land once in 3 - 4 years. Rotations with wheat, barley, maize, alfalfa, beans are a common practice.

CLIMATIC REQUIREMENTS - WHITE POTATO (growing cycle 90-120 days)

Climatic Characteristics	Class, degree of limitation and rating scale.					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Monthly rainfall(mm)						
1st month	> 60	60-45	45-30	30-20	-	< 20
2nd month	> 100	100-80	80-65	65-50	-	< 50
3rd month	> 100	100-80	80-65	65-50	-	< 50
4th month	70-40	40-20	< 20	-	-	-
	70-100	> 100	-	-	-	-
Mean temp. of the growing cycle (°C)	18-16 18-20	16-13 20-24	13-10 24-27	10-8 27-30	-	< 8 > 30
Average absol. min. temp. of first month (°C)	> 2	2-0	0 to -1	-1 to -2	-	< -2
Average absol. min. temp. 3 other months (°C)	> 0	0 to -1	-1 to -2	-2 to -3	-	< -3
Av. temp. difference between day-night (°C)	> 10	10-5	< 5	-	-	-
Average daylength growing cycle (h)	15-16 15-13	> 16 < 13	-	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - WHITE POTATO

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1	1-2	2-4	4-6	-	> 6
	(2) 0-2	2-4	4-8	8-16	-	> 16
	(3) 0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	F1	F2	F2+
Drainage	(4) good, (5) imperf.	moder.	imperf. good	poor and aeric	(corr.) poor but drainab	poor > not drainab
Physical soil characteristics (s)						
Texture/struct.	L,SCL	SC,SiL, SiCL,Cl, Si,SL,Co	C<60s,LS, Lfs	C>60v,LcS, C>60s,SiC, C>60v,fs	S,cS	Cm,SiCm
Coarse fragm(vol%)						
surface	0-1	1-3	3-15	15-35	-	> 35
depth (cm)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 90	90-60	60-40	40-20	-	< 20
CaCO ₃ (%)	0-5	5-10	10-15	15-30	-	> 30
Gypsum (%)						
Soil fertility characteristics(f)						
Apparent CEC (cmol+)/kg clay	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	65-50 65-80	50-35 80-100	< 35 -	- -	- -	- -
Sum of basic cations (cmol+)/kg soil	> 5	5-3.5	3.5-2	< 2	-	-
pH H ₂ O	6.3-6.0 6.3-6.5	6.0-5.6 6.5-7.0	5.6-5.2 7.0-8.0	5.2-4.8 8.0-8.2	< 4.8 -	- > 8.2
Organic carbon(%)	> 1.5	1.5-0.8	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-3	3-5	5-6	6-10	> 10
ESP (%)	0-15	15-25	25-35	35-45	-	> 45

RICE (*Oryza sativa*)

1. CLIMATE

Rice can be grown under a wide range of climatic conditions, both in temperate and hot tropical climates, from sea-level to high altitudes. Long periods of sunshine are essential for high yields. The yields are correlated with the received solar energy during the 45 days that precede the harvest.

No sudden temperature drops or strong winds should occur.

Germination does not take place at a soil temperature of $< 12^{\circ}\text{C}$.

Growth is optimal at air temperatures between 24 and 36°C . The difference between day and night temperature should be minimal during flowering and yield production. The irrigation water temperature is required to be $> 18^{\circ}\text{C}$.

Rice is sensitive to frost. Cool temperatures lead to head sterility.

The optimum precipitation for rainfed rice is > 1600 mm/year. Drought during 8 to 12 days at the time of flowering or at maturity has an adverse effect on the yield.

2. SOIL

Good management is more important than an ideal soil or climate.

Rice cultivation takes place on many types of soil. Soils with a heavy clay to even a sandy loam texture can be considered for rice growing. Soils on alluvial deposits with a heavy texture are usually better suited than those with a light texture. It should be possible to puddle the soil to maintain a high water-table during growth and to drain the soil for ripening and harvest.

Imperfectly to moderately well drained soils are most suited. The optimal permeability of the subsoil is: < 0.5 cm/hour.

Soils under rice cultivation are exposed to a low erosion hazard.

pH range: $4.5 - 8.2$, optimum pH: $5.5 - 7.5$

Salinity: no yield reduction at an electrical conductivity (EC)

of < 3 dS/m; the yield reduction is 10% at 3.8; 25% at 5.1; 50% at 7.2; 100% at 12 dS/m.

Sodicity: 50% yield reduction at an exchangeable sodium percentage (ESP) of 20.

Iron : should not be too high.

Nutrients

Due to the anaerobic conditions the decomposition of the organic matter is slowed down. N fixation takes place by Azobacter and blue-green algae.

Usually, deficiencies of N and P are observed. K and S deficiencies may occur in limited areas. Sometimes silica deficiency can be seen on peat soils.

Rice requires a high N input, and a moderate to high soil fertility.

Nutrient removal (kg/ha/growing cycle) to produce 3.4 ton/ha.

N	:	54
P ₂ O ₅	:	60
K ₂ O	:	55

Fertilizer application (kg/ha/growing cycle) to produce 4 ton/ha.

	min.	max.
N	75	100
P ₂ O ₅	25	50
K ₂ O	25	50

3. YIELDS

Rainfed

Average farmer yield : $1.5 - 2.5$ ton unhusked grain/ha.

Tradit. smallholder yield : $0.5 - 1.5$ ton unhusked grain/ha.

Rain (On-st. Experiments) : Control: 0.5t, NO: 1.5-2t, M: 2.5t (LA)

Irrigated

Good commercial yield : 6 - 8 ton unhusked grain/ha.
Average farmer yield : 4 - 5 ton unhusked grain/ha.

CLIMATIC REQUIREMENTS - RAINFED UPLAND RICE (growing cycle 90-150 days)

Climatic Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Precipitation of the 1st month (mm)	200-300 200-75	300-400 75-50	400-550 -	550-650 -	-	> 650 < 50
Precipitation of the 2nd month (mm)	200-300 200-125	300-400 125-100	400-550 100-75	550-650 75-50	-	> 650 < 50
Precipitation of the 3rd month (mm)	200-300 200-125	300-400 125-100	400-550 100-75	550-650 75-50	-	> 650 < 50
Precipitation of the 4th month (mm)	200-300 200-75	300-400 75-50	400-550 < 50	550-650 -	-	> 650 -
Mean temp. of the growing cycle (°C)	31-30 31-32	30-24 32-36	24-18 > 36	18-10 -	-	< 10 -
Mean max. temp. of warmest month G.C.(°C)	35-36 35-33	36-40 33-30	40-45 30-26	45-50 26-21	-	> 50 < 21
Mean temp. crop development stage (2nd month) (°C)	29-26 29-32	26-24 32-36	24-18 36-42	18-10 42-45	-	< 10 > 45
Mean min. temp. ripen. stage (4th month) (°C)	20-18 20-22	18-14 22-25	14-10 25-28	10-7 28-30	-	< 7 > 30
Relative humidity (%) tillage+veg. stage (1st + 2nd month)	65-60 65-75	60-50 75-90	50-40 90-100	40-30 -	-	< 30 -
Relative humidity (%) at harvest stage	50-37 50-65	37-33 65-80	33-30 > 80	< 30 -	-	- -
n/N growing cycle	> 0.75	0.75-0.65	0.65-0.45	< 0.45	-	-

LANDSCAPE AND SOIL REQUIREMENTS - RAINFED UPLAND RICE

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-2	2-4	4-8	8-16	16-25	> 25
(2)	0-4	4-8	8-16	16-30	-	> 30
Wetness (w)						
Flooding	no	-	F11	F12-F13	-	> F13
Drainage (4)	good,	moder.	imperf.	poor, aeric	poor, drain.	poor, not drain.
(5)	imperf.	moder.	good	poor, aeric	poor drain.	poor, not drain.
Physical soil characteristics (s)						
Texture/struct.	SiCs,Co, SiCL,Cl, Si,Sil	C-60s, C-60v, SC,L	C+60v, SCL,SL, Lfs	LS,LcS, fs	-	S,cS
Coarse fragm(vol%)	< 3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 120	120-90	90-50	50-20	-	< 20
Soil fertility characteristics(f)						
Apparent CEC (cmol+)/kg clay	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol+)/kg soil	> 4	4-2.8	2.8-1.6	< 1.6	-	-
pH H ₂ O	6.5-6.0	6.0-5.5	5.5-5.0	5.0-4.5	< 4.5	-
	6.5-7.0	7.0-7.5	7.5-7.9	7.9-8.2	-	> 8.2
Organic carbon(%)	> 2	2-1.5	1.5-0.8	< 0.8	-	-

CLIMATIC REQUIREMENTS - RAINFED BUNDED RICE (growing cycle 90-150 days)

Climatic Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Precipitation of the 1st month (mm)	300-200 300-400	200-175 400-500	175-125 500-650	125-100 650-750	-	< 100 > 750
Precipitation of the 2nd month (mm)	300-200 300-400	200-175 400-500	175-125 500-650	125-100 650-750	-	< 100 > 750
Precipitation of the 3rd month (mm)	300-200 300-400	200-175 400-500	175-125 500-650	125-100 650-750	-	< 100 > 750
Precipitation of the 4th month (mm)	150-200 150-70	200-300 70-50	300-500 50-30	500-600 < 30	-	> 600 -
Mean temp. of the growing cycle (°C)	31-30 31-32	30-24 32-36	24-18 > 36	18-10 -	-	< 18 -
Mean max. temp. of warmest month G.C.(°C)	35-36 35-33	36-40 33-30	40-45 30-26	45-50 26-21	-	> 50 < 21
Mean temp. crop development stage (2nd month) (°C)	29-26 29-32	26-24 32-36	24-18 36-42	18-10 42-45	-	< 10 > 45
Mean min. temp. ripening stage (4th month) (°C)	20-18 20-22	18-14 22-25	14-10 25-28	10-7 28-30	-	< 7 > 30
Relative humidity tillage+veg.stage (1st + 2nd month) (%)	65-60 65-75	60-50 75-90	50-40 90-100	40-30 -	-	< 30 -
Relative humidity at harvest stage (%)	50-37 50-65	37-33 65-80	33-30 > 80	< 30 -	-	- -
n/N growing cycle	> 0.75	0.75-0.65	0.65-0.45	< 0.45	-	-

FOR IRRIGATED RICE use only temperature, relative humidity and radiation characteristics.

LANDSCAPE AND SOIL REQUIREMENTS - RAINFED BUNDED RICE

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	< 2	2-4	4-8	8-25		> 25
Wetness (w)						
Flooding	no, F11, F12	F21, F22	F13,F23, F41,F42	F14,F23, F24,F34, F43	F15, F25, F44	F35, F45,
Drainage	poor	imperf.	moderate	good	- drain.	very poor
Physical soil characteristics (s)						
Surface texture(*)	Cm,SiCm, C+60v, C+60s	C-60v, C-60s, SiCs	Co, SiCl, Cl, Si	SiL, SC	-	L and lighter
(**)	Cm,SiCm, C+60v, C+60s	C-60v, C-60s, SiCs, Co, SiCL, CL, Si	SiL, SC, L, SCL	SL, LfS, LS, LcS, fs	-	S, cS
Coarse fragm(vol%)	0	1-3	3-15	15-35	-	> 35
Soil depth (cm)	to be considered with regard to levelling, grading and possibilities for land sliding					
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 80	80-50	50-35	35-20	< 20	-
Sum of basic cations (cmol(+)/kg soil)	> 6.5	6.5-4	4-2.8	2.8-1.6	< 1.6	-
pH H ₂ O	6.5-6.0	6.0-5.5	5.5-5.0	5.0-4.5	-	< 4.5
	6.5-7.0	7.0-8.2	8.2-8.5	8.5-9.0	-	> 9.0
Organic carbon(%)	> 2	2-1.5	1.5-0.8	< 0.8	-	-

(*) Subsoil from a depth of 30 cm has an infiltration rate of more than 0.1 cm/hour and no groundwater is present within 50 cm from the soil surface.

(**) Subsoil from a depth of 30 cm has an infiltration rate of less than 0.1 cm/hour and/or groundwater is present within 30 cm for the soil surface.

LANDSCAPE AND SOIL REQUIREMENTS - RICE CULTIVATION UNDER NATURAL FLOODS

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t) Slope (%)	can only be practiced in flat flood plains					
Wetness (w) Flooding	F32	F31	F42,F41 F43,F33	F22,F21 F23,F24 F34,F44	-	F11,F12 F13,F14 F15,F25 F45,F35 good
Drainage	very poor	poor	imperf.	moderate		
Physical soil characteristics (s) Surface texture (*)	Cm,SiCm, C+60v, C+60s	C-60v, C-60s, SiCs	Co SiCL CL,Si	SiL SC	-	L and lighter
(**)	Cm,SiCm, C+60v, C+60s	C-60v, C-60s, SiCs,Co, SiCL,CL, Si	SiL,SC, L,SCL	SL,Lfs, LS,LcS, fS	-	S,cS
Coarse fragm(vol%)	0	< 3	3-15	15-35	-	> 35
Soil depth (cm)	> 90	90-75	75-50	50-20	-	< 20
CaCo ₃	< 3	3-6	6-15	15-25	-	> 25
Gypsum (%)	< 1	1-3	3-10	10-15	-	> 15
Soil fertility characteristics(f) Apparent CEC (cmol+)/kg clay	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol+)/kg soil	> 4	4-2.8	2.8-1.6	< 1.6	-	-
pH H ₂ O	6.5-6.0	6.0-5.5	5.5-5.0	5.0-4.5	-	< 4.5
Organic carbon(%)	6.5-7.0	7.0-8.2	8.2-8.5	8.5-8.8	-	> 8.8
Salinity and Alkalinity (n) ECe (dS/m)	0-1	1-2	2-4	4-6	6-12	> 12
ESP	0-10	10-20	20-30	30-40	-	> 40

- (*) Subsoil has an infiltration rate of more than 0.1 cm/hour and no groundwater is present within 50 cm from the soil surface.
 (**) Subsoil has an infiltration rate of less than 0.1 cm/hour and/or groundwater is present within 50 cm for the soil surface.

LANDSCAPE AND SOIL REQUIREMENTS - IRRIGATED RICE

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t) Slope (%)	0	< 1	1-2	2-4	-	> 4
Wetness (w) Flooding	F0,F11, F12	F21,F23, F31,F32	F13,F23, F33,F41, F42,F43	F14,F24, F34,F44	-	F15,F25 F35,F45
Drainage	Imperf.	moderate	poor good	very poor	-	-
Physical soil characteristics (s) Surface texture (*)	Cm,SiCm, C+60v, C+60s	C-60v, C-60s, SiCs	Co, SiCL, CL,Si	SiL, SC	-	L and lighter
(**)	Cm,SiCm, C+60v, C+60s	C-60v, C-60s, SiCs,Co, SiCL,CL, Si	SiL,SC, L,SCL	SL,Lfs, LS,LcS, fs	-	S,cS
Coarse fragm(vol%)	0	< 3	3-15	15-35	-	> 35
Soil depth (cm)	> 90	90-75	75-50	50-20	-	< 20
CaCo ₃	< 3	3-6	6-15	15-25	-	> 25
Gypsum (%)	< 1	1-3	3-10	10-25	-	> 15
Soil fertility characteristics(f) Apparent CEC (cmol+)/kg clay	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 80	80-50	50-35	35-20	< 20	-
Sum of basic cations (cmol+)/kg soil	> 6.5	6.5-4	4-2.8	2.8-1.6	< 1.6	-
pH H ₂ O	6.5-6.0	6.0-5.5	5.5-5.0	5.0-4.5	-	< 4.5
Organic carbon(%)	6.5-7.0	7.0-8.2	8.2-8.5	8.5-9.0	-	> 9.0
Salinity and Alkalinity (n) ECe (dS/m)	0-1	1-2	2-4	4-6	6-12	> 12
ESP	0-10	10-20	20-30	30-40	-	> 40

- (*) Subsoil has an infiltration rate of more than 0.1 cm/hour and no groundwater is present within 50 cm from the soil surface.
 (**) Subsoil has an infiltration rate of less than 0.1 cm/hour and/or groundwater is present within 50 cm for the soil surface.

ROBUSTA COFFEE (*Coffea canephora*)

1. CLIMATE

Robusta coffee requires higher temperatures than arabica coffee. The temperature range for growth is 18 - 32°C. The crop does not tolerate frost.

Robusta coffee grows in areas that receive an annual precipitation between 1000 and 2500 mm. An optimal water supply is secured with 1750 mm of rainfall a year. The plant needs a drier period for the initiation of the flower buds.

The crop may be grown in the shade of banana trees. It prefers a high air humidity.

2. SOIL

Robusta coffee can be grown on shallow soils and will stand temporary waterlogging. Intermediate soil textures are preferred for coffee growing, not sands or poorly structured heavy clays.

pH range: 4.5 - 7.0, optimum pH: 5.3 - 6.0

Nutrients

See Arabica Coffee

3. YIELDS

Rainfed

Good commercial yield : 1.0 - 2.0 ton/ha (clean green hulled beans).

Smallholder yield : 0.5 - 1.2 ton/ha.

CLIMATIC REQUIREMENTS - ROBUSTA COFFEE

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitation (mm)	1900-1800 1900-2000	1800-1600 2000-2400	1600-1400 > 2400	1400-1200 -	-	< 1200 -
Length dry season (months : P < 1/2 PET)	0-1	1-2	2-3	3-4	-	> 4
Mean annual temp. (°C)	> 25	25-22	22-20	20-18	-	< 18
Mean annual max. temp. (°C)	> 29	29-27	27-24	24-22	-	< 22
Average daily min. temp coldest month (°C)	> 20	20-18	18-16	16-14	-	< 14
Mean rel. humidity dryest month (%)	65-75 65-60	75-80 60-45	80-90 45-35	> 90 35-30	- -	- < 30
n/N of 5 dryest months	> 0.5	0.5-0.6	< 0.5	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - ROBUSTA COFFEE

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	Fo	Fo	F1	-	F2+
Drainage	good, groundw. > 150 cm	good, groundw. 100-150 cm	moderate	imperf.	poor, but drainab	poor, not drainab
Physical soil characteristics (s)						
Texture/struct.	C<60s, Co SiCL, Cl, SC	C>60s, L, SCL	SL	LS, Lfs	-	Cm, SiCm C>60v, S, cs
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 200	200-150	150-100	100-50	-	< 50
CaCO ₃ (%)	0	-	-	0-1	-	> 1
Gypsum (%)	0	-	-	0-0.5	-	> 0.5
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 16	< 16(-)	< 16(+)	-	-	-
Base saturation(%)	> 35	35-20	< 20	-	-	-
Sum of basic cations (cmol(+)/kg soil)	> 4	4-2.8	2.8-1.6	< 1.6	-	-
pH H ₂ O	5.6-5.5	5.5-5.3	5.3-5.0	5.0-4.5	< 4.5	-
	5.6-5.8	5.8-6.0	6.0-6.5	6.5-7.0	-	> 7.0
Organic carbon(%)	> 1.5	1.5-0.8	< 0.8	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	-	-	1-2	2-4	> 4
ESP (%)						

RUBBER (*Hevea brasiliensis*)

1. CLIMATE

The rubber tree is original from the tropical rain forest. Therefore the temperature range for growth is situated between 22 and 35°C. Optimal growth conditions are met between temperatures of 27 and 28°C.

Rubber performs well in regions with an annual precipitation of 1250 - 4000 mm, well distributed over the entire year. All months should have > 100 mm of rainfall. Rubber has a low drought resistance. Both excessive amounts of rain and marked dry seasons reduce the yields.

Rubber trees are sensible to wind damage, in particular if the soils are shallow.

2. SOIL

The rubber tree has an extensive root system with a tap-root that can go 3.0 - 4.0 m deep and shallow lateral roots (in the 0-0.3 m layer) that can extend to over 20 m. Accordingly the ideal soils are deep (> 1.00 m), well aerated, well structured and provided with an adequate water holding capacity (the fine earth should contain up to 50 % of clay).

Rubber trees need well drained soils (a ground water table permanently at 4.0 - 6.0 m below the surface) with a good supply of water throughout the year. Under poor drainage conditions the roots atrophy.

Clayey and to some extent medium textures are most suitable.

Hardpans, stoniness (no gravels at < 1.0 m from the surface is optimal) and a high ground water table restrict root growth.

Soils that are subject to erosion need the application of conservation techniques. Land with slopes of < 8 % is most suitable.

pH range: 4.0 - 7.0, optimum pH: 5.0 - 6.0
at a pH > 6.5 growth is retarded and liming is deleterious.

Salinity: no yield reduction at an electrical conductivity (EC) of < 0.2 dS/m; the yield reduction is 50% at 1; 100% at 6 dS/m.

Nutrients

Rubber trees can grow adequately on impoverished soils, but they are equally responsive to a good nutrient supply and a balanced manuring programme. Though a CEC of > 15 cmol(+)/kg soil offers optimal conditions for rubber production, rubber production is not hampered at all at a CEC above 4 cmol(+)/kg soil. The organic matter content of the topsoil should be > 2 %.

Young rubber trees require N, P, K and Mg for optimum growth until tapping. However an excess of N should be avoided as this increases vegetative growth and tree height with a greater risk of trunk breakage.

Mature rubber trees have a low yield response to added fertilizers, but a balanced nutrient supply is essential.

Nutrient removal (kg/ha/growing cycle) to produce 1.5 ton/ha.

N	:	40
P ₂ O ₅	:	10
K ₂ O	:	25

Fertilizer application (kg/ha/growing cycle) to produce 1.5 ton/ha.

		min.		max.

N	:	25	-	45
P ₂ O ₅	:	20	-	35
K ₂ O	:	0	-	35

Mineral toxicity symptoms

Boron : faint interveinal mottled yellowing on the leaves followed by severe marginal and tip scorch.
Manganese : dull greenish-brown leaves and occasionally

interveinal scorch.

Mineral deficiency symptoms

Copper : defoliation and death of apical growing.
Magnesium : chlorosis in interveinal leaf areas spreading inwards from leaf margins.
Manganese : paling of leaf with bands of green tissue outlining midrib and veins (< 50 ppm in leaf).
Molybdenum : very pale scorch around leaf margins, particularly at leaf tip (in most acid soils).
Potassium : marginal and tip chlorosis followed by marginal necrosis.
Zinc : lamina becomes reduced in breadth and is often twisted and there is general chlorosis of the leaf with midrib and main veins remaining dark green.

3. YIELDS

Rainfed

Good commercial yield : 1 - 2 ton dry rubber/ha.

CLIMATIC REQUIREMENTS - RUBBER

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitation (mm)	> 2000	2000-1700	1700-1450	1450-1250	-	< 1250
Months of excessive rain (x)	0-1	1-2	2-4	> 4	-	-
Length dry season (months : P < 1/2 PET)	0-1	1-2	2-3	3-4	-	> 4
Mean annual temp. (°C)	> 25	25-22	22-20	20-18	-	< 18
Mean annual max. temp. (°C)	> 29	29-27	27-24	24-22	-	< 22
Average daily min. temp. coldest month (°C)	> 20	20-18	18-16	16-14	-	< 14
n/N mean annual	> 0.5	0.5-0.4	0.4-0.25	0.25-0.15	-	< 0.15

(x) : total of months with > 500 mm rainfall, plus half of the months with 300-500 mm rainfall

LANDSCAPE AND SOIL REQUIREMENTS - RUBBER

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)	0-4	4-8	8-16	16-30	30-45	> 45
Slope (%)	0-4	4-8	8-16	16-30	30-45	> 45
Wetness (w)	Fo	-	-	F1	-	F2+
Flooding	good :	good :	moderate	imperf.	poor,	poor,
Drainage	groundw. > 150 cm	groundw. 100-150 cm			but drainab	not drainab.
Physical soil characteristics (s)						
Texture/struct.	C<60s, Co, CL, SiCs, SC	C>60s, L, SCL	SL, LfS	LS, LcS, fs	-	Cm, SiCm, S, C<60v, cS, C>60v
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 200	200-150	150-100	100-50	-	< 50
CaCO ₃ (%)	0	-	-	0-1	-	> 1
Gypsum (%)	0	-	-	0-0.2	-	> 0.2
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	any(-)	any(+)	-	-	-	-
Base saturation(%)	25-30	30-35	35-50	50-80	> 80	-
Sum of basic cations (cmol(+)/kg soil)	25-20	< 20	-	-	-	> 6.5
pH H ₂ O	1.6-2.8	2.8-3.2	3.2-4	4-6.5	-	-
Organic carbon(%)	< 1.6	< 1.6	-	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	5.3-5.2	5.2-5.0	5.0-4.5	4.5-4.0	< 4.0	-
ESP (%)	5.3-5.5	5.5-6.0	6.0-6.5	6.5-7.0	-	> 7.0
	> 1.2	< 1.2	-	-	-	-
	0	0-0.5	0.5-1	1-2	2-6	> 6

SAFFLOWER (*Carthamus tinctorius*)

1. CLIMATE

Safflower is not well suited to the lowland humid tropics. It needs cool temperatures for root growth and rosette development (mean temperature between 15 and 20°C) and higher temperatures during stem growth, flowering and yield formation (mean temperature between 20 and 30°C). No germination occurs at temperatures below 2°C. Germination takes 16 days at 5°C and 4 days at 16°C.

The seedling is frost-resistant up to - 7°C, but after this stage frost below - 2°C kills.

The length of the growing cycle is 120-160 days (spring crop) or 200-230 days (autumn crop).

2. SOILS

Safflower needs fertile, deep, well-drained and medium-textured soils. The maximum crop rooting depth is 3.50 m. The watertable should be at a depth of > 1.00 m below the surface.

pH range: 5.2 - 8.3 ; optimal pH : 5.7 - 7.0 ; liming advised at pH < 6.

Salinity: No yield reduction occurs at an electrical conductivity (ECe) of 5.3 dS/m; the yield reduction is 10% at 6.2; 25% at 7.6; 50% at 9.9; 100% at 14.5 dS/m.

The crop is only half as tolerant to salinity at the time of germination.

Nutrients

Irrigated fertilizer requirements (kg/ha/growing cycle) :

N	: 60 - 110
P ₂ O ₅	: 35 - 70
K ₂ O	: 30 - 50

Responds well to N-fertilizers, but apply only after germination.

3. YIELDS

Rainfed

Good management : 1.0 - 1.5 ton/ha.
Average farmer yield : 0.8 - 1.3 ton/ha.

Irrigated

Good management : 2.0 - 4.0 ton/ha.
Average farmer yield : 1.5 - 2.0 ton/ha.

CLIMATIC REQUIREMENTS - SAFFLOWER (growing cycle 120-160 days)

CLIMATIC REQUIREMENTS - SAFFLOWER (growing cycle 110 days)

Climatic Characteristics	Climatic class, degree of limitation and rating						
	S1		S2		S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of the 1st month (mm)	100-75 100-150	75-50 150-300	50-25 300-475	- > 475	- -	< 25 -	
Precipitation of the 2nd month (mm)	150-125 150-175	125-100 175-300	100-50 300-475	50-25 > 475	- -	< 25 -	
Precipitation of the 3rd month (mm)	150-125 150-175	125-100 175-300	100-50 300-475	50-25 > 475	- -	< 25 -	
Precipitation of the 4th month (mm)	< 75	75-150	> 150	-	-	-	
Mean temp. of the 1st month (°C)	18-15 18-20	15-13 20-22	13-10 22-24	10-5 24-26	- -	< 5 > 26	
Mean temp. of the 2nd and 3rd month (C°)	25-28 25-22	28-30 22-20	30-32 20-17	32-34 17-12	- -	> 34 < 12	
Relative humidity of 3rd month (%)	< 60	60-65	65-75	75-85	-	> 85	
Relative humidity of 4th month (°C)	< 60	60-65	65-75	75-85	-	> 85	

LANDSCAPE AND SOIL REQUIREMENTS - SAFFLOWER

Land Characteristics	Class, degree of limitation and rating scale					
	S1	1	S2	S3	N1	N2
	0 100	95 85	2 60	3 40	4 25	0
Topography (t)						
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50
Wetness (w)						
Flooding	Fo	-	F1	F2	-	F3+
Drainage	(4) well	moderate s.exces	imperf. s.imperf.	poor and aeric	poor but drainab	poor, not drainab.
	(5) imperf. s.imperf.	moder.	well s.exces			
Physical soil characteristics (s)						
Texture/struct.	L,SiCL, SCL,CL	SiCs, SC,SL, SiL	Co,C<60, LS	SiCm, C>60,S	-	Cm,cS
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 100	100-75	75-50	50-30	-	< 30
CaCO ₃ (%)						
Gypsum (%)						
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 80	80-50	50-35	< 35	-	-
Sum of basic ca- tions (cmol(+)/kg soil)	> 6.5	6.5-4	4-2.8	2.8-1.6	< 1.6	-
pH H ₂ O	6.2-6.0	6.0-5.7	5.7-5.5	5.5-5.2	< 5.2	-
Organic carbon(%)	6.2-6.5	6.5-7.0	7.0-7.5	7.5-8.3	-	> 8.3
	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-6.2	6.2-7.6	7.6-9.9	9.9-12.5	-	> 12.5
ESP (%)						

SESAME (Sesamum indicum)

1. CLIMATE

Sesame seeds do not germinate at soil temperatures < 20°C. The optimal temperature range for growth is 25 - 29°C. The crop is sensitive to frost.

Sesame is secured of an adequate water supply in areas that receive 300-800 mm of precipitation in the growing cycle. Though the plant is considered to be drought resistant after the seedling stage, water is in particular required at establishment and at flowering. Sesame is very susceptible to hail damage at all stages of growth.

It needs a low to moderate air humidity. A high insolation is required at flowering. Shading (intercropping) reduces the yield.

Wind can cause damage.

2. SOILS

The soils that are optimally suited for the production of sesame are well-drained, deep, loamy soils. A wider range of textures can nevertheless be admitted. The crop is intolerant of water logging.

pH range: 4.5 - 8.5; optimal pH : 5.8 - 7.0

Salinity: the yield reductions at a given electrical conductivity (ECe) are as follows :
10 % at 2, 25 % at 4, 50 % at 6 and 75 % at 8 dS/m.

Nutrients

The amount of fertilizer needed for 1.5 ton/ha production (kg/ha/growing cycle) :

N	:	45
P ₂ O ₅	:	45
K ₂ O	:	10

Rotations are necessary.

3. YIELDS

Rainfed

Optimal yield : 1.2 - 1.5 ton/ha.
Average farmer yield : 0.5 - 0.6 ton/ha.

Irrigated

Optimal yield : 2.0 - 2.4 ton/ha.
Average farmer yield : 1.2 - 1.5 ton/ha.

CLIMATIC REQUIREMENTS - SESAME (growing cycle 70-100 days)

Climatic Characteristics	Climatic class, degree of limitation and rating						
	S1	1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of the 1st month (mm)	100-75 100-150	75-50 150-300	50-25 300-475	- > 475	- -	< 25 -	-
Precipitation of the 2nd month (mm)	175-150 175-200	150-100 200-275	100-50 275-475	50-25 > 475	- -	< 25 -	-
Precipitation of the 3rd month (mm)	< 120	120-200	> 200	-	-	-	-
Mean temp. of the growing cycle (°C)	25-27 25-24	27-28 24-20	28-30 20-18	30-38 18-16	- -	> 38 < 16	-
Mean max. temp. of growing cycle (°C)	35-36 35-34	36-38 34-25	38-40 25-15	40-42 -	- -	> 42 < 15	-
Mean min. temp. of growing cycle (°C)	19-18 19-20	18-16 20-28	16-14 28-30	14-12 > 30	- -	< 12 -	-
Relative humidity growing cycle (%)	< 60	60-65	65-75	75-85	-	> 85	-

LANDSCAPE AND SOIL REQUIREMENTS - SESAME

Land Characteristics	Class, degree of limitation and rating scale						
	S1	1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Topography (t)							
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50	
Wetness (w)							
Flooding	Fo	-	F1	F2	-	F3+	
Drainage	(4) well	moderate s.exces	imperf. s.imperf.	poor and aeric	poor but drainab	poor, not drainab.	
	(5) imperf. s.imperf.	moder.	well				
Physical soil characteristics (s)							
Texture/struct.	L,SCL,SL SiCL,CL	SiCs, SiL,SC	Cs,Co, LS	C>60,S	-	Cm,SiCm, CS	
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55	
Soil depth (cm)	> 100	100-75	75-50	50-30	-	< 30	
CaCO ₃ (%)							
Gypsum (%)							
Soil fertility characteristics(f)							
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-	
Base saturation(%)	> 80	80-50	50-35	< 35	-	-	
Sum of basic cations (cmol(+)/kg soil)	> 6.5	6.5-4	4-2.8	2.8-1.6	< 1.6	-	
pH H ₂ O	6.3-6.2 6.3-6.5	6.2-5.8 6.5-7.0	5.8-5.5 7.0-7.5	5.5-5.2 7.5-8.2	< 5.2 -	- > 8.2	
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-	
Salinity and Alkalinity (n)							
ECe (dS/m)	0-2	2-4	4-6	6-8	-	> 8	
ESP (%)							

SORGHUM **(*Sorghum bicolor*)**

1. CLIMATE

Germination of sorghum seeds takes place at soil temperatures above 10°C. Sorghum tolerates hotter and drier environmental conditions than maize. The optimum temperature for the growth of sorghum is 21 - 32°C. The crop is killed by frost.

The temperature has a marked effect on the length of time to maturity. A night temperature below 15°C for 5 nights completely inhibits anthesis.

Sorghum is grown in areas that have at least 150 mm of rainfall in the growing cycle. 400 to 900 mm of rainfall in the growing cycle guarantees an optimal water supply.

Its drought resistance makes sorghum suitable for areas of erratic rainfall. The plant remains dormant during drought. The stomata are scarcely affected by wilting for 14 days. Nevertheless the yield is reduced if the drought occurs during panicle formation and flowering.

Sorghum equally grows in areas of high rainfall in which waterlogging may occur, though under these conditions the plant may be attacked by fungi.

A high air humidity favors the occurrence of molds. Sorghum requires abundant sunshine. The crop is particularly susceptible to bird damage and storage pests.

2. SOIL

Sorghum grows on many types of soil. It grows particularly well on heavy soils, especially on the deep-cracking valley bottoms of the tropics (soils with vertic properties). The maximum crop rooting depth is 1.00-2.00 m. The crop tolerates a wide range of drainage conditions and also short periods of waterlogging.

Soils under sorghum cropping are exposed to a high erosion hazard.

pH range: 5.2 - 8.5, optimum pH: 5.5 - 8.2

Salinity: no yield reduction at an electrical conductivity (EC) of < 4 dS/m; the yield reduction is 10% at 5.1; 25% at 7.2; 50% at 11; 100% at 18 dS/m

Sodicity: 50% yield reduction at an exchangeable sodium percentage (ESP) of 20 .

Nutrients

Following the harvest, the root and stubble residues leave an excess amounts of sugar in the soil, causing a vigorous multiplication of the soil micro-organisms. This locks up the available N for some time (N-immobilization), inducing a N deficiency in a succeeding crop.

Droughted and freshly ratooned plants are a dangerous source of poisoning by HCN. N manuring increases the HCN content. The poison is destroyed when the fodder is made into hay or silage.

Nutrient removal (kg/ha/growing cycle) to produce 4 ton/ha:

N	:	120
P ₂ O ₅	:	50
K ₂ O	:	140

Fertilizer application (kg/ha/growing cycle) for high production:

	min.	max.
N	: 100	- 180
P ₂ O ₅	: 45	- 105
K ₂ O	: 40	- 95

3. YIELDS

Rainfed

Good commercial yield : 2.5 - 3.5 ton/ha.
Average farmer yield : 1.3 - 2.0 ton/ha.
Tradit. smallholder yield : 0.2 - 0.8 ton/ha.

Irrigated

Good commercial yield : 3.5 - 5.0 ton/ha.

CLIMATIC REQUIREMENTS - SORGHUM (growing cycle 90-130 + days)

Climatic Characteristics	Class, degree of limitation and rating scale.						
	S1		S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of growing cycle (mm)	600-500 600-700	500-400 700-900	400-300 900-1200	300-150 1200-1400	- -	< 150 >1400	
Precipitation of 3rd month	> 150	150-100	100-75	75-45	-	< 45	
Mean temp. of the growing cycle (°C)	25-24 25-26	24-21 26-32	21-18 > 32	18-15 -	- -	< 15 -	
Mean max. temp. of growing cycle (°C)	30-32 30-28	32-34 28-24	> 34 24-22	- 22-20	- -	- < 20	
Mean min. temp. of growing cycle (°C)	> 18	18-15	15-12	12-8	-	< 8	
Relative humidity growing cycle (%)	0-60	60-75	75-85	> 85	-	-	
n/N growing cycle	< 0.8	0.8-0.85	0.85-1	-	-	-	

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2
0

LANDSCAPE AND SOIL REQUIREMENTS - SORGHUM

Land Characteristics	Class, degree of limitation and rating scale						
	S1		S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Topography (t)							
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50	
Wetness (w)							
Flooding	Fo	-	F1	F2	-	F3+	
Drainage	(4) good (5) imperf.	moderate moderate	imperf. good	poor and aeric	poor, but drainab	poor, not drainab.	
Physical soil characteristics (s)							
Texture/struct.	C<60s, SiC,Co, SiCL,Si, SiL,SC	C<60v, C>60s,L, SCL	C>60v,SL	LFS,LS,S FS,LcS	-	Cm,SiCm, cS	
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55	
Soil depth (cm)	> 90	90-50	50-20	20-10	-	< 10	
CaCO ₃ (%)	3-20 3-2	20-30 2-0	30-45 -	45-75 -	-	> 75	
Gypsum (%)	0-3	3-5	5-10	10-20	-	> 20	
Soil fertility characteristics(f)							
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-	
Base saturation(%)	> 50	50-35	35-15	< 15	-	-	
Sum of basic cations (cmol(+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-	
pH H ₂ O	6.5-6.0 6.5-7.0	6.0-5.5 7.0-8.2	5.5-5.3 8.2-8.3	5.3-5.2 8.3-8.5	5.2	> 8.5	
Organic carbon(%)	(6) > 1.5 (8) > 0.8	1.5-0.8 0.8-0.4	< 0.8 < 0.4	- -	- -	- -	
Salinity and Alkalinity (n)							
ECe (dS/m)	0-4	4-8	8-12	12-16	16-20	> 20	
ESP (%)	0-10	10-20	20-28	28-35	-	> 35	

5.0

SOYA (Glycine maximum)

1. CLIMATE

The mean temperature range for a proper growth of soya is 15 - 40°C, the optimum temperature range being 20 - 30°C. The required mean minimum temperature in the growing season is 12 to 24°C.

Soya is only slightly resistant to frost.

Soya is produced in optimal conditions in areas that are secured of 350 - 1100 mm of rainfall in the growing cycle. Dry weather is required at maturation.

2. SOIL

Soya beans can be produced on a wide variety of soils. Flooding of the land is not permitted. The maximum crop rooting depth is 1.80 m.

pH range: 5.2 - 8.2, optimum pH: 5.5 - 7.5

Salinity: no yield reduction at an electrical conductivity (EC) of < 5 dS/m; the yield reduction amounts to 10% at 5.5; 25% at 6.2; 50% at 7.5; 100% at 10 dS/m.

Sodicity: 50% yield reduction is observed at an exchangeable sodium percentage (ESP) of 20 .

Nutrients

Nutrient removal (kg/ha/growing cycle) to produce 2 ton grain/ha:

N	:	125
P ₂ O ₅	:	30
K ₂ O	:	40

Fertilizer application (kg/ha/growing cycle) to produce 2 ton/ha.

min. max.

N	:	0	-	25
P ₂ O ₅	:	35	-	60
K ₂ O	:	35	-	75

3. YIELDS

Rainfed

Good commercial yield : 1.5 - 2.5 ton seed/ha.
Average farmer yield : 0.8 - 1.3 ton seed/ha.

Irrigated

Good commercial yield : 2.5 - 3.5 ton seed/ha.
Average farmer yield : 1.5 - 2.0 ton seed/ha.

4. ROTATIONS

Rotations should not include tobacco, but maize, sorghum and millets.

CLIMATIC REQUIREMENTS - SOYA (growing cycle 90-120 days)

Climatic Characteristics	Climatic class, degree of limitation and rating						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of growing cycle (mm)	600-800 600-450	800-1100 450-350	1100-1600 350-250	1600-1900 250-180	- -	> 1900 < 180	
Precipitation of the 1st month	150-200 150-85	200-275 85-60	275-400 60-50	400-475 -	- -	> 475 < 60	
Precipitation of the 2nd month (mm)	170-200 170-140	200-275 140-115	275-400 115-80	400-475 80-50	- -	> 475 < 50	
Precipitation of the 3rd month (mm)	170-200 170-140	200-275 140-115	275-400 115-80	400-475 80-50	- -	> 475 < 50	
Precipitation of the 4th month (mm)	140-200 140-85	200-275 85-60	275-400 60-40	400-475 < 40	- -	> 475 -	
Mean temp. of the growing cycle (°C)	24-22 24-25	22-20 25-30	20-18 30-35	18-15 35-40	- -	< 15 > 40	
Mean min. temp. of growing cycle (°C)	17-16 17-18	16-12 18-24	12-9 24-30	9-7 > 30	- -	< 7 -	
Relative humidity of devel. stage (%) (2nd month)	65-50 65-80	50-42 > 80	42-36	36-30	- -	< 30 -	
Relative humidity of maturation stage (%) (4th month)	45-30 45-60	30-24 60-75	24-20 75-85	< 20 > 85	- -	- -	
n/N develop. stage (2nd month)	0.55-0.5 0.55-0.6	0.5-0.35 0.6-0.75	< 0.35 > 0.75	-	-	-	
n/N maturation stage (4th month)	> 0.7	0.7-0.5	< 0.5	-	-	-	

LANDSCAPE AND SOIL REQUIREMENTS - SOYA

Land Characteristics	Class, degree of limitation and rating scale						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Topography (t)							
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50	
Wetness (w)							
Flooding	Fo	-	-	F1	-	F2+	
Drainage	(4) good (5) imperf.	moderate moderate	imperf. good	poor and aeric	poor, but drainab	poor, not drainab.	
Physical soil characteristics (s)							
Texture/struct.	C<60s, SiC,Co, SiL,CL, Si,SiCL	C<60v, C>60s, SC,L,SCL	C>60v,SL, LS,LfS	LcS,fS, S	-	Cm,SiCm	
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55	
Soil depth (cm)	> 100	100-75	75-50	50-20	-	< 20	
CaCO ₃ (%)	0-6	6-15	15-20	20-25	-	> 25	
Gypsum (%)	0-0.1	0.1-0.2	0.2-1	1-2	-	> 2	
Soil fertility characteristics(f)							
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-	
Base saturation(%)	> 50	50-35	35-20	< 20	-	-	
Sum of basic cations (cmol(+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-	
pH H ₂ O	6.5-6.0	6.0-5.5	5.5-5.4	5.4-5.2	-	< 5.2	
	6.5-7.0	7.0-7.5	7.5-7.8	7.8-8.2	-	> 8.2	
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-	
Salinity and Alkalinity (n)							
ECe (dS/m)	0-5	5-6	6-7	7-8	8-10	> 10	
ESP (%)	0-8	8-15	15-20	20-25	-	> 25	

SUGAR CANE (*Saccharum officinarum*)

1. CLIMATE

Sugar-cane requires a warm, sunny and moist growing season: a mean day temperature close to 28°C, a high insolation (> 1200 hours/year) and an adequate water supply summarize the optimal conditions.

Sugar-cane cuttings do not sprout at temperatures below 20°C. The temperature range for the growth of sugar-cane is 15 - 45 °C. Very little growth occurs below 20°C and above 34°C. Growth is optimal between 24°C and 32°C. The soil temperature is more important than the air temperature.

During ripening dry and cool weather is required. Mean day temperatures in the range of 10 - 20°C are optimal. Only very light frost can be tolerated.

Areas where sugar-cane is produced need a precipitation that exceeds 1300 mm/growing period. An adequate water supply in the growing season is guaranteed if the rainfall amounts 110 -180 mm/month.

A high air humidity causes diseases. At maturation the relative air humidity is required to be below 70 %.

No strong winds should prevail in sugar-cane growing areas.

2. SOIL

Sugar-cane prefers well drained, well structured and aerated loams to clay loams that are more than 1.00 m deep. The maximum rooting depth of the crop is 3.00 m. Preferably the ground water table occurs at a depth below 1.50 m from the surface. An available water content of the soil of > 150 mm/m is optimal.

Though sugar-cane tolerates short spells of waterlogging (1-2 weeks) or flooding, these conditions enhance the risk for fungal, viral and bacterial diseases.

Sugar-cane can equally be grown on soils with textures other than loam or clay loam. Such textures nevertheless offer a number of disadvantages:

- In coarse textured soils nematode populations are easily built up. Infestations may be aggravated because sugar-cane is a perennial crop. The limited AWC may limit plant growth and fertilizer losses by leaching may be increased.
- Fine textured soils may have long lasting drainage problems. Surface capping (especially in silty soils) reduces the water penetration and aeration. Compaction further hinders the root development.

Once the full canopy is established (3-4 months) a good protection against erosion is secured.

pH range : 4.5 - 8.5, optimum pH : 5.5 - 7.5

Salinity : no yield reduction at an electrical conductivity (EC) of < 1.7 dS/m; the yield reduction is 10% at 3.3; 25% at 6; 50% at 10.4; 100% at 18.6 dS/m.

Sodicity : 50% yield reduction is observed at an exchangeable sodium percentage (ESP) of 20.

Mineral deficiency symptoms

- Copper : 'droopy top': failure of the spindle to uncurl, with drooping leaves in heavier canes, chlorosis and poor growth; the symptoms resemble the mosaic disease.
- Iron : pale, striped interveinal areas in young leaves, the leaves are almost white in severe cases.
- Boron : small, elongated, watery spots striping parallel to the vascular bundles.
- Manganese : pale yellowish-green to white interveinal stripes of uniform width, over mid-portion and tips of leaves; the early stages look like Fe deficiency; acute cases may show complete chlorosis of leaf with reddish-brown necrotic spots, developed into continuous lengthwise stripes that cause leaf splitting.
- Calcium : small chlorotic spots, developing to dark reddish brown with dead centres which may coalesce producing a rusty appearance to the leaf.
- Magnesium : rare, young leaves become pale green and older leaves show small chlorotic spots, becoming dark brown.
- Nitrogen : stunted growth, pale leaves, lack of vigor.

Phosphorus: root rot, stunting, pale green to yellow leaves, with drying of tips and margins.
 Potassium : leaf die-back from tips and margins; upper surfaces of midribs become reddish.
 Zinc : rare, pale green along major veins; increasingly pale interveinal areas with increasing deficiency. In severe cases young leaves are completely chlorotic, with necrosis spreading down from leaf tips.

Nutrients

Nutrient removal (kg/ha/growing cycle) to produce 90 ton/ha:

N : 85
 P₂O₅ : 60
 K₂O : 180

Fertilizer application (kg/ha/growing cycle) to produce 90 ton/ha.

min. max.

N : 75 - 100
 P₂O₅ : 60 - 100
 K₂O : 75 - 100

3. YIELDS

Rainfed

Good commercial yield : 70 - 100 ton/ha.

Irrigated

Good commercial yield : 110 - 150 ton/ha.

CLIMATIC REQUIREMENTS - SUGAR CANE (growing cycle 270-2100 days)

Climatic Characteristics	Climatic class, degree of limitation and rating						
	S1		S2		S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
10 days rainfall (mm)	> 70	70-60	60-50	50-30	-	< 30	
Mean day temp. at germination (°C)	28-30 28-26	30-32 26-24	32-34 24-20	34-35 20-16	-	> 35 < 16	
Mean day temp. for tillage stage (°C)	27-28 27-26	28-32 26-20	32-35 20-16	> 35 16-8	-	- < 8	
Mean day temp. for vegetative stage (°C)	26-25 26-27	25-22 27-32	22-20 32-35	20-18 > 35	-	< 18 -	
(Tmax-Tmin)/Tmean maturation stage	> 0.5	0.5-0.45	0.45-0.4	0.4-0.3	-	< 0.3	
Sunshine : hours/year	> 2200	2200-1800	1800-1400	1400-1200	-	< 1200	
Mean annual n/N	> 0.5	0.5-0.4	0.4-0.3	0.3-0.2	-	< 0.2	
Relative humid. of maturation stage (%)	0-60	60-70	> 70	-	-	-	

LANDSCAPE AND SOIL REQUIREMENTS - SUGAR CANE

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1	1-2	2-4	4-6	-	> 6
	(2) 0-2	2-4	4-8	8-16	-	> 16
	(3) 0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	F1	-	F2+
Drainage	(4) good	moderate	imperf.	poor and	poor,	poor,
	(5) imperf.	moderate	good	aeric	but	not
				drainab		drainab.
Physical soil characteristics (s)						
Texture/struct.	C<60s, SiC,Co, SiL,CL, Si, SiCL	C>60v, C<60s, SC,L,SCL	C>60v,SL, LS,Lfs	LcS,fs, LS	-	Cm,SiCm, S,cS
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 125	125-80	80-50	50-25	-	< 25
CaCO ₃ (%)	0-12	12-25	25-35	35-50	-	> 50
Gypsum (%)	0-3	3-6	6-12	12-20	-	> 20
Soil fertility characteristics(f)						
Apparent CEC (cmol+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 80	80-50	50-35	< 35	-	-
Sum of basic cations (cmol+)/kg soil)	> 8	8-5	5-3.5	3.5-2	< 2	-
pH H ₂ O	6.5-6.0	6.0-5.5	5.5-5.0	5.0-4.5	< 4.5	-
	6.5-7.0	7.0-7.5	7.5-8.0	8.0-8.5	-	> 8.5
Organic carbon(%)						
(6)	> 2.5	2.5-1.5	1.5-1.0	< 1.0	-	-
(7)	> 1.5	1.5-1.0	1.0-0.6	< 0.6	-	-
(8)	> 0.8	0.8-0.4	< 0.4	-	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-2	2-5	5-8	8-10	10-14	> 14
ESP (%)	0-5	5-10	10-15	15-20	-	> 20

SUNFLOWER
(*Helianthus annuus*)

1. CLIMATE

The temperature range for the growth of sunflower is 13 - 30°C. An optimal growth occurs in areas with an air temperature between 18°C and 26°C. The ideal air temperature however is 22 °C; each 1°C more decreases the oil content with 1.5 %. Sunflower is sensitive to frost, though it stands a little freezing.

Sunflower is grown in areas with a precipitation of 250 - 4000 mm/year. Though the plant is drought resistant, an equal distribution of the rainfall in the growing period enhances the chances of obtaining a high yield. Adequate moisture is required at flowering, but no heavy rains should occur.

Strong winds may cause damage.

2. SOIL

Sunflower is most often grown on ferruginous and brown calcimorphic soils. Well drained soils with a sandy clay loam to clay texture and a soil depth that exceeds 1.50 m are most suitable. The maximum rooting depth of the crop is 2.00-3.00 m. Sunflower is intolerant of waterlogging.

pH range : 5.0 - 8.5, optimum pH : 6.0 - 7.5;
liming is advised at pH < 6 .

Salinity : no yield reduction occurs at an electrical conductivity (EC) of < 1 dS/m; the yield reduction is 10% at 2; 25% at 4; 50% at 9; 100% at 12 dS/m.

Sodicity : 50% yield reduction is observed at an exchangeable sodium percentage (ESP) of 20 .

Micronutrients

Boron : the plant tolerates 1-2 mg/l in soil solution.
Magnesium : sensitive to deficiency when pH is low.
Aluminium : sensitive to toxicity especially on sandy soils with a low pH.

Nutrients

Nutrient removal (kg/ha/growing cycle) to produce 1 ton seed/ha:

N : 39
P₂O₅ : 6
K₂O : 75

Fertilizer application (kg/ha/growing cycle) to produce 1 ton seed/ha:

	min.	max.
N	50	100
P ₂ O ₅	45	105
K ₂ O	70	150

3. YIELDS

Rainfed

Good commercial yield : 2.1 - 2.4 ton seed/ha.
Average farmer yield : 1.0 - 1.5 ton seed/ha.

Irrigated

Good commercial yield : 2.5 - 3.5 ton seed/ha.
Average farmer yield : 1.5 - 2.0 ton seed/ha.

4. ROTATIONS

Sunflower should not follow safflower, cotton, pea, beets, potatoes or alfalfa in rotations because diseases can be transmitted.

Sunflower is grown on the same field only once in every 6 years.

CLIMATIC REQUIREMENTS - SUNFLOWER (growing cycle 100-140 days)

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Precipitation of growing cycle (mm)	650-800 650-500	800-900 500-400	900-1300 400-300	> 1300 300-250	- -	- < 250
Precipitation of the 1st month	105-135 105-75	135-215 75-60	> 215 < 60	- -	- -	- -
Precipitation of the 2nd month + 3rd month (mm)	195-230 195-160	> 230 160-125	125-85	85-70	-	< 70
Precipitation of the 4th month (mm) (flowering stage)	250-315 250-190	315-450 190-140	450-750 140-120	> 750 120-80	- -	- < 80
Precipitation of the 5th month (mm) (yield formation)	100-120 100-75	120-150 < 75	> 150 -	- -	- -	- -
Mean temp. of growing cycle (°C)	22-20 22-24	20-18 24-26	18-16 26-28	16-13 28-30	- -	< 13 > 30
Relative humidity growing cycle (%)	65-50 65-80	50-42 80-90	42-36 > 90	36-30 -	- -	< 30 -

LANDSCAPE AND SOIL REQUIREMENTS - SUNFLOWER

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%) (1)	0-1	1-2	2-4	4-6	-	> 6
(2)	0-2	2-4	4-8	8-16	-	> 16
(3)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Po	-	-	F1	-	F2+
Drainage (4)	good	moderate	imperf.	poor and	poor,	poor,
(5)	imperf.	moderate	good	aeric	but	not
				drainab	drainab	drainab.
Physical soil characteristics (s)						
Texture/struct.	C<60s, SiC,Co, SiL,Si, SiCL,CL	C>60s, SC,L,SCL C<60v	C>60v,SL, LFS,LS	LcS,fs,S	-	Cm,SiCm,
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 150	150-100	100-75	75-50	-	< 50
CaCO ₃ (%)	0-6	6-15	15-25	25-35	-	> 35
Gypsum (%)	0-2	2-4	4-10	10-20	-	> 20
Soil fertility characteristics(f)						
Apparent CEC (cmol+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol+)/kg soil)	> 4	4-2.8	2.8-1.6	< 1.6	-	-
pH H ₂ O	6.6-6.2	6.2-6.0	6.0-5.5	5.5-5.0	< 5.0	-
	6.6-7.0	7.0-7.5	7.5-8.0	8.0-8.5	-	> 8.5
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-2	2-4	4-9	9-12	-	> 12
ESP (%)	0-8	8-15	15-20	20-25	-	> 25

SWEET POTATO
(*Ipomoea batatas*)

1. CLIMATE

Sweet potato is grown in regions with air temperatures in the range of 16 - 40°C. The optimal mean air temperature for growth is 22°C to 32°C. A night temperature between 18°C and 21°C, and a day temperature between 29°C and 32°C are preferred. Growth stops at temperatures below 4°C and is reduced at temperatures below 10°C. The plant is sensitive to frost.

Sweet potato is adequately provided with water in areas that receive 550 - 1270 mm in the growing season. Though the crop is very resistant to drought, tuber formation will be highest in those areas where the rainfall is equally distributed over the growing period. At harvest little rain is required.

2. SOIL

Sweet potato prefers deep, moderately well to well drained sandy loam to clay soils. Massive clays or hard/stony soils are to be avoided. The minimum soil depth is 0.50 m. The optimum soil depth is > 1.0 m. The maximum rooting depth of sweet potato is > 180 cm. Waterlogging is not permitted.

Medium erosion hazard.

pH range : 4.5 - 8.5, optimum pH : 5.2 - 8.2

Salinity : no yield reduction occurs at an electrical conductivity (EC) of < 2 dS/m; the yield reduction amounts to 10% at 2.5; 25% at 3; 50% at 6; 100% at 11 dS/m.

Sodicity : 50% yield reduction is observed at an exchangeable sodium percentage (ESP) of 20 .

Micronutrients

Boron : tolerates 1-2 mg/l in soil solution.
Magnesium : tolerant to deficiency.

Nutrients

Sweet potato requires moderately fertile to fertile soils and is very demanding in K.

Nutrient removal (kg/ha/growing cycle) to produce 10 ton tubers/ha:

N : 90	CaO : 15
P ₂ O ₅ : 20	MgO : 15
K ₂ O : 120	

3. YIELDS

Rainfed

Good commercial yield : 25 - 30 ton tubers/ha.
Average farmer yield : 5 - 10 ton tubers/ha.

Irrigated

Good commercial yield : 25 - 35 ton tubers/ha.
Average farmer yield : 12 - 18 ton tubers/ha.

CLIMATIC REQUIREMENTS - SWEET POTATO (growing cycle 120-150 days)

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitation (mm)	950-750 950-1150	750-650 1150-1500	650-500 1500-1700	500-400 > 1700	- -	< 400 -
Number of dry months in growing cycle (P < 1/2 PET)	0	-	1	2	-	> 2
Mean temp. of the growing cycle (°C)	25-26 25-24	26-32 24-22	32-35 22-20	35-40 20-16	- -	> 40 < 16
Mean min. temp. of growing cycle (°C)	17-16 17-18	16-12 18-24	12-9 24-28	9-7 28-30	- -	< 7 > 30
RH at harvest (%)	< 60	60-75	75-85	> 85	-	-
n/N develop. stage	0.55-0.5 0.55-0.6	0.5-0.35 0.6-0.75	< 0.35 > 0.75	- -	- -	- -
n/N maturation stage	> 0.7	0.7-0.5	< 0.5	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - SWEET POTATO

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1	1-2	2-4	4-6	-	> 6
	(2) 0-2	2-4	4-8	8-16	-	> 16
	(3) 0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	F1	-	F2+
Drainage	(4) good	moderate	imperf.	poor and	poor,	poor,
	(5) imperf.	moderate	good	aeric	but	not
				drainab		drainab.
Physical soil characteristics (s)						
Texture/struct.	C<60s, SiC, Co, SiCL, Si	C<60v, SL, C>60s, L, SCL, SC	C>60v, LS, Lfs	LcS, fs, S	-	Cm, SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 100	100-75	75-50	50-20	-	< 20
CaCO ₃ (%)	0-6	6-15	15-25	25-30	-	> 30
Gypsum (%)	0-2	2-4	4-10	10-20	-	> 20
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-
pH H ₂ O	6.6-6.0	6.0-5.2	5.2-4.8	4.8-4.5	< 4.5	-
	6.6-7.2	7.2-8.2	8.2-8.4	8.4-8.5	-	> 8.5
Organic carbon(%)	> 3	3-2	2-1	< 1	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-3	3-6	6-10	-	> 10
ESP (%)	0-8	8-15	15-20	20-25	-	> 25

3. YIELDS

Rainfed

Good commercial yield : 1.5 - 2.5 ton /ha.

4. ROTATIONS

Tea should not follow safflower, cotton, pea, beets, potatoes or alfalfa in rotations (diseases).

CLIMATIC REQUIREMENTS - TEA

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Annual precipitation (mm)	> 1500	1500-1300	1300-1100	1100-1000	-	< 1000
Length dry season (months : P < 1/2 PET)	0-1	1-2	2-3	3-4	-	> 4
Length non-humid period (months : P < PET)	2	2-5 2-0	4-5	5-6	-	> 6
Mean annual temp. (C°)	21-19 21-23	19-17 23-24	17-15 24-26	15-13 26-30	-	< 13 > 30
Mean min. temp. of warmest month (°C)	< 20	20-22	22-24	24-26	-	> 26
Average min. temp. coldest month (°C)	> 13	13-10	10-5	5 to -3	-	< -3
Average max. temp. warmest month (°C)	< 28	28-30	30-34	34-36	-	> 36
Mean temp. of 4 warmest month (°C)	> 21	21-19	19-17	17-15	-	< 15
Mean rel. humidity (%)	> 80	80-70	70-60	60-50	-	< 50

LANDSCAPE AND SOIL REQUIREMENTS - TEA

Land Characteristics	Class, degree of limitation and rating scale					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	Fo	F1	F2	-	F3+
Drainage	good	moderate	imperf.	poor	very poor drainab	very poor not drainab.
Physical soil characteristics (s)						
Texture/struct.	SiCl, SiL, CL, Si, SCL	C<60v, Co, SCL	C>60v, SL, Lfs	LS, LcS, fs	-	Cm, SiCm, S, cS, C>60v
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 150	150-100	100-50	50-25	-	< 25
CaCO ₃ (%)	0	0	0	0-1	-	> 1
Gypsum (%)	0	0	0	0-0.2	-	> 0.2
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 16	< 16(-)	< 16(+)	-	-	-
Base saturation(%)	15-10	10-0	20-35	35-50	-	> 50
Sum of basic cations (cmol(+)/kg soil)	> 2.8	2.8-1.6	< 1.6	-	-	-
pH H ₂ O	5.0-4.8	4.8-4.5	4.5-3.8	3.8-3.0	< 3.0	-
Organic carbon(%)	5.0-5.2	5.2-5.5	5.5-5.8	5.8-6.0	-	> 6.0
	> 2.4	2.4-1.5	1.5-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-3	3-4	4-8	> 8
ESP (%)	0-5	5-8	8-10	10-15	15-20	> 20

TOBACCO
(*Nicotiana tabacum*)

1. CLIMATE

The temperature optimum for the growth of tobacco is 22 - 28°C. The crop does not like sudden temperature drops. It is damaged by frost.

Tobacco requires a well distributed precipitation that amounts 400 - 1400 mm/growing cycle. Though the crop exhibits some drought resistance when young, this is less so during growth.

Excessive rain is a major limitation. A high air humidity encourages diseases. Sunny days are required to secure growth and yield. Hail can cause serious damage.

2. SOIL

In tropical areas tobacco is grown on sandy to loamy soils. Clay loam to sandy clay loam soils are preferred provided they are friable and freely drained. A good structure is important. The soil depth is less important, but the crop performs better if the available soil depth exceeds 1.20 m. The maximum crop rooting depth is > 1.00 m. No drainage impedance should occur.

pH range: 5.0 - 7.8, optimum pH: 5.5 - 6.2

Salinity: no yield reduction at an electrical conductivity (EC) of < 0.5 dS/m; the yield reduction is 10% at 1; 25% at 2; 50% at 4; 100% at 6 dS/m.

Sodicity: 50% yield reduction at an exchangeable sodium percentage (ESP) of 15 .

Nutrients

Tobacco is not produced on very fertile soils.

Nutrient removal (kg/ha/growing cycle) to produce 2.5 ton barn dry leaves/ha:

N : 50
P₂O₅ : 15

K₂O : 125

Fertilizer application (kg/ha/growing cycle) for high production:

	min.	max.
N	40	80
P ₂ O ₅	70	205
K ₂ O	60	130
CaO		140

3. YIELDS

Rainfed

Good commercial yield : 1.0 - 1.5 ton air cured leafs/ha.

Irrigated

Good commercial yield : 1.5 - 3.0 ton air cured leafs/ha.

Average farmer yield : 1.5 - 2.0 ton air cured leafs/ha.

CLIMATIC REQUIREMENTS - TOBACCO (growing cycle 90-120 days + 40-60 days nursery)

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Precipitation of growing cycle (mm)	900-800 900-1000	800-600 1000-1200	600-500 1200-1400	500-400 > 1400	-	< 400
Mean temp. of the growing cycle (°C)	25-24 25-26	24-22 26-28	22-20 28-30	20-15 30-34	-	< 15 > 34
Relative humidity growing cycle (%)	40-30 40-50	30-24 50-75	24-20 75-90	< 20 > 90	-	-
Annual n/N	> 0.7	0.7-0.5	< 0.5	-	-	-

LANDSCAPE AND SOIL REQUIREMENTS - TOBACCO

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50
Wetness (w)						
Flooding	Fo	-	-	-	-	F1+
Drainage	(4) good (5) imperf.	moderate moderate	imperf. good	poor and aeric	poor, but drainab	poor, not drainab.
Physical soil characteristics (s)						
Texture/struct.	SL,L	Co,CL,SC SCL,Lfs	C<60s,LS, SiCs	C>60v,S C>60s	-	Cm,SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 150	150-100	100-50	50-10	-	< 10
CaCO ₃ (%)	0-1	1-2	2-5	5-10	-	> 10
Gypsum (%)	0-0.2	0.2-0.5	0.5-1	1-3	-	> 3
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-
pH H ₂ O	5.8-5.7 5.8-6.0	5.7-5.5 6.0-6.2	5.5-5.2 6.2-6.8	5.2-5.0 6.8-7.8	< 5.0 -	- > 7.8
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-1	1-2	2-4	4-6	-	> 6
ESP (%)	0-5	5-10	10-15	15-20	-	> 20

TOMATO
(*Solanum lycopersicum*
***esculentum*)**

1. CLIMATE

The germination of tomato seeds is observed at temperatures between 10 and 35°C, the optimum range for germination being 16 - 30°C. Tomatoes grow in areas with air temperatures between 13 and 35°C. Optimum growth can only be accomplished at air temperatures between 18 and 26°C. At flowering, the optimum temperature is 18 - 24°C. The required temperature range at fruit setting is 12 - 32°C; the optimal temperature range is 16 - 22°C. For high yields, day-and-night temperatures should not differ by more than 6 - 10°C. Too high temperatures cause flower drop; too low temperatures cause malformed fruits. The tomato plant is very sensitive to frost.

Tomatoes are best grown in areas that can provide 400 - 700 mm/growing cycle. Moisture is required from flowering to harvest. Too high rainfall causes the fruits to rot.

A high relative air humidity favours diseases. Tomato does not tolerate shade. Hot and dry winds lead to flower drop and reduce the yield.

2. SOIL

Tomatoes are grown on soils with very different textures, but a light silt or clay loam texture is preferred. The required minimum soil depth is 0.6 m. The soil depth is optimal if greater than 1.50 m. The maximum crop rooting depth is equally 1.50 m.

Water logging increases the incidence of diseases.

pH range: 5.0 - 8.2, optimum pH: 6.0 - 7.5

Salinity: most sensitive at germination and early growth.
no yield reduction at an electrical conductivity (EC) of < 2.5 dS/m; the yield reduction is
10% at 3.5; 25% at 5; 50% at 7.6; 100% at 12.5 dS/m.

Sodicity: 50% yield reduction at an exchangeable sodium

percentage (ESP) of 35 .

Micronutrients

Boron : somewhat tolerant to excess, 1-2 mg/l in the soil solution.

Magnesium : sensitive to deficiency.

Lithium : 12 ppm in soil means 25 % reduction of growth.

Nutrients

Tomato shows high requirements of organic matter and N.

Fertilizer application (kg/ha/growing cycle) to produce a crop of 20 ton /ha (before + after transplanting):

N	:	50	+	100
P ₂ O ₅	:	100	+	100
K ₂ O	:	100	+	75 x 2

3. YIELDS

Rainfed

Good commercial yield : 45 - 50 ton/ha.

Average farmer yield : 10 - 20 ton/ha.

Irrigated

Good commercial yield : 45 - 65 ton/ha.

Average farmer yield : 20 - 40 ton/ha.

4. ROTATIONS

With maize, cabbage, cowpea ...

CLIMATIC REQUIREMENTS - TOMATO (growing cycle 90-120 days + 25-35 days nursery)

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1		S2	S3	N1	N2
	0 100	1 95	2 85	3 60	4 40	5 25
Precipitation of growing cycle (mm)	550-500 550-600	500-400 600-700	400-300 700-800	300-200 > 800	- -	< 200 -
Mean temp. of the growing cycle (°C)	22-24 22-20	24-26 20-18	26-30 18-16	30-35 16-13	- -	> 35 < 13
Mean temp. at germination (°C)	22-26 22-18	26-30 18-16	30-32 16-12	32-35 12-10	- -	> 35 < 10
Mean temp. during yield form. period (°C)	19-18 19-20	18-16 20-22	16-14 22-27	14-12 27-32	- -	< 12 > 32
Temp. diff. day/night flowering stage (°C)	6.5-6 6.5-7	6-4 7-9	4-3 9-11	< 3 > 11	- -	- -
Relative humidity growing cycle (%)	45-60 45-30	60-80 30-24	80-90 24-20	> 90 < 20	- -	- -

LANDSCAPE AND SOIL REQUIREMENTS - TOMATO

Land Characteristics	Class, degree of limitation and rating scale					
	S1		S2	S3	N1	N2
	0 100	1 85	2 60	3 40	4 25	5 0
Topography (t)						
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - 30-50	> 6 > 16 > 50
Wetness (w)						
Flooding	Fo	-	-	F1	-	F2+
Drainage	(4) good (5) imperf.	moderate moderate	imperf. good	poor and aeric	poor, but drainab	poor, not drainab.
Physical soil characteristics (s)						
Texture/struct.	CL,L, SiCL,Si, SiC,Co	C<60s,SC SC,SCL	C>60s, C<60v,LS, Lfs	C>60v, fs,LcS	-	Cm,SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 150	150-100	100-75	75-50	-	< 50
CaCO ₃ (%)	0-3	3-5	5-10	10-25	-	> 25
Gypsum (%)	0-1	1-2	2-3	3-5	-	> 5
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-
pH H ₂ O	6.6-6.2 6.6-7.0	6.2-6.0 7.0-7.5	6.0-5.5 7.5-8.0	5.5-5.0 8.0-8.2	< 5.0 -	- > 8.2
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-3	3-5	5-8	8-10	-	> 10
ESP (%)	0-8	8-15	15-25	25-35	-	> 35

WATERMELON (*Colocynthis citrullus*)

1. CLIMATE

Germination takes place in the temperature range between 16 and 41°C. The optimum temperature for germination is 21 to 30 °C. Watermelon grows within the temperature range of 18 - 35°C. Optimal growth is however achieved at temperatures between 22 - 30°C. The crop is very sensitive to frost.

Watermelon is grown in areas with a very different water availability. Optimal conditions are created with a precipitation that amounts to 400 - 700 mm/growing cycle. Dry conditions are preferred at maturation.

2. SOIL

The optimal texture for growing watermelon is sandy loam. The soil depth should be at least 0.8 m. The maximum rooting depth of watermelon is 1.50-2.00 m. Watermelon prefers well drained soils.

pH range: 5.0 - 8.2, optimum pH: 5.8 - 7.6

Salinity: no yield reduction at an electrical conductivity (EC) of < 2.5 dS/m; the yield reduction amounts to 10% at 3.3; 25% at 4.4; 50% at 6.3; 100% at 10 dS/m.

Sodicity: 50% yield reduction at an exchangeable sodium percentage (ESP) of 20 .

Micronutrients

Magnesium : sensitive to deficiency.

Nutrients

Watermelon responds to a high soil fertility and high organic matter levels in the topsoil are required. An excessive N content may however depress yields.

Fertilizer application (kg/ha/growing cycle) for high production:

	min.	max.
N	80	100
P ₂ O ₅	55	135
K ₂ O	40	95

3. YIELDS

Rainfed

Good commercial yield : 20 - 27 ton/ha.
Average farmer yield : 10 - 20 ton/ha.

Irrigated

Good commercial yield : 25 - 35 ton/ha.
Average farmer yield : 20 - 30 ton/ha.

CLIMATIC REQUIREMENTS - WATERMELON (growing cycle 80-110 days)

Climatic Characteristics	Climatic class, degree of limitation and rating					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Precipitation of growing cycle (mm)	550-500 550-600	500-400 600-700	400-300 700-1000	300-200 > 1000	- -	< 200 -
Mean temp. of the growing cycle (°C)	26-24 26-28	24-22 28-30	22-20 30-32	20-18 32-35	- -	< 18 > 35
Relative humidity growing cycle (%)	45-30 45-60	30-24 60-80	24-20 80-90	< 20 > 90	- -	- -

LANDSCAPE AND SOIL REQUIREMENTS - WATERMELON

Land Characteristics	Class, degree of limitation and rating scale					
	S1	S2	S3	N1	N2	
	0 100	1 95	2 85	3 60	4 40	5 25
Topography (t)						
Slope (%)	(1) 0-1	1-2	2-4	4-6	-	> 6
	(2) 0-2	2-4	4-8	8-16	-	> 16
	(3) 0-4	4-8	8-16	16-30	30-50	> 50
Wetness (w)						
Flooding	Fo	-	-	F1	-	F2+
Drainage	(4) good	moderate	imperf.	poor and	poor, but	poor, not
	(5) imperf.	moderate	good	aeric	drainab	drainab.
Physical soil characteristics (s)						
Texture/struct.	SL,L, SiCL	Lfs,SCL, SC	C<60s,S, Co,LS,SiC	C>60V c>60S	-	Cm,SiCm
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55
Soil depth (cm)	> 150	150-100	100-75	75-50	-	< 50
CaCO ₃ (%)						
Gypsum (%)						
Soil fertility characteristics(f)						
Apparent CEC (cmol(+)/kg clay)	> 24	24-16	< 16(-)	< 16(+)	-	-
Base saturation(%)	> 50	50-35	35-20	< 20	-	-
Sum of basic cations (cmol(+)/kg soil)	> 5	5-3.5	3.5-2	< 2	-	-
pH H ₂ O	6.5-6.0	6.0-5.8	5.8-5.5	5.5-5.0	< 5.0	-
	6.5-7.0	7.0-7.6	7.6-8.0	8.0-8.2	-	> 8.2
Organic carbon(%)	> 2	2-1.2	1.2-0.8	< 0.8	-	-
Salinity and Alkalinity (n)						
ECe (dS/m)	0-3	3-4	4-6	6-8	-	> 10
ESP (%)	0-8	8-15	15-20	20-25	-	> 25

WHEAT
(*Triticum aestivum*)

1. CLIMATE

The temperature range for the growth of wheat is 10 - 25°C. Optimal growth conditions are obtained at temperatures between 12 and 23°C. The air temperature of the region where wheat cropping is intended is of particular importance with regard to the selection of the variety. Low temperatures encourage tillering.

The length of the growing cycle is as follows:

spring wheat : 100 - 130 days.
winter wheat : 180 - 250 days.

In tropical areas the number of days to maturity for spring wheat usually increases by 5 - 6 days for each 100 m above 1500 m, or each 0.5°C decrease in average temperature from 20°C. A cool period is needed for flowering.

Winter wheat can survive - 20°C in its early stages, but a temperature of - 1°C at the time of ear emergence and flowering can seriously reduce yields. Spring wheat is sensible to frost.

Wheat growing areas need to receive a precipitation that exceeds 200 mm/growing cycle. The mean annual rainfall should be around 350 - 1250 mm. A dry period is necessary at maturing.

High air humidity combined with high temperatures causes rust problems.

Strong winds may flatten the crop and render harvesting difficult.

2. SOIL

Wheat can grow on soils with a sandy loam to montmorillonitic clay texture. A sandy loam to clay loam texture is nevertheless preferred. The minimal soil depth is 0.1 m. Optimal conditions are met in soils with an available depth of > 0.9 m. The maximum rooting depth of spring wheat is 1.20-1.50 m, and of winter wheat 1.50-2.00 m.

Wheat performs best on moderately well to well drained soils. Though the crop is sensitive to waterlogging, it appears fairly tolerant of a high water-table. The following requirements have to be met in soils with light and heavy texture:

- sandy loam to silty loam : ground water > 0.6 m
- clay : ground water > 0.8 m

Ground water at 0.5 m from the surface for long periods decreases the yield with 20 - 40 %.

Soils cropped with wheat are exposed to a medium erosion hazard.

pH range: 5.2 - 8.5, optimum pH: 6.0 - 8.2

Salinity: wheat is less tolerant at germination (< 4 dS/m); no yield reduction is observed at an electrical conductivity (EC) of < 6 dS/m; the yield reduction is 10% at 7.4; 25% at 9.5; 50% at 13; 100% at 20 dS/m.

Sodicity: 50% yield reduction at an exchangeable sodium percentage (ESP) of 20 .

Micronutrients

- Boron : < 0.1 ppm required in the soil.
- Manganese : high response to application.
- Copper : high response to application.
- Mg and/or Fe : soils with high concentrations should be avoided.

Nutrients

Moderate to fertile conditions are required.

Nutrient removal (kg/ha/growing cycle) to produce 3 ton of grain/ha:

N	:	70
P ₂ O ₅	:	30
K ₂ O	:	60

Fertilizer application (kg/ha/growing cycle) to produce 3 ton of grain/ha:

	min.	max.
N	75	90
P ₂ O ₅	35	50
K ₂ O	35	75

3. YIELDS

Rainfed

- Good commercial yield : 2.5 - 3.5 ton grain/ha.
- Average farmer yield : 1.3 - 2.0 ton grain/ha.

Irrigated

- Good commercial yield : 4 - 6 ton grain/ha.
- Average farmer yield : 3 - 5 ton grain/ha.

CLIMATIC REQUIREMENTS - WHEAT (growing cycle wheat 100-130 days, winter wheat 180-250 days)

Climatic Characteristics	Class, degree of limitation and rating scale						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Precipitation of growing cycle (mm)	700-450 700-1000	450-350 1000-1250	350-250 1250-1500	250-200 1500-1750	- -	< 200 > 1750	
Monthly rainfall vegetative stage (mm)	65-45 65-90	45-20 90-120	20-12 > 120	12-8 -	- -	< 8 -	
Monthly rainfall flowering stage (mm)	75-60 75-90	60-30 90-120	30-15 > 120	15-10 -	- -	< 10 -	
Monthly rainfall of ripening stage (mm)	60-50 60-70	50-30 70-100	30-10 100-200	< 10 > 120	- -	- -	
Mean temp. of the growing cycle (°C)	18-20 18-15	20-23 15-12	23-25 12-10	25-30 10-8	- -	> 30 < 8	
Mean temp. of the vegetative stage (°C)	10-8 10-12	8-6 12-18	6-4 18-24	4-2 24-28	- -	< 2 > 28	
Mean temp. of the flowering stage (°C)	18-14 18-22	14-12 22-26	12-10 26-32	10-8 32-36	- -	< 8 > 36	
Mean temp. of the ripening stage (°C)	20-16 20-24	16-14 24-30	14-12 30-36	12-10 36-42	- -	< 10 > 42	
Average daily min. temp. coldest month combined with average daily max. t°coldest month (°C)	< 8 if < 21	- -	> 8 if < 21	8-19 if > 21	- -	- -	

LANDSCAPE AND SOIL REQUIREMENTS - WHEAT

Land Characteristics	Class, degree of limitation and rating scale						
	S1	S2	S3	N1	N2		
	0 100	1 95	2 85	3 60	4 40	5 25	6 0
Topography (t)							
Slope (%)	(1) 0-1 (2) 0-2 (3) 0-4	1-2 2-4 4-8	2-4 4-8 8-16	4-6 8-16 16-30	- - -	> 6 > 16 > 30	
Wetness (w)							
Flooding	Fo	-	F1	F2	-	F3+	
Drainage	(4) good, (5) imperf.	moder. moder.	imperf. good	poor and aeric	poor, but drainab	poor > not drainab	
Physical soil characteristics (s)							
Texture/struct.	C<60s, SiC,Co, Si,SiL, CL	C<60v, SC,C>60s L	C>60v, SCL	SL,LfS	-	Cm,SiCm LcS,fS, cS	
Coarse fragm(vol%)	0-3	3-15	15-35	35-55	-	> 55	
Soil depth (cm)	> 90	90-50	50-20	20-10	-	< 10	
CaCO ₃ (%)	3-20	20-30	30-40	40-60	-	> 60	
Gypsum (%)	0-3	3-5	5-10	10-20	-	> 20	
Soil fertility characteristics(f)							
Apparent CEC	> 24	24-16	< 16(-)	< 16(+)	-	-	
(cmol+)/kg clay	> 80	80-50	50-35	< 35	-	-	
Base saturation(%)	> 8	8-5	5-3.5	3.5-2	< 2	-	
Sum of basic cations (cmol+)/kg soil	7.0-6.5	6.5-6.0	6.0-5.6	5.6-5.2	< 5.2	-	
pH H ₂ O	7.0-7.5	7.5-8.2	8.2-8.3	8.3-8.5	-	> 8.5	
Organic carbon(%)	> 1.5	1.5-0.8	< 0.8	-	-	-	
(6)	> 2.5	2.5-1.5	1.5-1.0	< 1.0	-	-	
(7)	> 1.5	1.5-1.0	1.0-0.5	< 0.5	-	-	
(8)	> 0.6	0.6-0.4	< 0.4	-	-	-	
Salinity and Alkalinity (n)							
ECe (dS/m)	0-1	1-3	3-5	5-6	6-10	> 10	
ESP (%)	0-15	15-20	20-35	35-45	-	> 45	

GROWTH PERIODS AND DEVELOPMENT STAGES OF CROPS

GROWTH PERIODS (number of days)

- Establishment period
- Vegetative period
- Flowering period
- Yield formation period
- Ripening period

Total of days = growing cycle of the crop

Crop	Establ.	Veget.	Flow.	Y.form.	Ripen.	Total
Beans(green)	10-15	20-25	15-25	25-30	0- 5	60-90
(dry)	10-15	20-25	15-25	25-30	20-25	90-120
Cotton	15-25	25-35	60-70	30-40	15-20	145-190
Groundnuts	10-20	25-35	30-40	30-35	10-20	105-130
Maize	15-25	25-40	15-20	35-45	10-15	90-135
Onion	30-35	25-30	0	50-80	25-30	130-175
Pea (fresh)	10-25	25-30	15-20	15-20	0-5	65-100
(dry)	10-25	25-30	15-20	20-25	15-20	85-120
Pineapple	0	390	90-150	+ 90-150	+	600
Potato	15-25	30-40	0	45-55	10-15	90-120
Rice	35-45	40-60	10-15	25-35	10-20	120-155
Safflower	4-10	85	30	25	10	150-160
Sorghum	15-20	20-30	15-20	35-40	10-15	95-125
Soya	10	30-40	25-35	30-40	10-15	105-140
Sugar beet	25-35	+	75-115	+	40-50	140-200
Sugar cane	10-30	150-350	0	70-200	50-70	280-650
Sunflower	20	55	30	25	15	145
Tobacco	40-60	50-70	0	+ 40-70	+	130-200
Tomato	25-35	20-25	20-30	20-30	15-20	100-140
Water melon	10-15	20-25	15-20	20-30	15-20	80-110
Wheat	10-15	30-50	15-20	30-35	10-15	95-135

DEVELOPMENT STAGES (number of days)

- Initial stage
- Crop development stage
- Mid-season stage
- Late-season stage

Total of days = growing cycle of the crop

Crop	Initial Crop d. Mid-sea. Late-s.				Total
Artichokes	20-40	40	220-250	30	310-360
Aubergine	30	40-45	40	20-25	130-140
Barley	15-20	25-30	50-65	30-40	120-155
Beans(green)	15-20	15-20	20-30	5-20	55-90
(dry)	15-20	25-30	40-50	20	95-110
Cabbage	20-30	30-35	20-30	10-20	80-115
Carrots	20-25	30-35	30-80	20	100-150
Castor beans	25-30	40-55	95-105	20	180-200
Celery	25-30	40-55	45-105	15-20	125-180
Cotton	20-30	40-50	50-60	40-55	150-195
Cucumber	20-25	30-35	40-50	15-20	105-130
Flax	25-30	35-40	50-100	40-50	150-220
Groundnuts	15-35	30-45	30-50	20-30	95-160
Lentil	20-25	30-35	60-70	40	150-170
Lettuce	20-25	30-35	15-30	10	75-100
Maize	15-30	30-45	30-45	10-30	85-150
Melon	25-30	35-45	40-65	20	110-160
Milletts	15	25	40	25	105
Oats	15-20	25-30	50-65	30-40	120-150
Onion	15-20	25-35	25-45	35-45	100-145
Pea	10-25	25-30	25-30	5-10	65-95
Peppers	30	35	40	20	125
Potato	20-30	30-40	30-60	20-35	100-165
Pumpkin	20-25	30-35	30-35	15-25	95-120
Radish	5-10	10	15	5	35-40
Safflower	20-35	35-75	45-65	25-40	125-175
Sorghum	20-25	30-40	40-45	30	120-150
Soya	20-25	25-35	45-65	20-30	115-155
Spinach	20	20-30	15-40	5-10	60-100
Sugar beet	25-30	35-60	50-70	30-50	140-210
Sugar cane	30-60	90-120	210-480	30-60	360-720
Sunflower	20-25	35-40	40-50	25-30	120-145
Tobacco	10	20-30	30-35	30-40	90-115
Tomato	10-15	20-30	30-40	30-40	90-115
Water melon	10-20	15-20	35-50	10-15	70-105
Wheat	15-20	25-30	50-65	30-40	120-155

**CROP CHARACTERISTICS
CONSIDERED IN POTENTIAL NET
BIOMASS AND YIELD CALCULATIONS**

CROP CHARACTERISTICS

CROP	MOISTURE %	Kc of the crop development stages					total GP
		Initial	Crop dev.	mid-seas.	late-seas.	at harvest	
Alfalfa	hay:10-15	0.3-0.4	-	-	-	1.05-1.2	0.85-1.05
Artichokes				0.95-1.05		0.9-1.0	
Aubergine				0.95-1.1		0.8-0.9	
Banana trop.	fruit 70	0.4-0.5	0.7-0.85	1.0-1.1	0.9-1.0	0.75-0.85	0.7-0.8
subtr		0.5-0.65	0.8-0.9	1.0-1.2	1.0-1.15	1.0-1.15	0.85-0.95
Barley				1.05-1.2		0.2-0.25	
Beans green	lush 80-90	0.3-0.4	0.65-0.75	0.95-1.05	0.9-0.95	0.85-0.95	0.85-0.9
dry	dry 10	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.75	0.25-0.3	0.7-0.8
Cabbage	head 90-95	0.4-0.5	0.7-0.8	0.95-1.1	0.9-1.0	0.8-0.95	0.7-0.8
Carrots				1.0-1.15		0.7-0.85	
Cassava				1.05-1.2		0.5	
Castor beans						weeding: 0.65-0.75	
Citrus	fruit 85					no weeding 0.85-0.9	
Celery				1.0-1.15		0.9-1.05	
Cotton	seed 10	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.9	0.65-0.7	0.8-0.9
Cucumber				0.9-1.0		0.7-0.8	
Flax				1.0-1.15		0.2-0.25	
Grape	fruit 80	0.35-0.55	0.6-0.8	0.7-0.9	0.6-0.8	0.55-0.7	0.55-0.75
Groundnuts	dry 15	0.4-0.5	0.7-0.8	0.95-1.1	0.75-0.85	0.55-0.6	0.75-0.8
Lentil				1.05-1.2		0.25-0.3	
Lettuce				0.95-1.05		0.9-1.0	
Maize grain	grain 10-13	0.3-0.5	0.7-0.85	1.05-1.2	0.8-0.95	0.55-0.6	0.75-0.9
sweet		0.3-0.5	0.7-0.9	1.05-1.2	1.0-1.15	0.95-1.1	0.8-0.95
Melon				0.95-1.05		0.65-0.75	
Millet				1.0-1.15		0.25-0.3	
Oats				1.05-1.2		0.2-0.25	
Olives	fruit 30						0.4-0.6
Onion fresh	bulb 85-90	0.4-0.6	0.6-0.75	0.95-1.05	0.95-1.05	0.95-1.05	0.65-0.8
dry		0.4-0.6	0.7-0.8	0.95-1.1	0.85-0.9	0.75-0.85	0.8-0.9
Pea	fresh 70-90	0.4-0.5	0.7-0.85	1.05-1.2	1.0-1.15	0.95-1.1	0.8-0.95
dry 12							
Pepper	fresh 90	0.3-0.4	0.6-0.75	0.95-1.1	0.85-1.0	0.8-0.9	0.7-0.8
Pineapple	fruit 85						
Potato	fresh 70-75	0.4-0.5	0.7-0.8	1.05-1.2	0.85-0.95	0.7-0.75	0.75-0.9
Radish				0.8-0.9		0.75-0.85	
Rice	paddy 15-20	1.1-1.15	1.1-1.5	1.1-1.3	0.95-1.05	0.95-1.05	1.05-1.2
Safflower	seed 8-10	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.7	0.2-0.25	0.65-0.7
Sorghum	grain 12-15	0.3-0.4	0.7-0.75	1.0-1.15	0.75-0.8	0.5-0.55	0.75-0.85
Soya	grain 6-10	0.3-0.4	0.7-0.8	1.0-1.15	0.7-0.8	0.4-0.5	0.75-0.9
Spinach				0.95-1.05		0.9-1.0	
Squash				0.9-1.0		0.7-0.8	
Sugarbeet	beet 80-85	0.4-0.5	0.75-0.85	1.05-1.2	0.9-1.0	0.6-0.7	0.8-0.9
sugar 0							
Sugarcane	cane 80	0.4-0.5	0.7-1.0	1.0-1.3	0.75-0.8	0.5-0.6	0.85-1.05
sugar 0							
Sunflower	seed 6-10	0.3-0.4	0.7-0.8	1.05-1.2	0.7-0.8	0.35-0.45	0.75-0.85
Sweet Potato							
Tobacco	cured 5-10	0.3-0.4	0.7-0.8	1.0-1.2	0.9-1.0	0.75-0.85	0.85-0.95
Tomato	fresh 80-90	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.95	0.6-0.65	0.75-0.9
Watermelon	fresh 90	0.4-0.5	0.7-0.8	0.95-1.05	0.8-0.9	0.65-0.75	0.75-0.85
Wheat winter	grain 12-15	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.75	0.2-0.25	0.8-0.9
spring							

Kc values : first figure : RH>70%, wind speed <5m/s.
second figure: RH<20%, wind speed >5m/s

CROP CHARACTERISTICS

CROP	MOISTURE %	Ky of the growth periods					LAI	HI
		Veget.	Flow	Yl	Rip.	Total GP		
Alfalfa	hay:10-15	0.7-1.1				0.7-1.1	1.5-2	first y. 0.45 next ye. 0.85
Artichokes								
Aubergine								
Banana trop.	fruit 70					1.2-1.35	2.5-4	
subtr								
Barley								
Beans green	lush 80-90	0.2	1.1	0.75	0.2	1.15	1.5-2	3.0-4.0
dry	dry 10						0.3-0.6	0.3
Cabbage	head 90-95	0.2(e)		0.45	0.6	0.95	12-20	0.65
Carrots								
Cassava								
Castor beans								1.5-3.0
Citrus	fruit 85					0.8-1.1	12-5	0.55
Celery								
Cotton	seed 10	0.2	0.5	-	0.25	0.85	0.4-0.6	2.4-3.0
Cucumber								0.07
Flax								
Grape	fruit 80					0.85	2-4	
Groundnuts	dry 15	0.2	0.8	0.6	0.2	0.7	0.6-0.8	0.3
Lentil								
Lettuce								
Maize grain	grain 10-13	0.4	1.5	0.5	0.2	1.25	0.8-1.6	3.0-4.0
sweet								0.35
Melon								
Millet								3.1-4.0
Oats								0.25
Olives	fruit 30					0.85	1.5-2.0	
Onion fresh	bulb 85-90	0.45	-	0.8	0.3	1.1	8-10	0.75
dry								
Pea	fresh 70-90	0.2	0.9	0.7	0.2	1.15	0.5-0.7	0.35
dry 12								
Pepper	fresh 90					1.1	1.5-1.3	0.3
Pineapple	fruit 85					0.85	5-10	0.55
Potato	fresh 70-75	0.45(e)	-	0.7	0.2	1.1	4-7	3.0-5.0
		0.8(1)						0.6
Radish								
Rice	paddy 15-20					1.15	0.7-1.1	4.2-5.0
Safflower	seed 8-10	0.3	0.55	0.6	-	0.8	0.2-0.5	0.45
Sorghum	grain 12-15	0.2	0.55	0.45	0.2	0.9	0.6-1.0	3.0-4.0
Soya	grain 6-10	0.2	0.8	1.0	-	0.85	0.4-0.7	3.0-4.0
Spinach								0.35
Squash								
Sugarbeet	beet 80-85					0.6-1.0	6-9	0.4
sugar 0						0.7-1.1	10.9-1.4	
Sugarcane	cane 80	0.75	-	0.5	0.1	1.2	5-8	0.25
sugar 0							0.6-1	
Sunflower	seed 6-10	0.25(e)	1.0	0.8	-	0.95	0.3-0.5	0.25
		0.5(1)						
Sweet Potato								3.6-4.5
Tobacco	cured 5-10	0.2(e)	-	0.5		0.9	0.4-0.6	0.55
		1.0(1)						
Tomato	fresh 80-90	0.4	1.1	0.8	0.4	1.05	10-12	0.3
Watermelon	fresh 90	0.45(e)	0.8	0.8	0.3	1.1	5-8	
		0.7(1)						
Wheat winter	grain 12-15	0.2	0.6	0.5	1	1.0	0.8-1.0	4.0-5.0
spring		0.2	0.65	0.55	-	1.15	13.7-5.0	0.4

Ky values : <0.85 low (e) early
0.85-1.0 moderately low (1) late
1.0-1.15 moderately high
> 1.15 high

yield response to the
water supply

$$E_y = \text{Water use efficiency for land-based crop (kg yield/m}^2 \text{ water)}$$

CROP CHARACTERISTICS

Crop and Adaptability group	Crop characteristics	Growing period (days)			
		75-89	90-119	120-149	150-179
Oil palm II	Growing days	75-89	90-119	120-149	150-179
	Yield formation period	0	0	0	0
	LAI at maximum growth rate	1.2-1.5	1.5-2.0	2.0-2.5	2.5-3.0
	Harvest index	0	0	0	0
Banana II	Growing days	75-89	90-119	120-149	150-179
	Yield formation period	0	0	0	0
	LAI at maximum growth rate	1.2-1.5	1.5-2.0	2.0-2.5	2.5-3.0
	Harvest index	0	0	0	0
Sugarcane III	Growing days	75-89	90-119	120-149	150-179
	Yield formation period	0	0-29	30-59	60-89
	LAI at maximum growth rate	1.4-1.7	1.7-2.2	2.2-2.8	2.8-3.3
	Harvest index	0	0-0.03	0.03-0.06	0.06-0.09
Groundnut II	Growing days	75-89	90-119	90-120	90-120
	Yield formation period	30-44	45-60	45-60	45-60
	LAI at maximum growth rate	2.5-3.0	3.0-4.0	3.0-4.0	3.0-4.0
	Harvest index	0.20-0.29	0.30	0.30	0.30
Upland rice II	Growing days	75-89	90-119	100-120	100-120
	Yield formation period	8-22	23-39	33-40	33-40
	LAI at maximum growth rate	2.5-3.0	3.0-4.0	3.3-4.0	3.3-4.0
	Harvest index	0.07-0.21	0.21-0.30	0.30	0.30
Winter barley I	Growing days	75-89	90-119	90-120	90-120
	Yield formation period	15-29	30-39	30-40	30-40
	LAI at maximum growth rate	2.5-3.0	3.0-4.0	3.0-4.0	3.0-4.0
	Harvest index	0.2-0.4	0.4	0.4	0.4

CROP CHARACTERISTICS

Crop and Adaptability group	Crop characteristics	Growing period (days)			
		180-209	210-239	240-269	270-299
Oil palm II	Growing days	180-209	210-239	240-269	270-299
	Yield formation period	0	0-29	30-59	60-89
	LAI at maximum growth rate	3.0-3.4	3.4-3.9	3.9-4.4	4.4-4.9
	Harvest index	0	0-0.04	0.04-0.08	0.08-0.12
Banana II	Growing days	180-209	210-239	240-269	270-299
	Yield formation period	0	0	0-29	30-59
	LAI at maximum growth rate	3.0-3.4	3.4-3.9	3.9-4.4	4.4-4.9
	Harvest index	0	0	0-0.05	0.05-0.11
Sugarcane III	Growing days	180-209	210-239	240-269	270-299
	Yield formation period	90-119	120-149	150-179	180-209
	LAI at maximum growth rate	3.3-3.9	3.9-4.4	4.4-5.0	5.0
	Harvest index	0.09-0.12	0.12-0.15	0.15-0.19	0.19-0.22
Groundnut II	Growing days	90-120	90-120	90-120	90-120
	Yield formation period	45-60	45-60	45-60	45-60
	LAI at maximum growth rate	3.0-4.0	3.0-4.0	3.0-4.0	3.0-4.0
	Harvest index	0.30	0.30	0.30	0.30
Upland rice II	Growing days	100-120	100-120	100-120	100-120
	Yield formation period	33-40	33-40	33-40	33-40
	LAI at maximum growth rate	3.3-4.0	3.3-4.0	3.3-4.0	3.3-4.0
	Harvest index	3.0	3.0	3.0	3.0
Winter barley I	Growing days	90-120	90-120	90-120	-
	Yield formation period	30-40	30-40	30-40	-
	LAI at maximum growth rate	3.0-4.0	3.0-4.0	3.0-4.0	-
	Harvest index	0.4	0.4	0.4	-

CROP CHARACTERISTICS

Crop and Adaptability group	Crop characteristics	Growing period (days)			
		300-329	330-364	365 -	365 +
Oil palm	Growing days	300-329	330-364	365	365
II	Yield formation period	90-119	120-149	150	150
	LAI at maximum growth rate	4.9-5.4	5.4-6.0	6.0	6.0
	Harvest index	0.12-0.15	0.15-0.20	0.20	0.20
Banana	Growing days	300-329	330-364	365	365
II	Yield formation period	60-89	90-119	120	120
	LAI at maximum growth rate	4.9-5.4	5.4-6.0	6.0	6.0
	Harvest index	0.11-0.17	0.17-0.24	0.24	0.24
Sugarcane	Growing days	300-329	330-364	365	365
III	Yield formation period	210-239	240-269	270	270
	LAI at maximum growth rate	5.0	5.0	5.0	5.0
	Harvest index	0.22-0.25	0.25	0.25	0.25
Groundnut	Growing days	90-120	90-120	90-120	90-120
II	Yield formation period	45-60	45-60	45-60	45-60
	LAI at maximum growth rate	3.0-4.0	3.0-4.0	3.0-4.0	3.0-4.0
	Harvest index	0.30	0.30	0.30	0.30
Upland rice	Growing days	100-120	100-120	100-120	100-120
II	Yield formation period	33-40	33-40	33-40	33-40
	LAI at maximum growth rate	3.3-4.0	3.3-4.0	3.3-4.0	3.3-4.0
	Harvest index	3.0	3.0	3.0	3.0
Winter barley	Growing days	-	-	-	-
I	Yield formation period	-	-	-	-
	LAI at maximum growth rate	-	-	-	-
	Harvest index	-	-	-	-

**AGRO-CLIMATIC LIMITATIONS
OF CROPS**

**AGRO-CLIMATIC LIMITATIONS FOR THE CROPS OF GROUP II
AND III IN TROPICAL AND SUBTROPICAL LOW AREAS**

0 = no limitations
1 = moderate limitations
2 = severe limitations

a = yield reduction due to lack of water
b = yield reduction due to diseases, animals ...
c = yield reduction due to lack of water, diseases, animals,
climatic problems, quality of the crop
d = workability problems and conservation of the crop

Length grow. period (days)	Limitations for high and low inputs (H and L)							
	L	H	L	H	L	H	L	H
	abcd	abcd	abcd	abcd	abcd	abcd	abcd	abcd
	Millets		Sorghum		Maize		Soya	
75- 89	2010	2010(1)	2110	2010(1)	2120	2020(1)	2020	2020(1)
90-119	1000	1000(2)	2100	2000(2,3)	2110	2010	2010	2010
120-149	0000	0000	1100	1000	1100	1000	1000	1000
150-179	0000	0000	0000	0000	0000	0000	0000	0000
180-209	0100	0100	0000	0000	0000	0000	0100	0000
210-239	0110	0111	0110	0011	0100	0001	0110	0001
240-269	0221	0222(4)	0121	0022(4)	0101	0002	0110	0002
270-299	0221	0222	0221	0122	0101	0102	0111	0102
300-329	0221	0222	0221	0222	0101	0102(5)	0211	0112
330-364	0222	0222	0222	0222	0112	0112(610)	0222	0122(6)
365	0222	0222(7)	0222	0222(7)	0222	0222(7)	0222	0222(7)
	Beans		Cotton		Potato		Cassava	
75- 89	2020	2020(1)	2000	2000(1)	2010	2010(1)	2010	2010(1)
90-119	2010	2010(8)	2110	2000	2010	2010(13)	2010	2010(13)
120-149	1000	1000	1110	1000	1001	1001	1011	1011
150-179	0000	0000	0110	0000	0000	0000	1101	1001
180-209	0100	0000	0110	0000	0000	0000	0100	0000
210-239	0110	0001	0110	0110	0000	0000	0100	0000
240-269	0210	0002	0110	0111	0010	0000	0100	0000
270-299	0211	0102	0121	0121(11)	0010	0001	0100	0000
300-329	0211	0112(10)	0221	0122	0020	0012(12)	0100	0000
330-364	0222	0122	0222	0222	0020	0012	0110	0011
365	0222	0222(7)	0222	0222(7)	0021	0022(7)	0111	0012(7)

**AGRO-CLIMATIC LIMITATIONS FOR CROPS OF GROUPS I
AND IV IN TROPICAL AND SUBTROPICAL HIGH AREAS**

Length grow. period (days)	Limitations for high and low inputs (H and L)							
	L	H	L	H	L	H	L	H
	abcd	abcd	abcd	abcd	abcd	abcd	abcd	abcd
	Spring wheat				Winter wheat			
Alt(m)and /or Tmean	1500-2000 17.5-20.0		2000-2500 15.0-17.5		2500-3000 12.5-15.0		0 - 1500	
75- 89	2010	2010(1)	2010	2010(1)	2010	2010(1)	2010	2010(1)
90-119	2000	2000	2010	2010	2010	2010	2010	2010
120-149	1000	1000	1000	1000	2010	2010	2000	2000
150-179	0000	0000	0000	0000	1000	1000	1000	1000
180-209	0000	0000	0000	0000	0000	0000	0000	0000
210-239	0110	0011	0100	0101	0000	0000	0100	0100
240-269	0111	0111	0110	0111	0110	0111	0100	0100
270-299	0221	0222	0221	0222	0211	0212	-	-
300-329	0221	0222	0221	0222	0221	0222	-	-
330-364	0222	0222(9)	0222	0222(9)	0222	0222(9)	-	-
365	0222	0222(7)	0222	0222(7)	0222	0222(7)	-	-
	Beans				Potato			
Alt(m)and /or Tmean	1500-2000 17.5-20.0		2000-2500 15.0-17.5		2500-3000 12.5-15.0		1500-3000 12.5-20.0	
75- 89	2020	2020(1)	2020	2020(1)	2020	2020(1)	2010	2010(1)
90-119	2010	2010	2020	2020	2020	2020	2010	2010
120-149	1000	1000	2010	2010	2020	2020	1001	1001(13)
150-179	0000	0000	0000	0000	1010	1010	0000	0000
180-209	0100	0000	0100	0000	0100	0000	0000	0000
210-239	0110	0001	0110	0001	0110	0000	0100	0101
240-269	0210	0001	0210	0001	0210	0001	0111	0111
270-299	0211	0102(10)	0211	0102(10)	0211	0102(10)	0211	0212
300-329	0211	0112(11)	0221	0112(11)	0211	0112(11)	0221	0222(10)
330-364	0222	0122	0222	0122	0222	0122	0222	0222
365	0222	0222(7)	0222	0222(7)	0222	0222(7)	0222	0222(7)

Maize

Alt(m)and /or Tmean	1500-1600 19.5-20.0	1900-2000 17.0-17.5	2400-2500 15.0-15.5
75- 89	2120 2020(1)	2120 2020(1)	2120 2020(1)
90-119	2110 2010(3)	2120 2020(3)	2120 2020(3)
120-149	1100 1000	2120 2020	2120 2020
150-179	0000 0000	1010 1010	2020 2020
180-209	0000 0000	1000 1000	2020 2020
210-239	0100 0001	0000 0000	2010 2010
240-269	0101 0002	0000 0000	2010 2010
270-299	0101 0102(5)	0100 0001(5)	1100 1001(5)
300-329	0101 0102(10)	0101 0102(10)	0101 0101(10)
330-364	0112 0112(6)	0112 0112(6)	0112 0112(6)
365	0222 0222(7)	0222 0222(7)	0222 0222(7)

Sorghum

Alt(m)and /or Tmean	1500-1600 19.5-20.0	1900-2000 17.0-17.5	2400-2500 15.0-15.5
75- 89	2120 2020(1)	2120 2020(1)	2120 2020(1)
90-119	2110 2010(2,3)	2120 2020(3)	2120 2020
120-149	1100 1000	2120 2020	2120 2020
150-179	0000 0000	1010 1010	2020 2020
180-209	0000 0000	1000 1000	2020 2020
210-239	0110 0011	0000 0000	2020 2020
240-269	0121 0022	0100 0001	2010 2010
270-299	0221 0122(11)	0111 0012(11)	1010 1011(11)
300-329	0221 0222	0221 0122	0111 0112
330-364	0222 0222	0222 0222	0222 0222
365	0222 0222(7)	0222 0222(7)	0222 0222(7)

- (1) variability of precipitation
- (2) Quelea
- (3) Striga
- (4) Oidium
- (5) leaf spots
- (6) humid crop
- (7) workability
- (8) poor quality of the grain
- (9) germination of the grain
- (10) virus
- (11) insects
- (12) rotting
- (13) harvest difficulties : dry and compact soil.

**NUTRITIVE VALUES FOR
CALCULATION OF ENERGY
VALUES OF FOOD PRODUCTS**

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INTERNATIONAL NUTRITIVE VALUES TO BE USED FOR
CALCULATED ENERGY VALUE OF 100 g OF FOOD PRODUCT

Crop	Food product	Calorie (K Cal)	Protein (g)	Suggested factor for converting yield dry weight into food product
Wheat	Dry grain	262	7.8	1.00
Rice	Dry paddy	234	4.4	1.54 <u>2/</u>
Maize	Dry grain	327	7.6	1.00
Barley	Dry grain	277	7.2	1.00
Millet	Dry grain	306	8.7	1.00
Sorghum	Dry grain	309	9.1	1.00
Groundnut	Dry unshelled nut	388	18.2	1.54 <u>3/</u>
Bean	Dry grain	341	22.1	1.00
Soybean	Dry grain	335	38.0	1.00
White potato	Fresh tuber	70	1.7	3.33 <u>4/</u>
Sweet potato	Fresh tuber	97	1.1	3.13 <u>5/</u>
Cassava	Fresh tuber	109	0.9	2.86 <u>6/</u>
Sugarcane	Fresh cane	30	0.2	10.00 <u>7/</u>
Banana-plantain	Fresh fruit with skin	70	0.8	3.70 <u>8/</u>
Oil palm	Oil	984	-	1.00

1/ Used in FAO food balance sheets for converting production into food.
Reference: Food Consumption Tables for Use in Africa. FAO/USDHEW, 1968.

2/ Grain to paddy ratio = 0.65.

3/ Kernel to nut ratio = 0.65.

4/ Moisture content = 70 percent.

5/ Moisture content = 68 percent.

6/ Moisture content = 65 percent.

7/ Sugar in fresh cane = 10 percent.

8/ Skin = 10 percent of total weight; moisture content = 70 percent.

PUBLICATIONS AGRICOLES EDITIONNES PAR L'AGCD

- Cultures maraîchères au Sahel Tunisie
- Les principaux ennemis des cultures maraîchères au Sénégal (1)
- Traité pratique de l'irrigation sous pression (1)
- 1. Belgian Development cooperation in the Republic of Zambia - Project Mount Makulu, plant protection section - Research progress for the period 14.12.76 - 13.12.81
- 2. Comment tailler mes caféiers ? La pratique de la taille pluriannuelle chez le Robusta. (français et anglais)
- 3. Plaquelette de présentation de l'Institut des Sciences agronomiques du Burundi (ISABU). (1)
- 4. Proceedings of the Fourth International Soil Classification Workshop - Rwanda, 2 to 12 June 1981 (1)
 - Part I : Papers
 - Part II : Field trip and background soil data.
- 5. Projet "ferme modèle de Fretissa" - rapport final - Produire plus de grain et de lait en Afrique du Nord.
- 6. Projet "station d'appui du Nebhana" - S.A.N. - Amélioration des cultures maraîchères au Sahel Tunisien.
- 7. Land Evaluation (3 volumes).
- 8. La culture du théier au Burundi.
- 9. Carte des sols du Burundi (1/250 000^e). (1)
- 10. Actes du Dixième Forum international sur la Soil Taxonomy et les Transferts d'Agrotechnologie - Burundi et Rwanda - 1 au 12 avril 1985.
- 11. La culture cotonnière dans l'Imbo. Conditions de culture - Fumure minérale.
- 12. Synthèse des recherches forestières effectuées au Burundi.
- 13. Le bouturage du caféier Robusta. (français et anglais)
- 14. La culture du caféier d'Arabie au Burundi.
- 15. Séminaire sur les maladies et les ravageurs des principales cultures vivrières d'Afrique centrale. Bujumbura 16-20 février 1987. (1)
- 16. Commercial crop production recommendations - Zambia. (1)
- 17. Services d'appui du département des sciences du sol - Centre universitaire de Dschang - Cameroun. (français et anglais).
- 18. Au service du développement ... Le C.D.H. (Centre pour le Développement de l'Horticulture) et ses réalisations (Sénégal). (1)
- 19. La trachéomycose du caféier Robusta (français et anglais)
- 20. Les plantes indicatrices des caféières. (1)
- 21. La qualité du café - de la plantule à la tasse (français, anglais et portugais).
- 22. General aspects of Soil Salinity - Zambia. (1)
- 23. L'amélioration du cotonnier *Gossypium hirsutum* L. par hybridation interspécifique.
- 24. Maladies et ravageurs des cultures de la région des grands lacs d'Afrique centrale.
- 25. Consolidation de la défense des cultures - rapport final. (Tunisie).
- 26. Les adventices des cultures méditerranéennes en Tunisie.
- 27. L'élevage d'aulacodes au Zaïre - rapport final - dossier de vulgarisation.
- 28. Manuel de laboratoire pédologique - Centre Universitaire de Dschang (Cameroun)
- 29. Le cotonnier au Zaïre.
- 30. La vulgarisation agricole.
- 31. La vulgarisation agricole en Afrique Subsaharienne: principes généraux et description de quelques systèmes. (2)

- (1) épuisé
- (2) en préparation

Autres publications disponibles à l'AGCD

- "Jardins et vergers d'Afrique" de Hugues Dupriez et Philippe de Leener
- "Les chemins de l'eau, ruissellement, irrigation, drainage" de Hugues Dupriez et Philippe de Leener
- "Eaux et terres en fuite, métiers de l'eau du Sahel" J.-L. Chleq et H. Dupriez