Vegetable Seeds for the Tropics, Bulletin 301

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1. VEGETABLE GROWING AND SEED SUPPLY IN THE TROPICS

1.1 Introduction

In temperate areas vegetable growing has become an extremely technical activity. The grower can make his choice from a great diversity of cultivars[1] (varieties) which are offered by numerous seed companies. All these cultivars have been bred for prevailing climatic conditions and cultivation methods and for the quality of produce as required by the customer. The price is usually high, but the commercial grower and the common home gardener are willing to purchase these guaranteed and high quality seeds, since seed costs are only a very small part of the total production costs. Good seed pays!

In the tropics, commercial vegetable growing is increasing rapidly in order to meet the demands of the urban centres. Part of the vegetable seeds are purchased from the same large seed companies which supply growers in temperate countries. But the fact remains that these cultivars have been bred for a climate, for cultivation methods and for customers' requirements of quality and taste which are not at all the same as in tropical countries. On the other hand, a great deal of the seeds used by commercial growers and almost all the seeds used by the home gardener in the tropics are locally produced. This is especially true for the typical tropical species. Unfortunately, these locally produced seeds are often very heterogeneous (mixtures of different types) and their germination is poor.

This bulletin is meant to give guidelines for local seed growers, for extension workers and for vegetable growers, both commercial and non-commercial, to obtain high quality seeds. Bad seed gives an irregular stand, weak seedlings, a low yield and an inferior product. Good seed means a good start for a high yield of good quality vegetables.

1.2 Economic and nutritional value of vegetables

In this bulletin the term 'vegetables' will be used for plants which produce an aqueous foodstuff, rich in water, poor in calories and mostly consumed as an addition to the starchy basic food rich in calories. Starchy tubers such as sweet potato, Irish potato, cassava, yam and cocoyam, and also grain legumes (pulses) such as common dry bean, cowpea, chick pea and horse bean fall outside our definition of vegetables. Only real vegetables propagated by dry seed are treated here, excluding the fresh one-seeded chayote fruit and vegetatively propagated types like garlic, bamboo and Sauropus.

In developing countries - which are located mostly in the tropics - the average daily per capita vegetable consumption is about 100 g against 220 g in developed countries. At least three quarters of the vegetables consumed in temperate, developed countries are produced by highly technical, commercial enterprises, whereas in the tropics less than half of the consumed quantity is commercialized. These statements are broad generalizations and great local variations can be observed.

1. 'Cultivar' is a commonly used international word which means 'race' or 'cultivated variety', a distinct group of plants of a certain cultivated species; abbreviated as cv., plural cvs.

Vegetables are important as protective foods, providing vitamins and minerals. The most deficient vitamin in the tropics is vitamin A. This vitamin is largely present in all darkgreen leaf vegetables and also in some other species such as carrot, pumpkin and broccoli, in the form of carotene. Vitamin C, iron and calcium are also very important. The best sources of these nutrients are the cheapest ones, the green leaf vegetables. An average daily consumption of 150 g of vegetables per capita can be taken as a target, provided that one third of this quantity consists of vegetables.

1.3 Seed supply in various growing systems

The following systems for vegetable growing in the tropics may be distinguished:

a. *collection of wild plants* from the spontaneous vegetation. At present about 1500 vegetable species, mainly in the humid tropical lowlands and shifting cultivation areas are consumed. Some hundreds of species grow in the fields and are considered as weeds, although they are protected and consumed. This is probably less than 10% of the total production and decreasing. Propagation is by natural seed production and spreading.

b. *cultivation for home use* in the field generally in mixed croppings with other food plants, or in home gardens. About 200 vegetable species are used for this purpose and yield at least 50% of the total production. None, or very few, inputs are used and no expenses are made for seed, fertilizer, pesticides or equipment. Nearly all the seed needed is harvested by the farmer or gardener himself; a small part is obtained from other farmers or bought from a local dealer.

c. *market gardening* in mono-cultivation of a vegetable crop or in mixed plantings. Commercial gardening may be more or less intensive, i.e. with a more or less high input of labour and acquisition of seed, fertilizer, pesticides and equipment. Market gardening with about 80 species covers 40% of the total vegetable production, but it is fast increasing and very important for the alimentation of urban populations. Seed of the more local, traditional vegetables usually comes from the farmer's own production, but seed of the 'international' vegetables such as onion, tomato, sweet pepper, white cabbage, cauliflower, cucumber, watermelon, melon, lettuce, carrots, etc. is often bought from dealers who import it from well-known international seed companies.

It is not known exactly how much vegetable seed is imported, nor which part is locally produced for commercial purposes and which part by the farmer for his own use. A rough estimate could be that about 10% is imported, 30% comes from local commercial production and 60% is home produced. In fact, the picture is very diverse depending on the area and the type of vegetable. Many growers buy the expensive imported seed only occasionally and harvest their own seed from the first crop for 2 to 5 generations before proceeding to seed renewal.

The actual trend, buying imported or locally produced high quality seed of high yielding modern cultivars, holds the danger of 'genetic erosion', i.e. the loss of traditional, local cultivars, the so-called land races. These old cultivars represent a most valuable gene stock and are the basic material indispensable for future plant breeders. They ought to be collected and stocked in gene banks.

1.4 Problems of vegetable seed production in the tropics

In temperate countries, the cost of the seed is small, less than one per cent of the total investment in a vegetable crop. This may be somewhat more in the tropics, but the commercial grower is willing to pay a good price for reliable seeds, yet in many cases they are not available. Why is this?

The reason could be found in economic underdevelopment and a lack of good management and organization. A modern seed industry is a large scale enterprise, needing a heavy investment and many skilled people such as plant breeders, seed agronomists and seed technologists. In most developing countries, basic food crops such as cereals and tubers receive the highest priority in research and breeding. Vegetable breeding and seed production are given less priority than the urgently needed energy foods. Moreover, the number of vegetable species is so large that the costs of research and the establishment of a seed industry are excessively high and not in balance with the relatively small costs of seed importation.

Only a few countries in the tropics and subtropics have developed an important vegetable seed industry and have introduced legislation concerning seed production and trade: India, Taiwan, Brazil. Other countries such as Pakistan, Egypt, the Philippines, Sri Lanka, Thailand, Mexico and Kenya are building up their own seed industry and control agency. However, in most countries in the tropics the grower depends on imported, good quality but genetically not well adapted seed supplied by foreign seed companies and on uncertified locally produced, often very poor quality seed of local vegetable types. In most countries there is no legislation for seed production and no control agency to protect the producer and the grower.

In this bulletin, directions will be given to extension workers, vegetable growers and seed dealers on how to obtain the best quality imported seeds and how to improve the quality of the locally produced seeds. It is by no means a guide for large scale commercial seed production.

2. CLIMATIC INFLUENCES

2.1 Climate and vegetable growing

Each species or cultivar (variety) has its own special ecological requirements concerning soil, water, temperature, light and daylength. Unlike vegetables in temperate areas, those growing in the tropics are almost exclusively cultivated in the open. Apart from soil type and availability of water, the climate determines whether or not a given species can be grown successfully.

The most important climatic factor is temperature. We often distinguish between temperate (European-type) vegetables such as lettuce, white cabbage, carrots, cauliflower and French beans, and tropical vegetables such as kangkong, bitter gourd, yardlong bean, okra and hot peppers. It would be better to call these two groups cool-season vegetables and hot-season vegetables. For instance white cabbage is a cool-season vegetable which is extensively grown not only in the temperate zone but also in cool parts of the tropics, i.e. in mountainous areas and elsewhere during the cool season. Tomato, sweet pepper and eggplant, on the other hand, are warm-season vegetables, well-known in the tropics but also widely grown in temperate areas, either the whole year round in glasshouses, or only during the summer months in the open. Some species have a very wide temperature range: Chinese cabbage, sweet corn, cucumber, radish, spinach beet and bunching onion are grown in areas with diurnal temperatures varying from 15 to 35°C. Other species have a narrower temperature range. Spinach, for instance, requires a diurnal temperature between 10 and 20°C, while amaranth, its tropical counterpart, performs best at temperatures above 30°C. Table 1 gives an indication of the most suitable vegetable species for different climates.

Daylength influences flowering of plants. As far as vegetable production is concerned, it is important for those types which are cultivated for the fruits: solanaceous species, cucurbits, leguminous vegetables, cauliflower, broccoli, okra, roselle and sweet corn (see Table 2). For a successful cultivation of these vegetable species in the tropics, the daylength reaction ought to be either short-day or neutral. It is an advantage for leaf vegetables growing in the tropics if they react not too strongly to short days. Early flowering may decrease the total yield of leaves, it lowers the quality of the produce because it is mixed with inflorescences and hampers the harvest.

Onion cultivars grown in temperate areas during the summer months require a long day for bulbing, but cultivars used in the tropics do bulb in short days. Onions have been noted as day neutral in Table 2, since the seed production of the bulbed onion is mainly enhanced by a cold period, regardless of the daylength. It must be noted that some vegetable species have evolved into cultivar groups with different daylength reactions. For example, okra and yardlong bean exist as short-day, day neutral and long-day cultivars. Daylength has serious consequences for seed production, as will be shown in the next paragraph.

Air humidity can be very high in the hot, humid tropics ($>$80%) even during the dry season. Most tropical leaf vegetables and some other species such as chayote, wing bean and yardlong bean seem to perform better at a high relative humidity.

Table 1. *Climatic areas of the main vegetable types propagated by seed for cultivation in the open; mean day temperatures suitable for (possibly irrigated) cultivation (++), possible (+), difficult (-), not suitable (--).*

	tropics				*subtropics*		*temperate*
common name	low humid tropics	savanna: hot season	savanna: cool season	mountain areas	summer	winter	summer
	28-35°C	30-40°C	20-30°C	15-30°C	25-40°C	15-25°C	15-25°C
1. Solanaceous vegetables							
sweet pepper	+	++	++	++	++	+	-
hot pepper	++	++	++	+	++	+	- -
tomato	+	+	++	++	++	+	-
eggplant	++	++	++	+	+	-	-
2. Cucurbits							
wax gourd	++	++	+	+	+	-	- -
watermelon	-	+	++	++	++	-	-
melon	-	+	++	++	++	-	-
cucumber	+	+	++	++	++	++	+
pumpkin, squash	++	++	++	++	++	+	+
bottle gourd	++	++	+	+	+	- -	- -
loofah	++	++	+	+	+	- -	- -
bitter gourd	++	++	++	+	++	-	- -
snake gourd	++	++	+	+	+	- -	- -
3. Leguminous vegetables							
pigeon pea	+	++	++	+	-	-	- -
sword bean	+	++	++	+	+	- -	- -
hyacinth bean	++	++	+	+	+	- -	- -
soybean	+	+	++	++	++	-	-
yam bean	++	++	++	+	+	-	- -
lima bean	++	++	+	+	++	+	-
mung bean	++	++	+	+	++	- -	- -
common bean	-	-	+	++	-	++	++
pea	- -	- -	+	++	-	++	++
wing bean	++	++	+	+	+	-	- -
broad bean	- -	- -	+	++	+	++	++
yardlong bean, asparagus bean, climbing cowpea	++	++	+	+	++	- -	- -
voandzou	-	++	+	+	++	- -	- -
4. Crucifers							
Chinese cabbage (pakchoi)	+	++	++	++	++	+	+
Chinese cabbage (petsai)	-	+	++	++	++	++	++
African cabbage	++	++	++	++	+	+	+
turnip	-	-	+	+	-	++	++
mustard	+	+	++	++	+	++	++
borecole, kale	-	-	+	++	-	++	++
cauliflower	+	+	++	+	+	++	++
broccoli	+	+	++	++	++	+	+
white cabbage	+	+	++	++	+	++	++
radish	+	+	++	++	+	++	++

common name	*tropics*				*subtropics*		*temperate*
	low humid tropics	savanna hot season	savanna cool season	mountain areas	summer	winter	summer
	28-35°C	30-40°C	20-30°C	15-30°C	25-40°C	15-25°C	15-25°C
5. Tropical leaf vegetables							
amaranth	++	++	+	+	+	-	-
basella	++	++	+	+	+	- -	- -
jew's mallow	++	++	++	+	+	- -	- -
kangkong	++	++	++	+	+	- -	- -
nightshade	++	++	++	+	+	+	+
talinum	++	++	++	+	+	- -	- -
New Zealand spinach	- -	- -	+	++	+	++	++
6. Various hot-season vegetables							
okra	++	++	++	+	++	-	- -
roselle	+	+	++	+	+	- -	- -
sweet corn	+	++	++	++	++	+	+
7. Various cool-season vegetables							
onion	-	+	++	++	+	++	++
Japanese bunching onion	+	+	++	++	+	++	++
leek	-	-	+	+	+	+	++
celery	-	-	+	+	+	++	++
asparagus	- -	- -	-	+	+	++	++
spinach beet	+	+	+	++	++	++	++
garden beet	-	-	+	+	-	++	++
endive	-	-	+	++	+	++	++
carrot	-	-	+	++	-	++	++
lettuce	-	-	+	++	+	++	++
spinach	- -	- -	- -	-	-	++	++

However, a high air humidity is a handicap for most vegetable species, because it favours the development of pests and diseases. Therefore, the best results are generally obtained with irrigated vegetables in arid regions (R.H. < 60%).

Other climatic factors (rainfall, wind, radiation), although important in relation to cultivation practices, will not be discussed here.

2.2 Climate and seed production

The same climatic factors which influence the growing of vegetables also act on seed production, often very pronounced. Since it is important to produce disease-free seeds, it is advisable to select a dry climate or at least a season with a low air humidity. A dry atmosphere is unfavourable for pests and diseases and dry air facilitates the drying of the seeds. Naturally, in a humid tropical climate many vegetable seeds can be easily produced, notably all the vegetable species with a good performance (++) mentioned in Table 1. However, when humidity is high special arrangements have to be made for the artificial drying and storage of the seeds. During the cultivation period, more attention has to be given to the control of pests and diseases. Both factors will make the production of good quality seeds more costly. See also section 4.1, the production of market seed.

The daylength reaction is very important for seed production. Long-day plants do not normally flower in the lowland tropics. It has been proven that low temperatures replace the requirements for a long day to a certain extent, so that these vegetable species (many crucifers and cool-season vegetables, see Table 2) bolt and set seed when cultivated in mountain areas, above about 800 m.

Some vegetable species, more exactly the biennial cool-season vegetables, require a cold period, ranging from a few days to several weeks below 5 to 10°C, for bolting. This is true for white cabbage, onion (certain cultivars), leek, celery, beet, parsley and carrots. The cheap seed-to-seed method of certified seed production with the winter as natural cold period is not possible for these vegetables in the tropics, even at altitudes between 800 and 1200 m. They have to be uprooted for vernalization, i.e. putting the plants, bulbs, tubers or roots in a cold store in order to activate them to flower. The required cold period must be found experimentally for each crop and area. In Cuba for instance, well-developed carrot roots were stored for 60 days at 5°C before planting them out in low land during the cool season; seed yield and quality were reasonably good. The carrot crop produced from this seed had a quality similar to carrots produced from imported seed of the same cultivar. The question is if it is worth the costs. The relationship between low temperature and daylength reaction is not very clear. Seed setting of plants artificially made generative or cultivated at a high altitude, above 1200 m, is often very poor.

In the tropics some effort has been made to select cultivars of species normally requiring long days and/or a cold period, which will produce seed more easily in short days and at higher temperature: cabbage, cauliflower, onion. This type of breeding work is very costly, it may therefore be cheaper to move seed production to a geographic area with more favourable conditions. Yet it is important to carry out the real breeding and selection work in the vegetable growing areas, under the same circumstances as the future grower, even if seed propagation is done elsewhere.

Other factors which stimulate the initiation and further development of the generative phase, such as the C/N ratio, water stress and treatment with growth regulators (gibberellic acid) will not be discussed here, since they are only of interest to seed specialists.

2.3 Climate and seed storage

Seed gradually loses its viability[1] with age. This is caused by continuous enzymatic and metabolic activity and by respiration, consuming its reserves. Seed respiration is an important aspect of metabolic activity. This process of senescence or ageing is accelerated by a high temperature and humidity even if the moisture content of the seed is far below that required for germination. Properly dried and cool-stored seed can retain a high viability over several years since ageing under these conditions advances very slowly. The main requirement for seed storage in a hot humid climate is to prevent the well-dried seed from regaining moisture from the atmosphere.

Seed is a hygroscopic material which is in equilibrium with the surrounding air.

1. High viability of a seed lot is its faculty, when brought in good condition for germination,: 1. to germinate fast, 2. to show a high germination percentage and 3. to give rise to healthy seedlings.

Table 2. *Provisional data on seed production of vegetables in the tropics: (1) fertilization mainly by self-pollination, cross-pollination, or mixed; (2) main pollen agent for cross-pollination; (3) daylength reaction (photoperiodism) neutral = n, long day > 13h = l or short day < 13h = sh; (4) weight of 1000 seeds approximately, in grams; (5) seed needed for one ha of seed growing; (6) average period in months between sowing and harvesting; (7) seed yield under suitable climatic conditions; * require a cold period for bolting.*

vegetable type	*1* *fertili-zation*	*2* *pollen agent*	*3* *day-length*	*4* *g weight 1000 seeds*	*5* *seed kg/ha*	*6* *duration months*	*7* *seed yield kg/ha* *normal*	*high*
1. Solanaceous vegetables								
sweet pepper	mixed	insects	n	5.5	.4	4	60	100
hot pepper	mixed	insects	n	3.3	.5	9	200	600
tomato	self	----	n	3.3	.4	5	80	150
African eggplant	mixed	insects	sh	3.3	.6	10	120	150
eggplant	mixed	insects	sh/n	4.0	.8	7	200	300
2. Cucurbits								
wax gourd	cross	insects	n	70	2	5	250	400
watermelon	cross	insects	n	70	3	4	250	400
melon	cross	insects	n	25	2	4	300	600
cucumber	cross	insects	n	25	3	4	300	800
pumpkin (squash)	cross	insects	n	170(70)	2	4	500	800
bottle gourd	cross	insects	n	150	3	6	400	600
loofah	cross	insects	n	90	3	6	250	400
bitter gourd	cross	insects	n	60	5	4	250	400
3. Leguminous vegetables								
pigeon pea	mixed	insects	sh/n	125	15	9	1200	3500
sword bean	mixed	insects	sh	4000	60	9	1300	2500
hyacinth bean	self	----	sh/n/l	330	40	9	900	2000
soybean	self	----	sh	670	50	4	1300	3000
lima bean	self	----	sh/n	400-800	50	9	1000	2500
mung bean	self	----	sh/n	30	5	4	500	1200
common bean	self	----	n	290	100	4	800	2000
pea	self	----	n	170	120	3	1500	2500
wing bean	self	----	sh	500	20	7	1100	2500
yardlong bean	self	----	sh	270	20	6	500	1500
cowpea	self	----	sh/n	220	20	5	700	2500
voandzou	mixed	insects	sh	670	80	4	600	2000
4. Crucifers								
Chinese cabbage (pakchoi)	cross	insects	n/l	3	.6	5	500	800
Chinese cabbage (petsai)	cross	insects	l	3	.6	6*	500	800
African cabbage	cross	insects	n/l	2	1.0	5	600	900
turnip	cross	insects	l	3	1.5	9*	600	1200
mustard	cross	insects	n/l	2	1.0	6	600	900
kale, borecole	cross	insects	n/l	2	1.0	9*	600	900
cauliflower	mixed	insects	n	3	.3	6*	150	300
broccoli	cross	insects	sh/n	3	.3	6*	500	800
white cabbage	cross	insects	n	4	.6	9*	600	1200
radish	cross	insects	l	10	10	6	800	1200

vegetable type	1 fertilization	2 pollen agent	3 day-length	4 g weight 1000 seeds	5 seed kg/ha	6 duration months	7 seed yield kg/ha	
							normal	high
5. Tropical leaf vegetables								
amaranth	mixed	wind	sh/n	.3	1	4	500	1500
basella	self		sh	40	10	6	1200	2000
celosia	cross	insects	sh	1	1	5	400	700
jew's mallow	self		sh	2	1	5	300	400
kangkong	self?		sh?	40	5	5	500?	
nightshade	self		n	2	1	6	100?	
talinum	cross?	insects?	sh	.3	1	6	200	300
New Zealand spinach	self		sh/n?	65	10	6	400	800
6. Hot-season types								
okra	mixed	insects	sh/n	50	6	6	400	1000
roselle	self		sh	30	6	6	200	400
sweet corn	cross	wind	n	150	15	4	1000	2000
7. Cool-season types								
onion	cross	insects	n	3.0	4	9*	400	800
Japanese bunching onion	cross	insects	l	2.9	4	9*	300	600
leek	cross	insects	l	2.5	3	12*	200	600
celery	cross	insects	l	.3	.3	9*	300	500
asparagus	cross	insects	n	40	4	3 years	400	1000
beet	cross	wind	l	16	10	9*	800	1200
endive	self		l	1	1	9	200	300
carrot	cross	insects	l	1.2	1	9	300	1000
lettuce	self		l	.8	.3	6	125	200
spinach	cross	wind	l	10	20	6	600	1200

Dry seed in a humid atmosphere takes up water from the air whereas wet seed in a dry atmosphere loses water, until after some weeks equilibrium has been reached. This equilibrium depends on seed type and also fluctuates with temperature and with foregoing treatment, drying and storage, so deviations of 1 to 1.5% in seed moisture content may occur. See Fig. 1 for some approximate values. An increase in RH means a gradual decline in vigour because enzymatic and metabolic activity is stimulated. Above 65% relative humidity (RH) the decline is accelerated by storage fungi which are almost always present and which develop in and on the seed. A relative air humidity of 65% is considered as a safe lower limit for storage fungi and other organisms. The fungus *Aspergillus* which normally develops on seed in a humid atmosphere can do no harm when the air is drier than 65% RH. Normal starchy (non-oily) vegetable seed is in equilibrium with an atmosphere of 65% RH when its moisture content is about 12%. Fatty oil seeds of vegetables such as crucifers, cucurbits, carrot and lettuce attain this equilibrium at 8-10%. Since it is easier to measure the relative humidity of the ambient air in a storage room or of the seed-surrounding air in any container (see seed storage and testing, section 4.2), relative humidity (RH) is often used in stead of seed moisture content to indicate the effect of moisture on seed viability. Insects and mites are also favoured by a high RH. The lower limit for insect development is 30-40% RH but since disinfec-

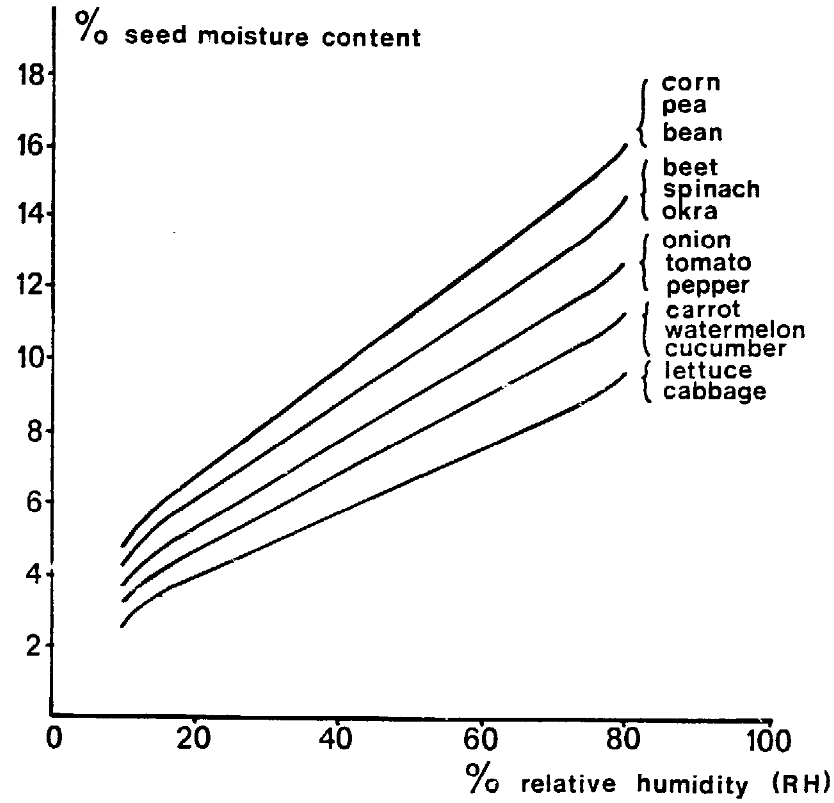

Figure 1. *Relation between seed moisture content (wet weight base) and relative humidity in equilibrium at 25°C.*

tion with insecticides is relatively easy in vegetable seed which is less bulky than agricultural seed, insects are less troublesome than fungi.

Temperature is also an important climatic factor for seed storage. Micro-organisms (fungi, bacteria) and also insects and mites are favoured by higher temperatures (25 - 35°C). The lower limit for insects is about 5°C and for fungi 10°C. The gradual increase in deterioration with higher temperatures is probably caused by accelerated enzymatic and metabolic activity, so the cooler the seed is stored the better.

It is obvious that these two additive or interacting climatic factors, temperature and humidity, are of crucial importance for the viability of vegetable seeds. Great differences exist in susceptibility of various seed types to deterioration. Onion and lettuce seed quickly deteriorates at high temperatures and humidity. Most legumes, cucurbits, crucifers and also pepper and eggplant are more tolerant. Okra, pea and especially tomato seed is very robust but, naturally, the storage room must meet the minimum requirements for the weakest, short-lived seed. Harrington (1972) gives two practical rules of thumb for seed storage between 15 and 70% RH and between 0 and 30°C:

1. for each 1% decrease in seed moisture (about 10% decrease in RH) seed life is doubled,
2. for each 5°C decrease in temperature seed life is doubled.

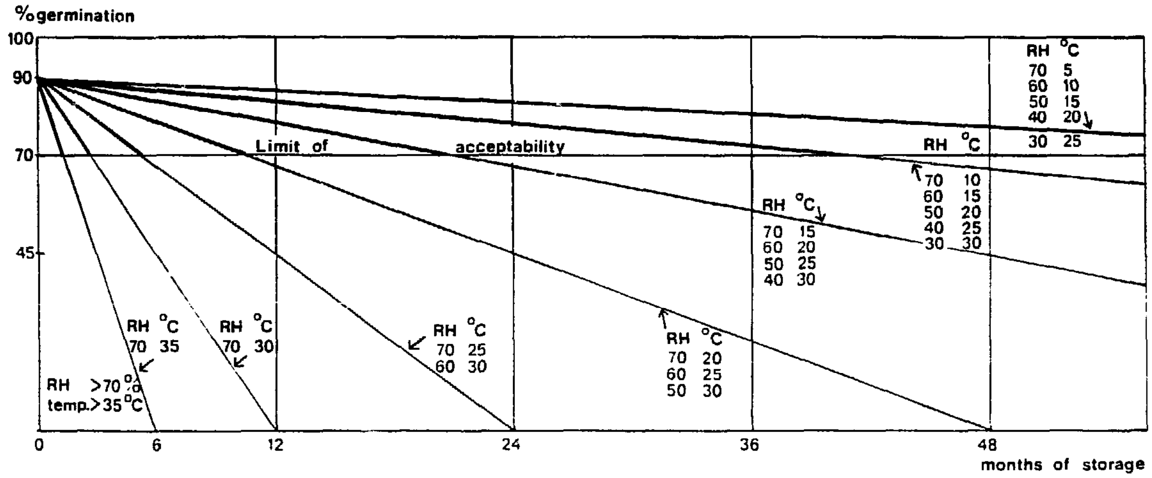

Figure 2. *Schematic diagram illustrating the influence of storage temperature and relative humidity on the germination capacity of vegetable seed.*

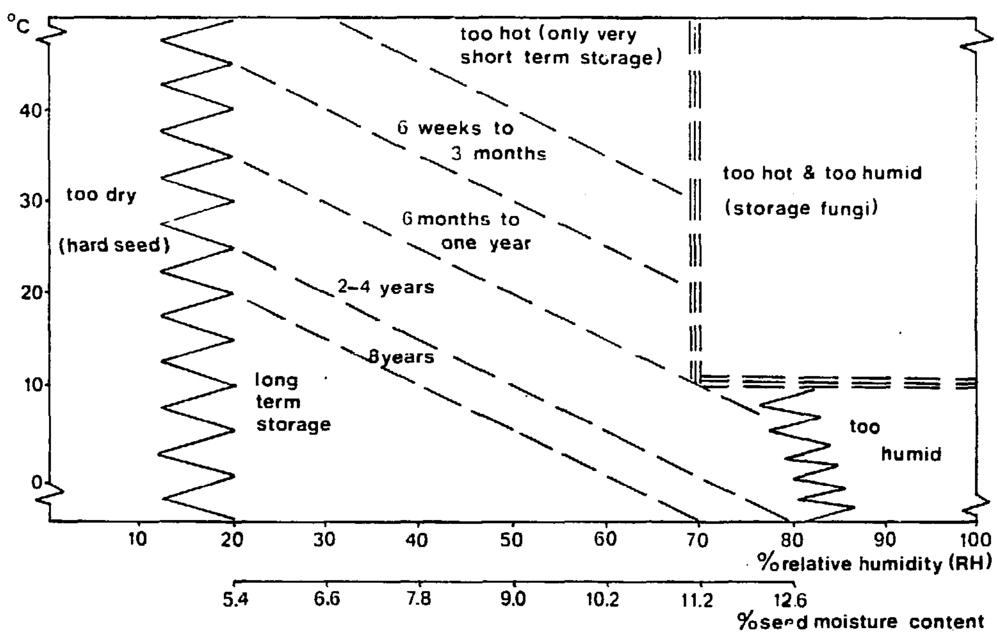

Figure 3. *Schematic diagram illustrating the safe storage period for vegetable seed under various conditions.*

Figure 2 and 3 present simplified diagrams of the influence of temperature and humidity on the germination capacity and safe storage of a susceptible type of vegetable seed such as onion or lettuce. When it is desirable to keep the viability at a sufficiently high level for one year, an air-conditioned room with an ambient temperature of 25°C and a RH of 50% will be suitable. For longer storage, the room should be drier and/or cooler. Air-tight packing of seed in air which is at least below 60% RH but preferably 30% further increases the longevity of the seed because it limits the entry of oxygen thereby reducing seed respiration.

It is believed that a certain genetic degeneration occurs by producing seed of temperate-type vegetables such as carrot, onion, lettuce and cabbage in the tropics. Although there is no evidence for this, the seed may be in a poor physical condition as a consequence of inferior growing, drying and storage conditions. Viability may be low and the seed may be infected with germs of seed-borne diseases, resulting in weak seedlings with many abnormalities. It must be judged from experience if good quality seed of a given vegetable type can be produced successfully in a certain area or if it is better to import the seed from elsewhere. In all cases, good storage conditions for locally produced as well as for imported seed is a necessity.

3. SEED PRODUCTION FOR HOME USE

Almost all vegetable seed cultivated in the tropics for home consumption and a large part of the seed for commercial vegetable growing is actually produced by the farmer himself. The seed is often of a poor quality, both physically and genetically. For tomatoes, peppers, cucurbits and other fruit vegetables, growers often use the bad, diseased fruits for seed extraction. For legumes and leaf vegetables, any plant is taken, without selecting the best producers, and the seed is poorly dried and stored. Consequently, yield and quality of produce grown from this seed will not be as good as it might be if a little more care had been given to seed production.

It is useless to prescribe technically advanced techniques for this small-scale activity, since there is not enough economic stimulus for their application. However, some simple rules may be respected which guarantee a reasonably good quality seed.

3.1 Selecting and harvesting

The highest yielding and healthiest plants with the best quality must be chosen (selected) for seed production. The seed is extracted immediately from vegetables cultivated for ripe fruits: tomato, pepper, eggplant, cucurbits. For others, one has to wait some time in order to get well-ripe fruits or dry pods. For plants such as leaf vegetables, crucifers and onions, flowering plants and seed setting will not be achieved until after several months. In this case it is advisable to mark the best plants in the field or bed with a stick, a label, a string or twine.

3.2 Separation

Three types of seed may be distinguished:

1. *seeds drying on the plant*
   Seeds of bottle gourd, loofah, all leguminous vegetables, crucifers, most leaf vegetables, onion, okra, corn, carrot, lettuce and others dry out in the pod or inflorescence on the plant. When reasonably dry, they can be collected with the pod or inflorescence and dried for some days by spreading in a thin layer on the floor or a mat in the sun, near a fire or any dry, warm, well-ventilated place. The seed is removed by hand, by rubbing or beating with a stick, the husks and the rest of the inflorescences are removed and the seed is allowed to dry further.
2. *seed in moist fleshy fruits*
   Peppers, eggplants, melons, pumpkins and gourds should be handled as follows. If not ripe enough, the fruits should be kept in a dry place in order to ripen-off. They are then cut in halves and the seed is washed out by rubbing in ample water. The cleaned wet seed is spread out on a towel or sheet of paper to dry.
3. *seed in wet fleshy fruits*
   Tomatoes and cucumbers are squeezed out into a container. The pulp is allowed to ferment for two to five days until the seed is well separated from the pulp. The seed is then washed out and dried as in 2. Good fermentation has the advantage of killing germs of diseases such as tomato bacterial canker.

3.3 Drying

Correct drying is very important if healthy, viable seed is to be obtained. When drying is done in the sun or in a warm, ventilated place, the seed must be spread out in a thin layer, not more than a few seeds thick. When using an artificial heat source e.g. an oven or electric bulbs, and this also applies to seed dried in the full sun, care must be taken that seed temperature does not rise above 30-35°C, since a higher temperature may kill the seed. Reasonably dry seed (moisture contents 10-18%) can withstand a temperature of 35-40°C for further drying.

Small samples can easily be dried in an airtight container (e.g. a wide-mouthed jar) with a desiccant. As a desiccant, the following hygroscopic materials may be used:

. silicagel: expensive; granular; noncorrosive; can be recycled by heating; very hygroscopic.
. calcium chloride: cheap; flakes which become clammy when humid; can be recycled by heating; somewhat corrosive.
. unslaked lime: very cheap, hard rock becoming dusty powder when wet; very corrosive.
. wood ash: available everywhere; must be taken very fresh but not hot; dusty powder, slightly hygroscopic.
. charcoal: like wood ash but easier to handle; slightly hygroscopic.

The desiccant should be placed at the bottom of the container, either loose or packed in a cotton bag. The desiccant is covered with a perforated metallic plate, a piece of perforated cardboard or wire mesh, and the moist seed, packed in paper or cotton bags, is placed on top.

Silicagel is the easiest to handle. It is coloured blue with cobalt chloride which turns pink when the relative humidity rises above 45%. At that point, one quarter of its weight is absorbed water and it has to be dried before further use. About the same quantity of dry silicagel must be used as the quantity of seed, for drying from about 20% to 6% moisture within a few days. Calcium chloride, unslaked lime and wood ash are less hygroscopic so larger quantities have to be used to produce a similar effect. After two days to one week, when the seed is well dried, the desiccant should be removed.

Too severe and prolonged drying risks extracting too much water from the seed. When it is dried to a RH below 20%, i.e. a seed moisture content of 3-5%, it might become hardcoated and as a consequence will germinate badly. This risk of induction of seed dormancy is great for legumes, okra and jute mallow.

3.4 Storage

Well-dried seed can be stored in an airtight container, for instance a glass jar with a rubber ring.

In many remote areas it is customary to store vegetable seed in a bottle gourd. This natural container is semi-airtight and protective against insect infestation when the surface is treated with oil and the neck is well plugged, but a glass jar or bottle is more satisfactory and easier to handle. Different lots can be stored together in one large container by packing them separately in paper or plastic bags. Opened packages of commercial seed can also be kept in this manner. If attack by insects or fungi is feared, a small amount of an insecticide (3 g of lindane, DDT, diazinon, dieldrin or malathion per kg of seed), a fungicide (thiram) or a mixture of both may

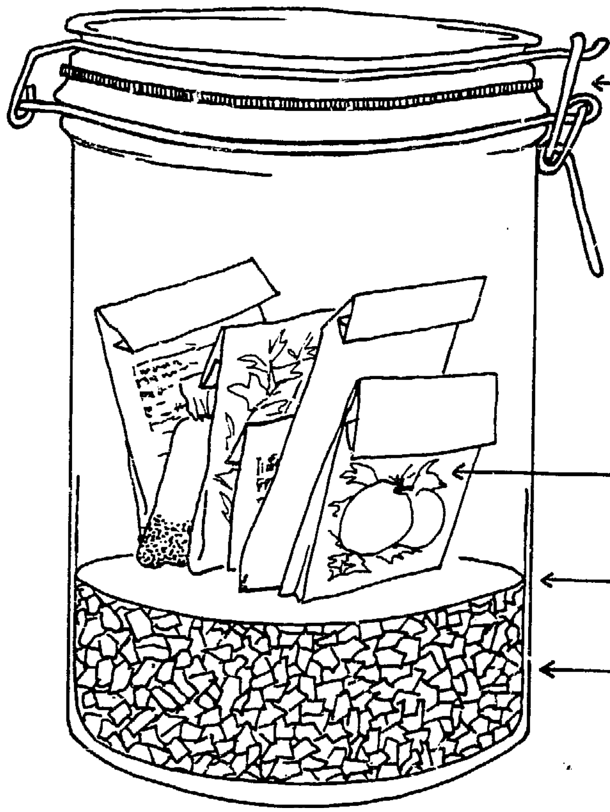

Figure 4. *Simple method for storage of small seed samples*

be added. When the seeds are still too moist, a desiccant can be put at the bottom of the jar for a few days. In a very humid atmosphere, one may keep some desiccant - for instance a small package of silicagel or calcium chloride, not more than 1/10 of the seed quantity - in the jar in order to keep the relative humidity low, especially after frequent opening (see Fig. 4).

It should be noted that it is dangerous to store a small quantity of seed in a large jar since the mass of humid air enclosed in the jar, especially if it is opened and closed frequently, can be sufficient to raise the humidity of the seed above the limit for mould growth. It is better to use smaller jars, well filled with dry seed with no room for humid air or oxygen.

Normally, no desiccant is needed during storage when seed humidity and relative humidity of the surrounding air are low (< 13% and < 60%, resp.). The bulky seeds of leguminous vegetables (beans, peas) will not lose their germination capacity even when stored in an open container or in a cotton bag in a reasonably dry place (RH < 70%). These seeds are very attractive to insects, so it is necessary to disinfect with an insecticide. Care should be taken that beans or peas treated with an insecticide are not used for consumption by accident.

If carefully dried and stored, most species will retain good germination power for several years. The safest method is to renew the seed every year, or at least after two years, throwing away the old stock.

Most vegetable seeds do not germinate well when used too fresh. It is better to start using the seed after a storage period of at least two weeks.

4. SMALL-SCALE COMMERCIAL SEED PRODUCTION

Horticultural stations and also private seed growers sometimes sell locally produced vegetable seeds to individuals. This can be seen as the first step towards a large scale national production of certified vegetable seeds. A high level and large-scale seed industry has already been built up in India, Taiwan and Brazil and is in progress in Egypt, Pakistan, the Philippines, Mexico, Sri Lanka, Thailand and maybe in some other countries in the tropics. These seed industries are mostly governmental but sometimes also private. They use skilled plant breeders, seed agronomists, seed technicians, and modern processing equipment. The bulk production of certified seed is confined to mechanized farms on a contract basis. Small-scale seed industries, however, have only limited resources and lack skilled seed specialists. Some technical recommendations will be given here for seed production by small-scale seed enterprises. It may be seen as a type of intermediate seed technology between the traditional 'primitive' system and the technically advanced one. The organization scheme of a modern vegetable seed industry and the relation with the control agency is presented in Fig. 5. For methods to establish a small-scale seed industry, the same set of operations should be followed.

4.1 Agronomy

Variety testing

First of all, a choice has to be made of those species and cultivars which can be used for seed production. To begin with, all popular local and imported types and cultivars should be tested. Eventually, a very small number of cultivars may be chosen which meet the requirements for both grower and consumer. As production of hybrid seed is a complicated and difficult process for a newly developing seed industry, only open-pollinated cultivars should be chosen.

Production of breeder seed and foundation seed

Breeder seed or nucleus seed is seed from the selected cultivar, produced in a small quantity as a basis for the production of foundation seed. The selected cultivars are planted in small, well-isolated fields, self-pollinating species 100 m and cross-pollinating species at least 500 m apart. The proper segregation distance depends on wind direction, area of the fields, degree of cross-pollination and desired purity. A barrier crop, for instance maize, can be used to make the segregation more safe. The plantings should receive very strict selection (roguing) i.e. removal of all the off-types starting before flowering. Some superior plants are harvested separately and their seed is used for the next generation of breeder seed and also for future selection and breeding. The seed of the rest of the plants is bulked and used for the production of foundation seed.

Foundation seed, also called elite seed or stock seed, is seed resulting from a controlled propagation of breeder seed and is produced in a medium/large quantity to be used by the seed grower for the production of certified market seed. The same production methods as for breeder seed must be practised. For small-scale seed production, breeder seed may be directly used for the establishment of fields of market seed.

Production of market seed

Market seed is seed produced by the seed grower from foundation seed (or from breeder seed) certified as to purity and trueness-to-type by a control agency and destined for sale to the vegetable growers. This seed is called 'certified' here, but it must be clear that it merits this title only when an independent control institution for the certification of vegetable seeds exists. The previous steps, the production of breeder seed and foundation seed, have to be carried out in the same area and under the same conditions as those prevailing for the vegetable growers. The bulk production of market seed, however, can be done in any area which best meets the requirements for seed growing (see section 2.2 page 12):

. a dry atmosphere favourable for a healthy crop;
. no heavy rainfall during blooming, since this endangers good pollination of cross-pollinating species;
. temperatures must not be too low or too high since these cause poor fruit setting; a diurnal temperature between 25° and 35°C will be convenient for warm-season vegetables, and 15°C to 25°C for cool-season types; pollen and ovaries may be killed above 35°C or under 10°C, but these values vary with the species;
. dry weather during the harvest period of crops with seeds drying in the pods or inflorescences;
. strong winds which would cause shattering of seed on the plant should not occur.

The crop must be sufficiently isolated. Roguing of diseased plants (especially with virus symptoms) and off-types must be carried out regularly. Pests, diseases and weeds must be strictly controlled. Since the produce is not destined for consumption, frequent treatment with toxic pesticides can be carried out if necessary. Cultural practices are largely identical to the system used for commercial vegetable growing. However, planting distance should be much wider. The cultivation period will last much longer, which means more chances for pests and diseases.

Harvesting and eventually threshing can be carried out, depending on the extent of the production and on local circumstances, by hand in one or more rounds or, in technically more advanced areas, mechanically. Once the seed has been harvested, the agronomic part of the seed industry is terminated and seed technology or preparation for sale can start.

4.2 Technology

Cleaning

For separation of the seed from the plant parts, the same categories and techniques can be used as described for home-produced seeds (section 3.2). For larger quantities, however, some technical aids can be applied; threshing by beating with a stick or mechanically and winnowing in the wind or with a fan. It is better to use a hand- or motor driven winnowing mill with trays and sieves, which removes husks, dust, seeds of weeds, deaf seeds and other impurities and which grades the seed.

Separation of the seed of fleshy fruits is done as described in section 3.2. For tomato and cucumber, a cleaner and faster method is to squeeze the fruits in a large

seed company		
departments	*operations*	*activities of the control agency*
1. Agronomy		
Research unit	*variety testing*	
	breeding, selection	
	breeders seed	testing for release
	propagation	
	↓	
	foundation seed	control
Production unit	*production fields*	
	roguing	field inspection
	harvesting	
	threshing	
	↓	
	bulk seed	
2. Technology	*drying*	
	cleaning	
	grading	
	storage	
	dressing	
	testing	seed inspection
	packaging	
	↓	
	market seed	
3. Distribution	*promotion*	
	marketing	
	transport	
	retail trade	control

Figure 5. *Scheme of an advanced seed industry*

container and to add one liter of 40% hydrochlorid acid per 100 l of squeezed mass. After 30 minutes the seed can easily be washed off from the flesh. The disadvantage of this method is that it does not kill germs of diseases such as bacterial canker of tomato, and the seed coat may be slightly damaged by the acid, so most seed producers prefer the fermentation method.

Drying

The seed can be dried by spreading it out in a thin layer in the open on a cement floor or on a mat, or artificially by air which is heated and then blown over or through the seed with a fan. The higher the moisture content, the lower the drying temperature in order to avoid injury. For very moist seed with a moisture content of over 18%, the drying temperature must not exceed 35°C. Under 18% moisture, the seed can safely be dried with air of 35-40°C and under 10% with air of 45°C. One must be especially careful with weak seeds such as onion and lettuce. The high ambient air temperature and relative humidity in the tropics are a great handicap. The risk of seed damage can be avoided by using air of ambient temperature which has been dried by passing through silicagel or by a combination of heating and a dehumidifier.

The seed must be dried to a moisture content of not more than 8% for oily seeds (Brassicas, cucurbits) or for very small seeds (lettuce) and not more than 12% for legumes and other large, non-oily vegetable seeds, in equilibrium with a RH of 50%. At 25°C this seed keeps viable for one or two years. For long-term storage, more than five years, it would be safer to dry to a point in equilibrium with a relative humidity of 30-40%.

Disinfection

Insects, spider mites and storage fungi have little opportunity to spoil well dried seed, but they multiply rapidly when the moisture content is critically high, causing a quick decline of seed viability. Germs of seed-borne fungal and bacterial diseases survive on the seed coat or in the seed and attack after germination. It is a normal procedure to disinfect all commercial seed against insects and seed-borne diseases. Seed above 65% RH, disinfected with a fungicide such as pentachloronitrobenzene or an antibiotic (puromycin, chloramphenicol) can sometimes keep better than non-disinfected seed, but in most cases the fungicide will not penetrate well enough into the dried seed to kill also the storage fungi. Therefore, it is necessary to dry the seed to a moisture content below 65% RH in order to prevent deterioration by fungi. It is easier to disinfect against insects. Suitable insecticides are lindane (3 g/kg), carbaryl (10 g/kg), dichlorvos and pyrethrum. Some commonly used products against microorganisms are mercury-fenyl or -methyl (2 ml/kg), thiram (3 g/kg) and benomyl (4 g/kg). These products may protect the seed to some extent against storage fungi, but their principal function is to act as a seed dressing, i.e. to protect the young seedling after germination. Many products are commercially available. The fungicides benomyl and thiram and the insecticides carbaryl and bromophos are often used as seed dressings. These dressings can best be given just prior to packaging. Care must be taken, for chemical prestorage disinfection and for seed dressing, that the dosage on the label of the commercial product is not exceeded, because an overdose may damage or kill the seed.

For killing storage insects in well insulated stores for large quantities of seed fumigation is often used. It is also a suitable method for cleaning the store room itself. Capsules or tablets in plastic bags may be used, for instance for storage of beans. These chemicals (methylbromide, phosphine, hydrocyanic acid) may affect the seed viability when too large dosages are used, especially when the moisture content of the seed is high. They are very toxic to man, so one has to be careful when carrying out fumigation.

Storage

Small quantities of not more than a few kilogrammes of seed can easily be stored in airtight containers, possibly with a desiccant, in a cool place or in a refrigerator. Usually this will be impractical or impossible for larger commercial stocks. Well dried and cleaned seed should be kept in good condition right up to the time of distribution and use. It is clear that in a humid tropical climate special arrangements should be made to counteract ambient humidity and temperature. The best method is the installation of a cold store (temperature $< 10^\circ C$, relative humidity $< 50\%$). If this is too expensive, an air-conditioned room (temp. $< 25^\circ C$, RH $< 50\%$) would be a good alternative, in order to keep the seed in a good state for at least one year. If such facilities are not available, the seed should be stored as fresh, ventilated and cool as possible. The seed store room must always be kept very clean in order to avoid infection and to keep rodents out.

It has been shown that in the hot humid tropics the relative humidity of a storage room of 50 m^3 can be kept below 50% with a small one h.p. air-conditioner provided the room is well insulated. It must have thick, oil-painted walls, no windows and a well-insulated double entry door. Artificial insulating materials such as plastified fiber board which might give off toxic gases affecting seed viability should not be used.

It is necessary to control the temperature and relative humidity of the seed storage room from day to day, so it must be equipped with a thermometer and a hygrometer. A simple hair hygrometer is not accurate enough, a more reliable type, for instance a wet and dry bulb hygrometer, should be used.

Packaging

In a humid climate it is advisable to have an air-conditioned packaging room next to the storage room. The easiest way of packing is the use of moisture-proof heat-sealed polyethylene bags of 0.25 mm thickness (at least 0.1 mm = 400 gauge) with a label indicating the origin (seed company), variety, harvest month and year, sample number, weight, treatment given and toxicity warning, seed test data and percentage of germination and, if possible, recommendations for sowing. Each variety should be packed in two or three different quantities, for instance small size packets (50 m^2 planting), medium (500 m^2) and large (5000 m^2). Another possibility is to make packets of a certain weight, for instance 2.5 and 10 g for small seeds and 100 or 200 g for legumes and other large seeds. Other packaging methods, more expensive and complicated, are used by large seed companies: aluminium laminated multi-wall paper bags with printed text, or vacuum tins. It is important that the seed should be packed in a 'tropical' vapourproof material.

Testing

Seed delivered by the dealer to the grower must be highly reliable. Germination tests of seed lots for trade should be carried out regularly. It is recommended to follow the instructions of the ISTA (Anon. 1976) as much as possible. A fairly reliable picture of the seed viability can be obtained as follows. Spread four samples of 50 seeds on moist paper in petri-dishes and put them in a room ambient temperature (20-30°C). Moist sand can be used for large seeds such as beans. The germinated seeds are counted and removed from the dishes every other day during 10-14 days. When less than the minimum prescribed percentage germinates within this period the lot should not be used for distribution.

For hard-coated seeds such as okra, New Zealand spinach, jew's mallow, peas and beans, which have been stored under very dry conditions, scarification, previous soaking for one night or dipping in water of over 90°C for a few seconds or for larger quantities in water of 55°C during 20 minutes may be required in order to get good germination. This should also be indicated on the label. Minimum germination percentages as legally required in the USA are presented in Table 3. These

Table 3. *Minimum official germination percentages as laid down in the Federal Seed Act, USA. Completed with unofficial percentages which might be used for tropical vegetables (*), estimated on the basis of experience; h = including hard seed.*

1. Solanaceous vegetables	
African eggplant	50*
eggplant	60
pepper (sweet, hot)	55
tomato	75
tomato, husk	50
2. Cucurbits	
cucumber	80
melon	75
pumpkin	75
squash	75
watermelon	70
other cucurbits	70*
3. Leguminous vegetables	
common (French) bean	70h
cowpea	75h
lima bean	70h
pea	80h
yardlong bean	75h
other legumes	70*h
4. Crucifers	
African cabbage	75*
broccoli	75
cauliflower	75
Chinese cabbage	75
kale	75
mustard	75
radish	75
turnip	80
white cabbage	75
5. Tropical leaf vegetables	
amaranth	80*
basella	60*
jew's mallow	50*h
kangkong	70*
nightshade	60*
talinum	60*
New Zealand spinach	40h
6. Various hot-season species	
okra	50h
roselle	50*
sweet corn	75
7. Various cool-season species	
asparagus	70
beet (spinach, garden)	65
carrot	55
celery	55
endive	70
Japanese bunching onion	70
leek	70
lettuce	80
onion	70
spinach	60

percentages may also be used by countries lacking legal rules for seed quality. For tropical vegetable species which are not mentioned in this list, the same percentage as for the most similar or most related seed type from the list may be used.

Another test commonly executed in seed laboratories is the determination of the seed moisture content. However, determination of seed moisture content with the air-oven method is laborious, difficult for non-professionals and requires too much precision. Measurement of the seed moisture content with an electric humidity testing apparatus is also not easy for the relatively small lots of vegetable seed. This apparatus must be adjusted separately for each seed type. The most practical method is not to control the seed moisture content but the relative humidity in the seed lot. A cheap instrument (about $ 100) is the dip-shaft hygrometer, the most accurate and easiest type is an electronic hygrometer equipped with a piercing probe (about $ 1500). This apparatus is easily transportable, works also on batteries and is suitable for small quantities. It can be used for any seed type and is not affected by impurities or dirt. The equilibrium relative humidity in the seed (abbreviated as % ERH) is correlated to the seed moisture content as explained in section 2.3 and Fig. 1. It clearly indicates if the seed is well dried.

An official, independent control agency will not only test germination percentage and moisture content, but also other factors determining the quality. The seed should be viable, free from seed-borne diseases, weed seeds and other impurities. Moreover, it should be genetically pure and true to the name of the cultivar, a requirement that is not easy to control since there is a great resemblance between various cultivars of a species. This 'testing for genuineness' protects the producer of the cultivar and also the vegetable grower from falsifications and errors. Lacking a control agency, the seed producing institution should take every precaution to ensure delivery of first class seed.

4.3 Distribution

Much emphasis is placed on the necessity for a good distribution system. Without this, all the care given to the production of high quality seeds is wasted. In many countries it will not be easy to set up a good distribution system and to reach the vegetable growers, in spite of the apparent need for quality seed. Seed is sold in market stands, in shops for foodstuffs or other goods, in equipment and material stores, by agricultural or horticultural extension agencies and in cooperative stores. Seed may also be ordered by mail from a local dealer or from abroad.

If vegetable seed arrives at the distribution centre in good condition it may deteriorate during the weeks or months of storage and exposure to high temperature and humidity before it is sold. If the retailer has no convenient place to store the seed and the climate is a real handicap then he must make arrangements to renew his stock regularly after some weeks and to order no more than what he can sell in that period.

In seed technology, many levels of sophistication exist between the simple techniques for obtaining small quantities for home use and large scale commercial seed production. For information on cheap and easy-to-handly equipment and the more advanced large scale techniques, one may contact the Ministry of Agriculture in the home country or one of the following two addresses:

1. International Seed Testing Association (ISTA)
   ISTA Secretariat
   Reckenholz
   P.O. Box 412
   CH-8046 Zürich, Switzerland

2. Seed Industry Development Programme
   Division of Plant Production and Protection
   FAO
   Via delle Terme di Caracalla
   Rome, Italy

5. SEED IMPORTATION

5.1 Principles

When ordering seed from abroad, it is important to consider: 1. which is the best variety, 2. how to get good quality seed of that variety and 3. for a reasonable price.

1. *variety.* Variety testing of foreign cultivars has been carried out in most countries. Often the grower or seed dealer knows from experience which cultivars perform well in the area. Yet it is not uncommon to see packets of seed for sale in warehouses in the lowland tropics containing seed of temporate vegetable types which can never be grown successfully in that area!
   Variety testing should be a continuous experiment to be repeated regularly with the appearance of new varieties. It is mostly an activity of national experimental stations.
2. *quality.* Seed must be delivered in tropical, vapourproof packages in order to avoid rapid deterioration. Most international seed companies deliver retail vegetable seed in vapourproof, aluminium-laminated packets which can be safely stored for several months in a humid, hot atmosphere without losing much of its germination capacity. They should be kept in a refrigerator, cold store or air-conditioned room. Dealers who import seed in bulk and re-pack them in small packets often keep the opened tins or bags in a warm humid place, causing a quick decline in viability. It might be better to import the seed in retail packages. Also, much depends on the facilities for getting seeds through customs in a short time and on quarantine and import regulations.
3. *price.* Good quality seed pays. Although the price of the vegetable seed is only a small part of the total costs, it is worthwhile to find out which company offers good quality seed for the best price.
   The price of vegetable seeds may show wide variations, as illustrated by the figures given in Table 4. In general, prices of Western European companies are somewhat higher than those of companies in the USA. South African, Taiwanese and Japanese seeds are even cheaper and Indian companies offer seed for the lowest price.
   Naturally, new varieties are often more expensive than older ones because of development and promotion costs. The high price of hybrid seeds is due to the high amount of labour involved in hand pollination and to a relatively low rate of seed production.
   A new technique in the preparation of vegetable seeds is to coat the seed with a clay-like substance, making each seed a regularly shaped globule (pelletization). This reduces the amount of seed needed considerably, facilitates mechanical sowing and decreases the risk of failure. Pelleted seed, however, is very expensive and up to now rarely used in the tropics.

A list of cultivars generally recommended for the tropics is presented on the following pages, a list of seed companies in paragraph 5.3. The easiest way of ordering

Table 4. *Prices of seeds of popular non-hybrid vegetable cultivars (f.o.b., in US $) in medium size package (½-1 kg). Average of some European, North American, African and Asian seed companies as presented in seed catalogues of 1976.*

vegetable type	*method*	*price in US$ per kg*		*seed needed g per 100m²*	*cost of seed US$ per 100m²*
		mean	*range*		
tomato	transplanted	80	2 -1500	3	.24
sweet pepper	transplanted	60	36 -1700	4	.24
eggplant	transplanted	40	11 - 500	5	.20
cucumber	direct sowing	20	13 - 240	10	.20
melon	direct sowing	25	13 - 240	8	.20
French beans	direct sowing	3	1.5- 8	800	2.40
pea	direct sowing	3	1.5- 10	1500	4.50
cabbage	transplanted	35	7 - 124	3	.10
cauliflower	transplanted	60	18 - 320	4	.24
onion	transplanted	50	7 - 60	50	2.50
beet	direct sowing	20	4 - 240	200	4.00
carrot	direct sowing	15	7 - 32	80	1.20
lettuce	transplanted	45	7 - 460	8	.36

vegetable seed is a permanent contact with one single company, but it may be wiser, considering the variation in prices and cultivars, to order more specifically the best and cheapest cultivars from different companies. However, when good quality seed of a given vegetable type is offered locally, it is not necessary to order it from abroad.

5.2 Varieties recommended for the tropics

In the following list a number of varieties (cultivars) has been compiled which are commonly used for cultivation in the tropics or have been proven in variety tests to be superior to others. Many popular local varieties exist and are superior to imported ones in yield and resistance to diseases or simply more in agreement with the local taste. If good local varieties are present, then it is better to produce good quality seed from these than to import foreign varieties.

Much depends on traditional relations with seed companies. Japanese and Chinese, and Australian and New Zealand companies to a lesser extent, are the most popular in South East Asia. India produces its own seed and also China is largely self-supporting. Middle Eastern, Mediterranean and African countries import a great deal from France, The Netherlands, England and Denmark. Israel and Egypt are partly self-supporting. East Africa obtains part of the required seed from a South African company. About ten North American companies deliver the greatest part of vegetable seed to Latin America. Here, only Brazil and Mexico have established an important seed industry.

The varieties named in this list are not described in detail. The reader is advised to order seed catalogues for data on characteristics of interesting varieties and to order seed samples for variety testing.

1. SOLANACEAE

eggplant: local varieties; Black Beauty, Black Magic, Florida High Bush, Florida Market, Jersey King, Long Purple, Pusa Purple Cluster
hot pepper: local varieties; Anaheim, Caribe, Fresno, Long Red Cayenne, Red Chili
sweet pepper: local varieties; Burlington, California Wonder, Florida Giant, Keystone Resistant Giant, Ruby King, World Beater, Yolo Wonder
tomato: local varieties; AVRDC 24, Best of All, Bonset, Calypso, Campbell, Floradel, Heinz 1370, Homestead, Indian River, Isabella, Manalucie, Manapal, Marglobe, Moneymaker, Panase, Parker, Piacenza, Piervil, Pritchard, Roma, Rossol, Rutgers, San Marzano, UHN Hybrid 52, Vemone, VF 1402

2. CUCURBITS

bitter gourd: local varieties; Coimbatore Long
bottle gourd: local varieties; Pusa Summer Prolific Long
cucumber: local varieties; Ashley, Cherokee, Chinese Long, Fengshan Green, Gemini, Japanese Long Green, Poinsett, Southern Cross
loofah: local varieties; Pusa Chikni
melon: local varieties; Burpee Hybrid, Dessert Sun, Dulce, Gulfstream, Hale's Best, Honey Dew, Imperial 45, Smith's Perfect, Supermarket
pumpkin: local varieties; Butternut, Cheese, Cushaw, Sugar
snake gourd: local varieties
squash: Ambassador, Cocozelle, Crookneck, Long French Bush, Long White, Straightneck, Zucchini
watermelon: local varieties; Charleston Grey, Congo, Crimson, Dixie Queen, Fairfax, La Mallorca, Mississippi, Sugar Baby, Sunrise, Sweet Carnival

3. LEGUMES

Bambara groundnut: local varieties
broad bean: local varieties; Long Pod
common bean (snap bean, French bean):
– bush type (bush bean): Canadian Wonder, Contender, Fin de Bagnols, Seminole, Stringless, Tendergreen, Top Crop, local varieties
– pole type (climbing bean): local varieties; Canfreezer, Florigreen, Kentucky Wonder, Witza
cowpea: local varieties; Pusa Barsati
hyacinth bean: local varieties; Pusa Early Prolific, Waby Salad Bean
lima bean:
– bush type: Fordhook 242, Henderson, Ventura
– pole type: local varieties; Carolina, Easy Shell, Sieva
mungbean: local varieties
pea: local varieties; Arkel, Bonneville, Blue Bantam, Little Marvel, Mammoth,
pigeon pea: local varieties
soybean: local varieties; Giant Green
sword bean: local varieties
winged bean: local varieties
yardlong bean (asparagus bean): local varieties; Extra Long

4. CRUCIFERS

broccoli: Calabrese, Type A, Green Sprouting
cabbage: Copenhagen Market, Drumhead, Gloria Osena, Golden Acre, KK-cross, KY-cross, Tainong Hybrid All Season, Titan 90, Ursa, Yehsen, local varieties
cauliflower: local varieties; Early Market, Early Patna, Pua Kea, Snowball, Snow Diana, Snow Peak, Snow Queen
Chinese cabbage:
– pakchoi (leaf type): local varieties; Taisai
– petsai (heading type): local varieties; Cantonner Whitehead, Granat, Kyoto, Michihli, Nagaoka, Tropicana, Waka, Wongbok
leaf cabbage:
– African cabbage: local varieties
– kale (borecole): local varieties; Thousand Headed kale
– mustard: local varieties; Prize Winner
radish:
– European: French Breakfast, Globemaster, Scarlet Globe
– Chinese: local varieties; Japanese White
turnip: White Globe

5. TROPICAL LEAF VEGETABLES

amaranth: local varieties; Bari chaulai, Katwa Data, Tampala
basella: local varieties; Malabar Spinach
jute: local varieties
kangkong: local varieties
nightshade: local varieties
talinum: local varieties
New Zealand spinach: New Zealand

6. VARIOUS WARM SEASON VEGETABLES

okra: local varieties; Clemson, Emerald, Ladyfinger, Louisiana, Pusa Sawani
roselle: local varieties
sweet corn: local varieties; Branco, Cubana, Golden Bantam, Puerto Rico 50, Supersweet, USDA 34

7. VARIOUS COOL SEASON VEGETABLES

asparagus: Glory of Brunswick, Mary Washington
carrot: Chantenay Red Core, Danvers Half Long, Imperator, New Kuroda, Pusa Kedar, local varieties
celery: Golden Self Blanching, Plein Blanc Doré, Summer Pascal
endive: Batavian Broad Leaved, Green Curled
garden beet: Detroit Dark Red, Detroit Nero, Egyptian, Rouge Noire Plate
Japanese bunching onion: local varieties; Long White Bunching
leek: Gros Long d'Eté, Italian Giant, Large American Flag, Musselburgh
lettuce:
– butterhead: Kagraner Summer, Prado, Reine de Mai

— loosehead: local varieties; Simpson
— crisphead: Great Lakes, Iceberg, Reine de Glace
onion: local varieties; Bombay White, Bombay Red, Crystal Wax, Excel, Red Creole, Texas Grano 502, Tropicana Tropic Ace, Yellow Granex
parsley: Paramount, Triomphe
spinach: Saloniki, Viroflay
spinach beet: Lucullus, Pusa All Green

5.3 List of seed companies for import

Some addresses of seed growers with frequent deliveries to tropical and subtropical countries have been compiled. The list is purely informative and not restrictive. National seed companies not exporting are omitted.

Australia

Yates & Co.
90-100 Sussex Street
P.O. Box 2707 GPO
Sydney

Brazil

Agroceres S.A.
Avenida Dr. Vieira de Carvalho 40-3. Andar
Caixa Postal 30.723
Sao Paulo

Egypt

Horticultural Research Institute
Giza

France

Clause
Bretigny-sur-Orge
Seine-et-Oise

Tézier
B.P. 223
Valence-sur-Rhône

Vilmorin Andrieux
4 Quai de la Megisserie
75001 Paris

India

National Seeds Corporation
Beej Bhavan, Pusa Complex
New Delhi 110012

Pocha's Seeds
P.O. Box 55
1A Middle Road
Poona 411001

Suttons Seeds
13-D Russell Street
P.O. Box 9010
Calcutta-16

Israel

Hazera Seed Co
P.O. Box 1565
Haifa

Japan

Fujita Seed Company
P.O. Box 211
Osaka C.

Sakata & Co.
2 Kiri batake, Kanagawa-Ku
Yokohama, Japan

Takii & Co. Ltd. Seed Growers
P.O. Box 7
Kyoto Central
Kyoto

Kenya

Kirchhoff's East Africa
P.O. Box 30472
Nairobi

The Netherlands

Nunhem's Zaden
Haelen

Royal Sluis
P.O. Box 22
Enkhuizen

Sluis & Groot
Westeinde 62
Enkhuizen

Philippines

Bureau of Plant Industry
Economic Garden
Los Baños
Laguna

Farmers Seed Co.
415 Aldedoa St.
P.O. Box 4158
Manila

Taiwan

Taiwan Seed Service
Shinshieh
Taichung, Taipei

Known-you Nursery
26 Chung-Cheng 2nd Road
Kaohsiung

United Kingdom

Hurst Gunson Cooper Taber
Witham
Essex

United Kingdom

Sutton & Sons Ltd.
Seed Growers
Reading

U.S.A.

Asgrow Seed Company
P.O. Box 72
Milford
Connecticut

Burpee Co.
Seed and Bulb Growers
Philadelphia 47
Pennsylvania

Dessert Seed Co.
P.O. Box 187
El Centro
California

Ferry-Morse Seed Co.
P.O. Box 100
Mountain View
California

Harris Seed Co.
Rochester, New York
14624

Petoseed Co.
P.O. Box 4206
Satocoy
California 93003

Denmark

J.E. Ohlsen Enke
Ny Munkegaard
Taastrup
Copenhagen

6. LITERATURE

The most relevant publications consulted by the author are presented in the following annotated list. For more detailed information on certain subjects of vegetable seed production and technology it is recommended to consult the following abstract journals:

1. Horticultural Abstracts. Published by the Commonwealth Bureau of Horticulture and Plantation Crops, East Malling Research Station, Maidstone, England;
2. Plant Breeding Abstracts. Published by the Commonwealth Agricultural Bureaux, Farnham Royal, Slough, England;
3. Abstracts on Tropical Agriculture. Published by the Department of Agricultural Research, Royal Tropical Institute, Amsterdam, The Netherlands.

When requiring information on vegetable growing in a given area, contact first of all the local Agricultural Extension Services. They often provide extension bulletins and information on where to obtain useful handbooks on vegetable growing, written especially for the given country. These local or national vegetable handbooks are not presented in the following list. It only mentions those handbooks which have a broader significance. Much information on vegetable growing and seed production can be found in libraries of Agricultural Universities and Horticultural Research Institutes.

Anonymus 1961. *Agricultural and horticultural seeds.* FAO Agricultural Studies no. 55, Rome; 531 p.
(a guide for professional seed producers)

– 1961. *Seeds* The Yearbook of Agriculture 1961. The United States Department of Agriculture.
(information on seed production and processing in the USA)

– 1969. *Equipment numbers.* Proc. Int. Seed Test. Ass. Vol. 31 no. 1: 177 p.
(description of equipment and techniques for cleaning, sampling and testing seeds)

– 1976. *International Rules for Seed Testing. Rules 1976.* Int. Seed Test. Ass., Seed Sci. & Technol. 4 (1): 1-180
(international rules for seed testing with detailed instructions; French edition: 4(4): 558-751)

– 1978. *Symposium on seed problems in horticulture. The search for practical solutions.* Acta Horticulturae 83: 321 p.
(a survey of ongoing research and developments in seed production and technology of vegetables; the paper of R.A.T. George, p. 23-29, deals with problems of seed production in developing countries)

Chauhan, D.V.S., 1972. *Vegetable production in India.* Ram Prasad & Sons, Agra-3; 325 p.
(handbook for extension workers in India and surrounding countries)

Choudhury, B. 1976. *Vegetables.* India, the land and the people, New Delhi; 227 p.
(handbook for extension workers in India and surrounding countries)

Chupp, Ch. and A.F. Sherf, 1960. *Vegetable Diseases and Their Control.* The Ronald Press Company, New York; 693 p.
(handbook for vegetable diseases, including many tropical vegetable types)

Epenhuijsen, C.W. van, 1974. *Growing native vegetables in Nigeria.* FAO, Rome; 113 p.
(description of small-scale seed production; cultivation of local vegetables useful for the hot-humid tropical area of West and Central Africa)

Filgueira, F.A.R., 1972. *Manual de olericultura.* Cultura e comercializaçâo das hortiliças. Sao Paulo; 460 p.
(handbook for vegetable growing in Portuguese, for Brazil; typical tropical vegetable types are poorly described)

Fundacion Shell, 1968. *Hortalizas. Cagua, Venezuela* (FUSAGRI); 136 p.
(guide for commercial vegetable growing in Venezuela, in Spanish; useful to other Spanish speaking countries with subtropical conditions)

Grubben, G.J.H., 1977. *Tropical vegetables and their genetic resources.* Edited by H.D. TINDALL and J.T. WILLIAMS, International Board for Plant Genetic Resources, FAO, Rome: 197 p.
(data on economic and nutritional importance, agronomy, seed production, recommendations for germplasm collection, breeding and research)

Hadfield, F., 1960. *Vegetable gardening in Central Africa.* Purnell and Sons, South Africa (Pty) Ltd.; 178 p.
(handbook for Central Africa, more suitable for mountainous areas than for lowland)

Harrington, J.F., 1972. *Seed storage and longevity.* In: KOZLOWSKI T.T. (ed.), Seed Biology, Academic Press, New York and London, Vol. III: 145-244
(a comprehensive description of theoretical background and practical implications of seed storage)

Hawthorn, L.R. and L.H. Pollard, 1954. *Vegetable and flower seed production.* Blakiston, New York, 626 p.
(the most popular handbook for vegetable seed production, also outside the USA)

Herklots, G.A.C., 1972. *Vegetables in South-East Asia.* George Allen & Unwin, London; 525 p.
(handbook for vegetable growers in S.E. Asia and elsewhere in the low humid tropics; the typical tropical vegetable types are well described)

Hill, A.G.G., 1948. *Seed production of European vegetables in the tropics.* Commonwealth Bureau of Horticultural and Plantation Crops, Technical Communication 19: 28 p.
(a review of experience in this field until 1948)

Knott, J.E., 1966. *Handbook for vegetables growers.* Wiley and Sons, Inc., New York, London, Sydney; 245 p.
(handbook with tabulations giving detailed information on vegetable growing techniques and seed production in temperate or subtropical areas)

Knott, J.E. and J. Deanon, 1967. *Vegetable production in South-East Asia.* Univ. Philippines, Manila; 366 p.
(handbook for research workers in S.E. Asia, also useful for other humid tropical areas)

Messiaen, C.M., 1975. *Le potager tropical.* Tome 1, Généralités. Tome 2, Cultures spéciales. Tome 3, Cultures spéciales. Presses Universitaires de France. Paris;

470 p.
(handbook for practical vegetable growing, in French, especially for the Caribbean area, also suitable for other tropical lowland areas; extensive description of vegetable diseases)

Ochse, J.J. and R.C. Bakhuizen van den Brink, 1931. *Vegetables of the Dutch East Indies.* Bogor. Reprint Elsevier, Amsterdam, 1977; 1004 p.
(classical work on tropical vegetables, for botanically interested research workers)

Oomen, H.A.P.C. and G.J.H. Grubben, 1976. *Tropical Leaf Vegetables in Human Nutrition.* Comm. 69. Department of Agricultural Research, Royal Tropical Institute, Amsterdam; 136 p.
(guide for home gardening and for the cultivation of tropical leaf vegetables)

Roberts, E.H. (ed.), 1972. *Viability of seeds.* Chapman and Hall, London: 448 p.
(basic principles of seed viability, for research workers and seed technologists)

Ruck, H.C., 1976. *Horticulture, a select bibliography.* FAO Plant Production and Protection Papers 1. Food and Agriculture Organization of the United Nations, Rome; 56 p.
(a list of publications on horticulture in developing countries, including vegetables, fruits and ornamentals)

Terra, G.J.A., 1966. *Tropical Vegetables.* Comm. 54, Department of Agricultural Research, Royal Tropical Institute, Amsterdam; 107 p.
(botanical list of tropical vegetables, giving much information on cultivation, for research workers interested in taxonomy and human nutrition)

Toole, E.H., V.K. Toole and E.A. Gorman, 1948. *Vegetable seed storage as affected by temperature and relative humidity.* USDA Techn. Bull. 972: 24 p.
(description of an experiment with seed of 15 common vegetable types)

Tindall, H.D., 1968. *Commercial vegetable growing.* Oxford Tropical Handbooks. London; 300 p.
(concise handbook for vegetable growing in the tropics, including many tropical type vegetables)

Winters, H.F. and G.W. Mikimen, 1967. *Vegetable gardening in the Caribbean area.* Agricultural Handbook, 323,USDA Agric. Research Service; 114 p.
(handbook for vegetable growing in the Caribbean area)

7. NAMES OF VEGETABLES COMMONLY CULTIVATED IN THE TROPICS[1]

Latin	*English*	*French*	*Spanish*
1. Solanaceae	**Solanaceae**	**Solanées**	**Solanáceas**
Capsicum annuum	sweet pepper	poivron	pimentón
Capsicum spp.	hot pepper	piment	chile, ají
Lycopersicon esculentum	tomato	tomate	tomate
Solanum macrocarpon	African eggplant	aubergine locale	---
Solanum melongena	eggplant, brinjal	aubergine	berenjena
2. Cucurbitaceae	**Cucurbits**	**Cucurbitacées**	**Cucurbitáceas**
Benincasa hispida	wax gourd	courge cireuse	calabaza china
Citrullus vulgaris	watermelon	pastèque	sandía
Cucumis melo	melon	melon	melón
Cucumis sativus	cucumber, gherkin	concombre	pepino
Cucurbita moschata	pumpkin	courge	calabaza
Cucurbita pepo	squash	courgette	calabaza
Lagenaria leucantha	bottle gourd	calebasse	calabaza
Luffa spp.	loofah	loofah	patola
Momordica charantia	bitter gourd bitter melon, bitter cucumber	margose, concombre amer	cundeamor, ampalaya
Trichosanthes anguina	snake gourd	serpent végétal	patola
3. Leguminosae	**Legumes**	**Légumineuses**	**Leguminosas**
Cajanus cajan	pigeon pea	pois d'Angole	guisante de paloma
Canavalia ensiformis	sword bean	pois sabre	haba blanca
Dolichos lablab	hyacinth bean	dolique d'Egypte	lablab, batao
Glycine max.	soy bean	soya	soya
Pachyrrhyzus erosus	yam bean	dolique bulbeux	jicama de agua
Phaseolus lunatus	Lima bean	haricot Kissi	frijol trepador, judía de Limá
Phaseolus radiatus	mung bean	haricot velu haricot à grain vert	frijol mungo
Phaseolus vulgaris	common bean	haricot vert	habichuela, ejote, frijol común, vainitas
Pisum sativum	pea	petit pois	arveja, guisante

1. only vegetable species propagated by dry seed.

Latin	*English*	*French*	*Spanish*
Psophocarpus tetragonolobus	wing bean, Goa bean	pois carré	sesquidillas
Vicia faba	broad bean	fève	haba
Vigna unguiculata	yardlong bean, asparagus bean	dolique-asperge, niébé	chaucha por metro, frijol de ojo negro, nitao
Voandzeia subterranea	Bambara groundnut	voandzou	
4. Cruciferae	**Crucifers**	**Crucifères**	**Crucíferas**
Brassica campestris var. *chinensis*	Chinese cabbage (pakchoi)	chou de Chine	col China
Brassica campestris var. *pekinensis*	Chinese cabbage (petsai)	chou de Chine	col China
Brassica campestris var. *rapa*	turnip	navet	nabo, rutabaga
Brassica carinata	African cabbage	chou africain	
Brassica juncea	mustard	moutarde de Chine	mostaza
Brassica oleracea var. *acephala*	kale, borecole	chou vert	col berza
Brassica oleracea var. *botrytis*	cauliflower	choufleur	coliflor
Brassica oleracea var. *botrytis*	broccoli	broccoli	broccoli
Brassica oleracea var. *capitata*	(white) cabbage	chou	repollo
Raphanus sativus	radish	radis	rábano
5. (various species)	**tropical leaf vegetables**	**légumes-feuilles tropicaux**	**hojas vegetales tropicales**
Amaranthus spp.	amaranth	amarante	amaranto, bledo, tampala
Basella alba	Basella, Ceylon spinach	baselle	espinaca de Ceilán
Corchorus olitorius	jute, jews mallow	jute	yute
Ipomoea aquatica	kangkong, water spinach	patate aquatique	espinaca acquática
Solanum nigrum	nightshade	morelle noire	yerba mora, morella
Talinum triangulare	Talinum, water leaf	grassé	espinaca de Filipinas
Tetragonia expansa	New Zealand spinach	tétragone	espinaca de Nueva Zelandia

Latin	*English*	*French*	*Spanish*
6. (various species)	**various hot-season species**	**différentes espèces des saisons chaudes**	**algunas especies para temporadas cálidas**
Hibiscus esculentus	okra	gombo	quingombo
Hibiscus sabdariffa	roselle	oseille de Guinée	agrio de Guinea
Zea mays	sweet corn	maïs	maíz dulce, elote
7. (various species)	**various cool-season species**	**différentes espèces des saisons fraîches**	**algunas especies para temporadas frías**
Allium cepa	onion	oignon	cebolla
Allium fistulosum	Japanese bunching onion	ciboule	cebolleta
Allium porrum	leek	poireau	puerro
Apium graveolens	celery	celéri	apio
Asparagus officinalis	asparagus	asperge	espárrago
Beta vulgaris var. *cicla*	spinach beet	poirée	acelga
Beta vulgaris var. *rubra*	garden beet	betterave	remolacha
Cichorium endivia	endive	chicorée	escarola, endivia
Daucus carota	carrot	carotte	zanahoria
Lactuca sativa	lettuce	laitue	lechuga
Spinacia oleracea	spinach	épinard	espinaca