1. Acerola

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1.1. Introduction

The acerola shrub (*Malpighia emarginata*; see appendix of chapter 1) is a tropical plant that produces fruit with a large concentration of vitamin C. It is native to the Caribbean Islands, Northern South America, Central America and Southern Mexico. In Brazil, its cultivation has increased from 1988 to 1992, owing to the discovery of its importance to human nutrition as a result if its richness in vitamin C, estimated at between 1,200 and 1,900 mg/100 g of pulp (Paiva *et al*., 2003).

Brazil has seen a considerable expansion of the area cultivated with acerola, principally because of its nutritional qualities, ease of cultivation and appropriate climatic conditions. These factors were responsible for the large increase in commercial plantations and, as a result, the emergence of pests and diseases.

Table 1.1 shows that the total area of acerola in Brazil is more than 10,000 ha, with Bahia state, followed by Pernambuco and Ceará as the greatest producers of this fruit shrub. The production is estimated at 33,000 mt of fruit, principally originating from the north-eastern region and from Sao Paulo state (IBGE, 2004).

The export of acerola, which is largely destined for the USA, Germany, France and Japan, is estimated to be about 37 to 43% of the total production (Manica *et al*., 2003), i.e. around 12,800 mt.

In spite of its current elevated status as an economically important crop for many regions, as shown by the annual increase in the planted area, it can be

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assumed that little attention has been given to the considerable nutritional benefits of acerola.

Table 1.1. Area harvested and quantity of acerola produced in the principle states of Brazil in 1996.

State	Area harvested	Production
	ha	mt
Bahia	1,881	3,458
Pernambuco	1,467	7,625
Ceará	1,358	4,724
Paraíba	1,156	2,686
São Paulo	956	3,759
Pará	935	1,814
Paraná	620	1,751
Rio Grande do Norte	584	2,683
Minas Gerais	443	978
Maranhão	317	593

Source: IBGE, Censo Agropecuário, 2004.

1.2. Climate, soil and plant

1.2.1. Climate

The acerola shrub grows as well in tropical as in subtropical climates, the ideal temperature is around 26ºC (Simão, 1971; Ameida and Araújo, 1992; Teixeria and Azevedo, 1995).

Although adapted for cultivation in semi-arid regions, the largest production occurs in regions with an evenly distributed annual average precipitation of between 1,200 and 1,600 mm (Gonzaga Neto and Soares, 1994). In regions with less precipitation, the leaves fall from the shrubs in the dry season, but grow again during the rainy season.

The quality of acerola fruit is largely influenced by solar radiation, and there is a positive correlation between the composition of ascorbic acid and the intensity of solar radiation (Nakasone *et al*., 1968).

1.2.2. Soil

The acerola shrub can be grown on a range of soil types, from sandy to clay-based soils, as long as the fertilization and drainage requirements are met (Gonzaga Neto and Soares, 1994). However, soils of medium fertility and sandy clay texture are the most productive due to their increased capacity to retain water (Simão, 1971).

1.2.3. Plant

The acerola shrub has a low basic water potential. In 12-month-old plants grown in polyethylene pots in clay soil, under a mesh canopy, the leaf water potential before dawn is around –1.0 MPa (Oliveira, 1996). Non-irrigated adult plants (seven years old) have a pre-dawn leaf water potential of –0.4 MPa during the rainy season and –1.5 in the dry season (Nogueira *et al*., 2000).

Stomatal conductance and transpiration of this species are very small, compared to other fruit trees (Oliveira, 1996; Nogueira *et al*., 2000). Despite this, a deficit in vapour pressure is more strongly correlated with the leaf water potential than with the stomatal resistance. This, on the other hand, seems to depend more on solar radiation, especially in the dry season. The stomatal system does not seem to be very efficient in avoiding water loss through the leaves and the low basic water potential acts principally as an internal adjustment for the plant.

Nogueira *et al*. (2000) found maximum rates of photosynthesis in the range of 6.0 to 6.40 µmol CO_2 m^{-2} s^{-1}, values that are within the accepted limit for deciduous fruit plants (6.5 to 20 µmol CO_2 m^{-2} s^{-1}) (Korner *et al*., 1979).

1.3. Soil and plantation management

The propagation of the acerola shrub may be sexual (by seeds) or vegetative (budding and grafting). Seeds can be germinated in beds or in soil in bags or plastic jars. In budding propagation, it is recommended to use buds with a stem of about 30 cm, taken from vigorous branches on young plants. The stems should be treated with indolbutyric acid (IBA) and put in sandy soil or vermiculite to develop roots. Propagation by grafting favors the formation of a more vigorous root system.

Similarly to what is done for other fruit plants, preparation of the soil includes ploughing, harrowing, liming and fertilization, when necessary, and preparing the planting holes.

Liming of the soil is extremely beneficial, increasing the depth and density of the root system, and the growth and production of the plants (Ledin, 1958; Landrau Júnior and Hernández-Medina, 1959; Hernández-Medina *et al*., 1970). Preferably, calcareous dolomite should be applied over the whole area and incorporated to the greatest depth possible. The operation ought to be completed before ploughing and two to three months before planting. In established plantations, most of liming material should be applied at the base of the plant, because of the acidification produced by the addition of fertilizers.

Kavati (1995) recommended that liming, should aim to establish a base saturation of about 70% and that this should be repeated when soil analysis reveals a base saturation of less than 60%. For this and other crops it can be recommended to use liming principally in soils with a Mg content of less than 5 $mmol_c/dm^3$ (Federal University of Ceará, 1993). In Porto Rico, when Hernández-Medina *et al*. (1970) increased soil pH from 4.5 to 6.5 with liming there was a 170% increase in fruit production.

The planting holes or pits should be spaced at 4.0 m x 4.0 m or 4.0 m x 3.0 m. The pits should be opened about one or two months before planting. This operation may be manual or mechanical and the size can be from 40 to 60 cm in all three dimensions. The slips or young plants are transplanted when they are 30 cm to 40 cm tall. In non-irrigated areas this operation should be done during the rainy season.

Careful supervision is essential after planting during the initial growth of the plants. Until the slip reaches 30 cm to 40 cm in height it should be supported by a stake or pole to ensure an upright trunk. Then three to four branches should be left dominant until the plant reaches 50 cm to 60 cm in height, at which point it is pruned for breaking the apical dominance. Any suckers should be removed and the bush pruned after each production cycle to maintain the plants at an adequate height.

Weed control is an indispensable practice, because weeds decrease the availability of nutrients and water and also favor the dissemination of pests and diseases in addition to making maintenance of the irrigation system difficult (especially drip systems). Finally, the presence of weeds makes harvesting difficult, besides reducing the production of fruit.

Generally, weeds can be controlled by mechanical or manual harrowing and by using herbicides. Currently, the primary form of weed control is manual harrowing around the base of the plants (crowning) along with the use of a mower between the rows. In some regions ploughing is used between the rows, however this practice is not recommended during the period of initial establishment of the plants, and even in older plants the use of a plough can harm the root system, which is concentrated in the top 60 cm of the soil (Musser, 1995). In areas with drip irrigation systems the use of herbicides is recommended, because it reduces the damage caused to the irrigation system like cutting of the hoses. The use of a mulch is also recommended at the base of the plant, because it not only controls the formation of weed growth, but it also preserves the moisture in the soil.

1.4. Mineral nutrition

Although a large number of new acerola orchards have been established in areas of low soil fertility, the literature on nutrition and fertilization is still scarce. Thus, discussions about this subject need to be very cautious, because fertilization cannot safely be recommended based on other plant cultures.

Leaf analysis as a method of evaluating a plant's nutritional state started in the 1930's as a technique to interpret the effects of and estimate the requirement for fertilization. However, it is essential to establish a positive correlation between the quantities of nutrients supplied, the composition of the leaves and the production of the plants (Malavolta *et al.*, 1967). Even then the results of leaf analysis alone does not permit a precise and thorough calculation of the quantities of fertilizer to apply, given that it is a complimentary technique and not exclusive.

There is very little data in the literature on the methodology of leaf sampling for the acerola shrub. For research, it is recommended to collect an average of 100 mature leaves per plant, from the same height, the middle of the crown (±1.5 m above the ground) and from all sides of the plant.

1.4.1. Uptake and export of nutrients

The nutrient requirement of the acerola plant has been assessed by the export of nutrients through the fresh fruits, at the time of harvest. This data was obtained by various researches in the team SF/DF/CCA/UFPB, in Areia, Paraíba, Brazil, who studied fruits coming from orchards situated in different localities in Paraíba (Table 1.2). This data, shows that the order of exportation of the primary macro-nutrients by the fruits is K>N>P and that the variations between the different data sets are due to the local conditions and the nonuniformity of the orchards from which the fruits were obtained, especially the sexual origin of the plants.

Regarding the remaining nutrients, Alves *et al*. (1990) found the following order of export: K>N>Ca>P>Mg>S>Fe>Zn>Mn>Cu. These authors observed that in the fruit, the concentrations of N and Ca were highest in the seed, while those of P and K were in the pulp. Silva (1998) found the order of export was similar in one year old plants: K>N>Mg>S>P>Mn>Zn>B.

Regarding the quantities of minerals found in the leaves and branches, Tables 1.3 and 1.4, respectively, give values of N, P and K found in plants cultivated in the greenhouse and under field conditions. In general, it is observed that N was most prevalent in the leaves, followed by K and P. In the branches, the sequence was found to be the same as that in the fruit, i.e. N>K>P. It is observed, therefore, that K is of great significance to the mineral nutrition of this crop, as much in young plants as in those already in production.

Table 1.2. Composition (%) of N, P and K in acerola fruit parts: skin and pulb (S + P) and seed (S) from different sources from different regions of Paraíba state.

Source	Region	Part	Nutrients (%)		
			N	P	K
1	Marsh	S + P	0.10	0.25	2.60
		S	1.60	0.15	0.72
2	Costal	S + P	1.22	0.22	2.55
		S	1.35	0.20	0.97
3	Costal	S + P	1.94	0.30	3.52
		S	1.57	0.21	1.09
4	Cariri	S + P	1.41	0.23	2.82
		S	1.47	0.20	1.35
5	Cariri	S + P	1.00	0.16	2.64
		S	1.27	0.19	0.90
	Cariri	S + P	1.14	0.22	2.62
		S	1.33	0.21	1.33
	Costal	S + P	1.86	0.30	2.56
		S	1.44	0.20	1.02
	Forest	S + P	1.16	0.19	2.48
		S	1.48	0.20	0.89
	Rural	S + P	1.57	0.20	2.59
		S	1.72	0.19	1.00

Sources: 1. Alves *et al*., 1990; 2. Silva Júnior *et al.*, 1989; 3. Nascimento, 1995; 4. Cunha, 1992; 5. Freire, 1995.

Table 1.3. Composition (%) of N, P and K contained in acerola leaves cultivated in a greenhouse and in field conditions, in different regions of Paraíba state.

Source	Region	Age (years)	Nutrients (%)		
			N	P	K
1	Greenhouse	-	2.46	0.97	2.73
2	Marsh	>10	2.20	0.11	1.72
3	Coastal	2	2.70	0.31	1.63
4	Cariri	1	2.44	0.15	1.27
	Cariri	3	1.78	0.15	1.23
	Cariri	4	1.65	0.15	1.54
	Marsh	4	2.06	0.21	3.02
5	Coastal	1	2.68	0.26	0.21
	Coastal	2	2.40	0.28	2.20
	Coastal	3	2.66	0.32	2.23
6	Coastal	4	2.98	0.25	1.61
	Forest	5	2.86	0.19	2.77
	Rural	5	3.00	0.21	2.55
	West Cariri	3	3.11	0.20	2.18
	West Cariri	4	2.71	0.21	1.69
	West Cariri	5	3.18	0.24	2.18

Sources: 1. Cibes and Samuels, 1955; 2. Alves *et al.*, 1990; 3. Silva Júnior *et al.*, 1990; 4. Nascimento, 1995; 5. Cunha, 1992; 6. Freire, 1995.

Table 1.4. Composition (%) of N, P and K found in branches of acerola cultivated in field conditions, in different regions in Paraíba state.

Source	Region	Age (years)	Nutrients (%)		
			N	P	K
1	Marsh	>10	0.90	0.08	2.21
2	Coastal	2	1.03	0.24	1.48
3	Cariri	1	1.00	0.14	1.29
	Cariri	3	1.35	0.15	4.36
	Cariri	4	1.06	0.16	1.43
	Cariri	4	0.47	0.10	1.25
4	Coastal	1	0.90	0.19	1.35
	Coastal	2	0.85	0.18	1.30
	Coastal	3	0.90	0.18	1.40
5	Cariri		0.55	0.12	1.19
	Cariri		0.56	0.11	1.44
	Cariri		0.67	0.12	1.56
	Coastal		0.62	0.15	1.03
	Forest		0.60	0.08	1.27
	Rural		0.64	0.10	1.31

Sources: 1. Alves *et al*., 1990; 2. Silva Júnior *et al*., 1990; 3. Nascimento, 1995; 4. Cunha, 1992, 5. Freire, 1995.

It should be pointed out that the concentration of N, P and K in the leaves and branches and, consequently, the demands of the plant for these nutrients, vary according to the season (Cunha *et al*., 1993).

1.4.2. Functions and importance of nutrients

Nitrogen (N): Nitrogen is of fundamental importance in the plant's nutrition and is required in large amounts. Oriented around the current prices of fertilizers, it is important to know the point at which N becomes effective for production.

When deficient, N accumulated in the oldest organs, principally the leaves, is redistributed to the young organs. Consequently, deficiency symptoms appear initially as a yellowing or chlorosis in the oldest leaves. Nitrogen deficient plants develop less than those well supplied with N because proteins are not produced. On the other hand, excess of N in the soil produces vegetative growth, producing few fruits and storing less sugar and carbohydrate (Malavolta, 1989).

Cibes and Samuels (1955) working in a greenhouse with acerola in Porto Rico determined that the omission of N contributed most to the decrease in plant development and production. The complete yellowing of the leaves, with premature leaf fall was the principal symptom of acute deficiency. Plants deficient in N had an increased concentration of P, Ca, Mn, Fe and S in the leaves. Landrau Júnior and Hernández-Medina (1959) increased production with the application of N up to 185 kg N/ha. Miranda *et al*. (1995) studied the effect of N, P, K, Ca, Mg and Fe omission in a nutrient solution experiment. The omission of N caused a reduction in the height of the plants and in the production of aboveground dry matter.

Phosphorus (P): Phosphorus has been considered the element that most limits production in tropical and subtropical regions. In many Brazilian soils, the total P is small.

Although essential, plants in production take up smaller quantities of P, compared to those of N and K. This can be observed in the production of the acerola shrub (Table 1.2). Similarly to what occurs with N, P is easily distributed in the plant, especially when there is a deficiency, which causes the emergence of typical symptoms in the oldest leaves.

In acerola seedlings 90 days old, the application of increasing amounts of P linearly increased plant height, number of leaves and amount of dry matter amongst the roots and aboveground parts (Corrêa *et al*., 2002). The presence of mycorrhizal fungi on the roots of slips results in an increased absorption of P, increasing their growth (Chu, 1993). Cibes and Samuels (1995) report that the omission of P in the nutritive solution produces symptoms not specific to this nutrient. Acerola plants submitted to treatment without P did not show significant differences regarding the production of dry matter, height or diameter (Miranda *et al*., 1995).

Potassium (K): Potassium is the nutrient most in demand and that which is assimilated most by the fruits (Table 1.2). Fertilization with K and N, both quantity and balance, in the production phase, is fundamental, because much K is exported in fruits and seeds.

The transport of carbohydrates produced in the leave for the other organs is done inefficiently when the plant is deficient in K.

Potassium is highly mobile in the plant, and is transported from the oldest organs to the youngest ones. Consequently the symptoms of K deficiency are first manifest in the older leaves (Malavolta, 1989).

Cibes and Samuels (1995) observed that the absence of K is characterized by the formation of a large number of small spots on the leaf cuticle and in this condition the composition of both Ca and Mg was increased because there was also a decrease in the composition of P in the leaf. These authors also reported that the absence of K reduced the diameter of the crown and that although large quantities of fruits were produced, they were small.

In six-month-old slips cultivated in a nutritive solution, Barbosa *et al.* (1995) observed that the absence of K in the nutritive solution caused an increase in the concentration of N in the leaves.

Calcium (Ca): The deficiency of Ca provokes leaf loss, with symptoms in the remaining leaves characterized by a yellowing at the tips and edges. When the deficiency is acute, there is severe burning at the leaf tips (Cibes and Samuels, 1995; Lugo-López *et al*., 1959). On the other hand, Ledin (1958) noticed that the leaves in Ca deficient acerola plants showed yellowing starting from the apex and going towards the edges. Miranda *et al.* (1995) observed a significant reduction in the production of aboveground dry matter of acerola cultivated with the omission of Ca.

The application of calcium in the form of lime, proven beneficial to the root system, accelerates the growth and increases the production of the plants (Landrau Júnior and Hernández-Medina, 1959; Hernández-Medina *et al*., 1970).

Magnesium (Mg): Besides making up part of the chlorophyll molecule, Mg is known as the activator of numerous enzymes, especially the “activators” of “amino acids” which catalyse the first step in protein synthesis. Magnesium is also important for the absorption of P (Malavolta, 1979). With very large concentrations of K in the soil or in solution, there could be a deficiency of Mg. Deficiency symptoms appear first in the oldest leaves. The symptoms of deficiency are characterized by yellowing along the edges of the oldest leaves, extending to between the veins, in the case of acute deficiency (Cibes and Samuels, 1955).

Sulphur (S): Held in the soil in the form of sulphate, sulphur participates in the composition of some of the amino acids and proteins, it also serves as an enzyme activator, besides participating in the synthesis of chlorophyll and the absorption of CO_2, among other functions. In situations of deficiency, its low phloem mobility results in an emergence of symptoms initially in the youngest leaves (Malavolta, 1989). Conditions of low availability of sulphur are observed in soils with a lack of organic material, soils with a high ratio of C/N, which hinders mineralization, periods of drought and constant use of fertilizers without S. The symptoms of deficiency are similar to those of nitrogen deficiency (Cibes and Samuels, 1955).

Boron (B): Deficiency of B is common in Brazilian soils, principally in those that are sandy and deprived of organic material or where there has been excessive liming, in regions with long droughts or also where B has been leached from the soil by rain or irrigation water.

The element is practically immobile in phloem and in the acerola shrub the symptoms of its deficiency emerge first in the youngest leaves, with yellowing and later death of upper the extremities of the leaves (Cibes and Samuels, 1955).

Iron (Fe): In acidic soils a lack of Fe could be induced by an excess of Mn, which inhibits the competitive absorption of the former. Excessive liming that increased soil pH to above 7.0 could make Fe insoluble, leading to its deficiency.

The presence of this micro-nutrient is crucial for the plant because amongst other functions, it is an enzymatic activator, participating in the constitution of some co-enzymes and of molecules that participate in the transport of electrons in the processes of photosynthesis and respiration. Owing to its immobility in phloem, the symptoms of its deficiency in the acerola emerge first in the youngest leaves, characterized by a yellowish-green color. With the intensification of Fe deficiency, only the veins remain greenish, while the leaf cuticle is yellow (Cibes and Samuels, 1955).

Manganese (Mn): Since Mn is poorly distributed in the plant, the symptoms of its deficiency emerge first in the young leaves. The symptoms of deficiency include leaf chlorosis with a background of light green, contrasting with the dark green veins (Cibes and Samuels, 1955).

Copper (Cu): The visual symptoms of Cu deficiency in the acerola shrub may be seen in plants developed in sandy soils and also in conditions where there has been an application of a large quantity of organic material, lime and of phosphate. Symptoms may also occur as a consequence of N fertilization, by the “dilution effect” of the cuticle composition. Its low level of distribution by the phloem results in the symptoms of its deficiency first appearing in the young leaves.

Zinc (Zn): The deficiency of Zn in Brazilian soils is just as common as that of boron, being principally in acidic and sandy soils. It is worth stressing that in any soil excessive liming may also reduce the availability of Zn to the plants. Ledin (1958) comments that Zn deficiency results in a general yellowing of young leaves and a retarded growth of acerola shrubs.

1.5. Fertilization

Acerola is a rugged plant that has the capacity to obtain nutrients from most of the soils where it grows (Ledin, 1958; Couceiro, 1985), and, in consequence, there is a lack of information on its nutrient requirements.

In treating it as a perennial plant, fertilization should offer survival conditions in an ideal situation to guarantee the physical and economic maximum in production and productivity. For this, it is necessary to have knowledge of the orchard's situation, and beyond a visual assessment of the nutritional state, soil analysis and leaf analysis.

1.5.1. Fertilization in the nursery phase

The nursery phase is the period transpires between germination and the time when the slip can be planted in the orchard.

The substrate for filling the plastic bags should be two to three parts fertile soil mixed with one part cured bovine manure. To every cubic meter of this mixture, 3.0 to 5.0 kg of single superphosphate (SSP) should be added as well as 0.5 to 0.7 kg of potassium chloride (KCl) (São José and Batista, 1995). Subsequently it is convenient to supply nutrients with a weekly or biweekly addition of the following solution: 100 g of $(NH_4)_2SO_4$, 100 g of SSP and 50 g of KCl in 100 L of water, with every square meter of surface receiving 3 to 4 L of solution.

For acerola slips cultivated in jars, Miranda *et al.* (1995) noticed a significant effect of P on the height of the plant, the number of leaves and the root and aboveground dry matter.

1.5.2. Fertilization in the planting phase

When preparing the planting pits it is generally recommended to apply a manure which has been well cured (chicken, bovine, goat and sheep), principally on light textured soils where nematodes can occur. The quantities vary from 10 to 20 L of manure per pit (Simão, 1971; UFC, 1993; Musser, 1995). Besides manure, P, K and even lime should be applied (Musser, 1995). Recommendations vary between 400 and 500 g of SSP, 300 to 400 g of KCl and 200 g of calcareous dolomite (Gonzaga Neto and Soares, 1994; Kavati, 1995).

1.5.3. Fertilization in the growing phase

During the growing phase, which is until three years old, there are many recommendations in the literature (Table 1.5). For example, Simão (1971), suggests that the plants require fertilization with a mixture of 400 g of $(NH_4)_2SO_4$ or $Ca(NO_3)_2$, 400 g of SSP and 200 g of KCl per plant at the initiation of fruit bearing. Gonzaga Neto and Soares (1994) recommend 20 L of cured bovine manure to be supplemented by addition of mineral fertilizers (Table 1.5).

Table 1.5. Recommendations for fertilizing acerola.

Year	Fertilizer	g/plant	Reference
	Nitrogen		
1	8-8-15	500	Simão, 1971; UFC, 1993
2	14-4-10	1,300	Marty and Pennock , 1965
2	8-8-15	500	Araújo and Minami, 1994
12	Urea	30–40	Gonzaga Neto and Soares, 1994
1	Urea	53	Musser, 1995
3-4	N	20	Kavati, 1995
	Phosphorus		
1	8-8-15	500	Simão, 1971; UFC, 1993
2	14-4-10	1,300	Marty and Pennock, 1965
1	SSP	250	Musser, 1995
2	8-8-15	500	Araújo and Minami, 1994
	Potassium		
1	8-8-15	500	Simão, 1971; UFC, 1993
2	14-4-10	1,300	Marty and Pennock, 1965
2	8-8-15	500	Araújo and Minami, 1994
12	K_2SO_4	30–40	Gonzaga Neto and Soares, 1994
1	KCl	33	Musser, 1995

1.5.4. Fertilization in the production phase

In the fruit bearing phase the application of 60 to 100 g of $(NH_4)_2SO_4$ or of $Ca(NO_3)_2$ and 375 to 500 g of KCl/plant is recommended (Simão, 1971). This fertilization, which is recommended for rainfed areas, should be divided into two equal doses, with the first being applied at the start of the rainy season and the other at the end of the rainy season, in a circular band about 20 to 40 cm from the trunk. Kavati (1995) recommends for production plants from two to five years old, an annual fertilization with about 200 g of N, 180 g of P_2O_5 and 250 g of K_2O/plant, divided into eight monthly applications, applied during the fruit bearing period, in moist soils at the base of the plant.

It should be stressed that fertilization during fruit bearing, the average productivity of the orchard should be considered, taking into account nutrient export harvest, so that the nutrients lost will be replenished by the addition of fertilizers.

1.6. Irrigation

In non-irrigated crops the production of acerola normally begins 30 to 35 days after the start of the rainy season. The large production of acerola in this rainy season floods the market and increases the difficulties of selling the fruit. Irrigation permits an increase in productivity, increases the period of harvest and increases the size of the fruit. In regions where the average temperature remains above 20ºC, irrigation permits an increase in the yield up to 100% and an average of eight to nine harvests per year (Gonzaga Neto and Soares, 1994). In the region of Nova Alta Paulista, Sao Paulo state, Konrad (2002) confirmed that the use of irrigation gives a better distribution of production, facilitating the flow of production and increasing the gross income of the producer up to 98% in relation to a non-irrigated crop.

1.6.1. Methods of irrigation

Acerola adapts well to the following methods of irrigation: conventional and sprinkling, jet, drip, sub-superficial drip, laser perforated hose and ditches. The choice of system of irrigation should take into account the availability of water, land topography, climate, soil and the financial resources of the producer. Irrigation by ditches may be used in locations with level topography, with limitations of water resources, and clay based soils. In medium to sandy soils, where there is a limitation of water resources, localized systems of irrigations (drip or jet) are best because water is used more efficiently. When using jet it is recommended to use one unit per plant and in dripping it is recommended to use four drippers per plant. In using laser perforated hoses one hose could be used for every two rows of plants, depending on row spacing.

Comparing different systems of irrigation for the acerola crop, Konrad (2002) concluded that there was no difference between the systems of irrigation concerning the composition of vitamin C and the quality of the fruits. Amongst the systems of irrigation evaluated, the laser perforated hose, drip and sub-superficial drip where those which produced the best results. Using one jet for two plants was not adequate for the crop.

1.6.2. Water requirements

The water requirements for the acerola shrub vary according to the climate, the size of the plants (leaf area and height), the frequency of irrigation and the percentage of soil surface wetted by irrigation. Water consumption tends to be greater in conditions of high evapo-transpiration demand, frequent irrigation and wetting of more than 60% of the soil surface.

In the climatic conditions of Ceará state, Martin Neto *et al.* (1998) observed values of evapo-transpiration of the acerola crop (ET_c) varying from 4.4 to

8.0 mm/d, with an average of 5.1 mm/d and an average crop coefficient (Kc) of 0.98. According to Konrad (2002) the use of a Kc value of 1.0 and a soil evaporation reduction coefficient (Kr) of 0.8 proved adequate for irrigation management of an acerola orchard in the production phase. Table 1.6 presents average values of ET_c and volume of water recommended for irrigation of mature acerola plants, as a function of evapo-transpiration in reference (ETo) to the local plantation.

In an experiment conducted in sandy soil of Paraipaba, Ceara state, using irrigation with jet emitters, Bandeira *et al.* (1998) applied average volumes of 21 to 27 L/plant/d to acerola plants at the start of production (two to three years old), obtaining an average production of 20 mt/ha. The authors did not observe significant differences in production between frequencies of irrigation varying from one to eight days.

Table 1.6. Values of evapo-transpiration of an acerola cultivar (ET_c) and volume of water to be applied per plant as a function of evapo-transpiration of reference (ET_o).

ET_o	ET_c	Volume of water[1]
mm/d	mm/d	L/plant/d
2.0	1.6	26
3.0	2.4	38
4.0	3.2	51
5.0	4.0	64
6.0	4.8	77
7.0	5.6	90

[1]Considering spacing between plants to be 4 x 4 m.

Source: Miranda, F. R. de., 2005; unpublished data.

1.6.3. Fertigation

The use of localized irrigation systems in acerola cultivation makes possible the application of fertilizers through the irrigation system (fertigation), which has as primary advantages the increased efficiency of fertilizers and the reduction of costs like labour and machinery used for its application. Fertigaion permits application of nutrients to the soil with a greater frequency, without increasing the cost of application, minimizing the losses by volatilization and leaching and optimizing uptake by the roots. Konrad (2002) showed a reduction in consumption of fertilizers of about 35% with fertigation, without a reduction in the productivity of the acerola.

The recommended procedures for the application of the fertilizers with the irrigation water consist of dividing the operation into three steps. In the first step the irrigation system operates only with water, until the pressure and discharge rate in all of the emitters is stabilized. In the second step the fertilizer solution is injected into the system. After injection, the irrigation system should operate with only water for about 20 or 30 minutes more, in order to remove all the fertilizer solution from the tubes.

1.7. References

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