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Capers and caperberries

G. O. Sozzi, Consejo Nacional de Investigaciones Científicas y Técnicas, Argentina, K. V. Peter, World Noni Research Foundation, India, K. Nirmal Babu, Indian Institute of Spices Research, India and M. Divakaran, Providence Women's College, Calicut, India

Abstract: This chapter on capers and caperberries gives a detailed account of the plant description, distribution, important cultivars, chemical composition, flavour volatile profiles, cultivation practices, reproductive biology, propagation, production technology, caper grading system and post-harvest technology. It also deals with its uses in food, processing, functional and health benefits, nutritional properties, health-promoting and therapeutic characteristics, quality issues and future trends.

Key words: *C. orientalis*, *C. sicula*, *C. spinosa*, caper bush, caperberries, *Capparis*, cultivation, flavour, glucosinolate, orchard establishment, pests and diseases, plant nutrition, postharvest technology; reproductive biology, volatile profiles.

10.1 Introduction

The caper bush (*Capparis spinosa* L., Capparidaceae) is a perennial winter-deciduous species that bears rounded, fleshy leaves and large white to pinkish white flowers. It is widespread in Mediterranean Europe, Africa, Asia and Australia. Its young flower buds, known as capers, are used for food seasoning, and different parts of the plant are used in the manufacture of medicines and cosmetics (Sozzi, 2001; Rivera *et al.*, 2003). The plant is also known for its fruit (caperberry) which are usually consumed pickled. Other species of *Capparis* are also picked along with *C. spinosa* for their buds or fruits (Bouriche *et al.*, 2011).

The economic importance of the caper plant led to a significant increase in both the area under cultivation and production levels during the late 1980s. The main production areas are in harsh environments found in Morocco, the south eastern Iberian peninsula, Turkey and the Italian islands of Pantelleria and Salina. The species has developed special mechanisms in order to survive in Mediterranean conditions, and introduction in semi-arid lands may help to prevent the disruption of the equilibrium of those fragile ecosystems. This drought-tolerant perennial plant has a favourable influence on the environment and it is utilized for landscaping and reducing erosion along highways, steep rocky slopes, sand dunes or fragile semi-arid ecosystems (Lozano Puche, 1977). The caper plant has low flammability and may

play a role in cutting down forest fires (Neyişçi, 1987). It favours rural economies in marginal lands in many Mediterranean countries and neighbouring regions: Turkey, Morocco, south eastern Spain, Italy (especially the Mediterranean island of Pantelleria, the Aeolian island of Salina, and Sicily), Tunisia, France (Provence), Greece, Algeria, Egypt, Asia Minor, Cyprus and the Levant. Whether the species is indigenous to the Mediterranean or not is still unknown (Zohary, 1960). Considerable genetic variation for the caper bush and its relatives exists, mainly in dry regions in west or central Asia. The genus *Capparis* could be of a subtropical or tropical origin later naturalized in the Mediterranean basin (Pugnaire, 1989).

The caper bush is a perennial shrub 30–50 cm tall. Its roots can be 6–10 m long (Reche Mármol, 1967) accounting for 65 % of the total biomass (Singh *et al.*, 1992). Caper canopy is made up of four to six radial decumbent branches from which many secondary stems grow. In wild bushes, Singh *et al.* (1992) observed up to 47 branches per plant. Branches are usually 2–3 m long. Stipular pale yellowish spines are often hooked and divaricate but sometimes weakly developed or absent. Leaves are alternate, 2–5 cm long, simple, ovate to elliptic, thick and glistening, with a rounded base and a mucronate, obtuse or emarginate apex. Flower bud appearance is continuous so that all transitional stages of development, from buds to fruit, can be observed simultaneously. The first ten nodes from the base are usually sterile and the following ten only partially fertile; the subsequent nodes have a caper each, almost to the tip of the stem. Flowers are hermaphroditic, 5–7 cm across, axillary and solitary, with purplish sepals and white petals. Stamens are numerous, with purplish filaments. The gynophores are approximately as long as the stamens. The ovary is superior, one-locular, with five to ten placentas. The fruit (caperberry) is ellipsoid, ovoid or obovoid, with a thin pericarp. The fruit bursts when ripe, exposing many seeds embedded in a pale crimson flesh. Seeds are 3–4 mm across, grey-brown and reniform. The embryo is spirally in-curved. Germination is epigaeal. A thousand seeds weigh 6–8 g (Gorini, 1981; Akgül and Özcan, 1999; Li Vigni and Melati, 1999).

The caper bush is the most important member of the Capparidaceae in economic terms. It has been suggested that *Capparis* and its relatives form a basal paraphyletic complex within the Brassicaceae group (Zomlefer, 1994; Judd *et al.*, 2007) on the basis of molecular (Rodman *et al.*, 1993) and morphological (Judd *et al.*, 1994) cladistic analyses. Taxonomists have long agreed that the caper family is very closely related to Brassicaceae based on some major shared characters, particularly the original bicarpellate ovary with parietal placentae, the vacuolar and utricular cysternae of the endoplasmic reticulum, the presence of myrosin cells and glucosinolate production. Species identification in the highly variable *Capparis* genus is difficult; the continuous flux of genes (Jiménez, 1987) throughout its evolution has made it hard to reach conclusions in the field of systematics. Besides, there have been divergent opinions concerning the rank assigned to the different taxa and to their subordination (Zohary, 1960; Jacobs, 1965; St. John, 1965; Bokhari and Hedge, 1975; Rao and Das, 1978; Higton and Akeroyd, 1991; Fici and Gianguzzi, 1997; Rivera *et al.*, 1999; Fici, 2001). *C. spinosa* is morphologically closely related to *C. orientalis* Duhamel and *C. sicula* Duhamel (Inocencio *et al.*, 2005), and some authors have included those taxa as belonging to *C. spinosa* (Higton and Akeroyd, 1991; Fici, 2001).

Identification and characterization of cultivars and species have traditionally been based on morphological and physiological traits. However, such traits are not always available for analysis and are affected by varying environmental conditions. Molecular marker technology offers several advantages over just the use of phenotypic traits. Molecular markers developed for *Capparis* are also a powerful tool for phylogenetic studies. Genetic variation in capers from Italy and Tunisia was estimated by means of random amplified polymorphic DNA techniques (Khouildi *et al.*, 2000). On the basis of amplified restriction fragment length polymorphism fingerprinting, Inocencio *et al.* (2005) suggested that *C. spinosa* could be a cultigen-derived form of *C. orientalis* with some introgression from *C. sicula*.

10.2 Chemical composition

A considerable body of literature exists on the phytochemical constituents of caper bush, capers and caperberries (reviewed by Sozzi, 2001). The chemical composition of capers and caperberries is affected by the genotype, harvest date, size, environmental conditions and preservation procedures (Nosti Vega and Castro Ramos, 1987; Rodrigo *et al.*, 1992; Özcan and Akgül, 1998; Özcan, 1999a, b; Inocencio *et al.*, 2000). Capers and caperberries are a good source of K, Ca, S, Mg, and P (Özcan, 2005) (Table 10.1). High salt brine treatments greatly affect their chemical composition. Protein and fibre, as well as mineral (Mg, K, Mn) and vitamin (thiamine, riboflavin, ascorbic acid), contents drop during preservation procedures, while ash increases due to the addition of NaCl.

Both capers and caperberries are rich in unsaturated fatty acids. Oleic, linoleic and linolenic acid represent 58–63.5 % of total fatty acids in flower buds (Nosti Vega

Table 10.1 Proximate composition of raw *Capparis spinosa* fruit and flower bud

Constituent	Fruits (caperberries) (%)	Flower buds (capers) (%)
Water (%)	79.6[A]; 82.7[B]	78.4[C]; 76.8–80.3[D]
Protein (%)	4.6[A]; 3.34[B]	6.31[C]; 4.59–6.79[D]
Lipid (fat) (%)	3.6[A]	0.47[C]; 1.51–1.77[D]
Carbohydrate (%)	3.2[A]	–
Fibre (%)	7.2[A]	2.0[C]; 4.5–5.9[D]
Ash (%)	1.8[A]	1.7[C]; 1.33–1.84[D]
Rutin (%)	–	0.28[C]
Minerals		
Calcium (mg/100 g)	28[A]	183[C]; 49–134[D]
Iron (mg/100 g)	0.9[A]; 0.54[B]	1.37[C]; 0.9–2.1[D]
Magnesium (mg/100 g)	39[A]	57[C]; 46.9–81.1[D]
Manganese (mg/100 g)	0.72[B]	0.29[C]
Phosphorus (mg/100 g)	116.8[B]	103.6[C]; 16.6–26.4[D]
Potassium (mg/100 g)	383[A]; 326.9[B]	504.9[C]; 502.4–598.3[D]
Sodium (mg/100 g)	18[A]; 12.1[B]	5.9[C]; 19–28.5[D]
Vitamins		
Ascorbic acid (mg/100 g)	23[A]	26[E]
Thiamine (mg/100 g)	0.69[A]	0.7[C]
Riboflavin (mg/100 g)	–	0.22[C]

Sources: [A]Brand and Cherikoff (1985); [B]Özcan (1999b); [C]Nosti Vega and Castro Ramos (1987); [D]Rodrigo *et al.* (1992); [E]Lemmi Cena and Rovesti (1979).

and Castro Ramos, 1987; Rodrigo *et al.*, 1992) and 73 % in fruit (Özcan, 1999b). The oil content of the seeds ranges from 27.3–37.6 % in *C. spinosa* and from 14.6–38.0 % in *C. ovata*, linoleic being the main fatty acid in both species (25–50 %; Matthäus and Özcan, 2005). These authors found that seed oils show high contents of Δ^5-avenasterol (138.8–599.4 mg/kg); this compound has been suggested as an antioxidant and antipolymerization agent in cooking oils.

Capers are a good source of natural antioxidants. Antioxidant effectiveness of caper methanolic extracts is conserved even after removal of glucosinolates, thus suggesting that the radical scavenging properties of capers are mainly due to other metabolites such as phenolic compounds and flavonoids (Germanò *et al.*, 2002) (Table 10.1): rutin (quercetin 3-rutinoside), quercetin 7-rutinoside, quercetin 3-glucoside-7-rhamnoside, kaempferol-3-rutinoside, kaempferol-3-glucoside, and kaempferol-3-rhamnorutinoside (Rochleder and Hlasiwetz, 1852; Zwenger and Dronke, 1862; Ahmed *et al.*, 1972a; Tomás and Ferreres, 1976a, b; Ferreres and Tomás, 1978; Artemeva *et al.*, 1981; Rodrigo *et al.*, 1992; Sharaf *et al.*, 1997; Inocencio *et al.*, 2000). Rutin and kaempferol-3-rutinoside are probably the most abundant flavonoids, followed by kaempferol-3-rhamnorutinoside in significantly lower concentrations (Rodrigo *et al.*, 1992; Sharaf *et al.*, 1997). Sharaf *et al.* (2000) identified a quercetin triglycoside (quercetin 3-*O*-[6‴-α-L-rhamnosyl-6″-β-D-glucosyl]-β-D-glucoside) in methanolic extract of the aerial part of the caper bush. Two different 1*H*-indole-3-acetonitrile glycosides, as well as (6*S*)-hydroxy3-oxo-α-ionol glucosides, have been isolated in methanolic extracts of caperberries (Çaliş *et al.*, 1999, 2002). Total flavonoids are greatly variable (1.82–7.85 mg/g) (Inocencio *et al.*, 2000). A serving of capers (10 g) will provide 65 mg flavonoid glycosides or its equivalent, 40 mg quercetin as aglycone (Inocencio *et al.*, 2000).

Capers are rich in glucosinolates whose hydrolysis to glucose, sulphuric acid and isothiocyanates is catalyzed by the enzyme myrosinase. Guignard (1893b) first reported the presence of this enzyme in *C. spinosa*. Isothiocyanates are well known for the important role they play in plant defence mechanisms, and also in human health as cancer-preventing agents (Verhoeven *et al.*, 1997). The high levels of glucosinolates found in caper buds are only comparable with those of Brussels sprouts; other widely-consumed glucosinolate-containing vegetables such as cabbage or broccoli show lower amounts (Matthäus and Özcan, 2002). Brassicaceae are usually considered a major source of glucosinolates (Kjoer, 1963; Kjoer and Thomsen, 1963; Rosa *et al.*, 1997). The presence of glucosinolates is synapomorphic for members of this family and lends additional support to the new phylogenetic classification (Judd *et al.*, 2007). In fact, the conclusion that Capparidaceae and Brassicaceae should remain together, based on the presence of glucosinolates, was drawn over 50 years ago (Hegnauer, 1961; Kjoer, 1963).

Methyl glucosinolate (glucocapparin) is the most common glucosinolate in the *Capparis* genus (Ahmed *et al.*, 1972b). Moreover, it accounts for 90 % of the total glucosinolates in *C. spinosa* buds (Matthäus and Özcan, 2002). Nevertheless, other glucosinolates have also been detected in and isolated from caper plants. Those include 2-propenyl glucosinolate (sinigrin), 3-methylsulfinylpropyl glucosinolate (glucoiberin), indol-3-ylmethyl glucosinolate (glucobrassicin), and 1-methoxyindol-3-ylmethyl glucosinolate (neoglucobrassicin) (Ahmed *et al.*, 1972a; Matthäus and Özcan, 2002). There are qualitative and quantitative differences in glucosinolate

composition in different caper tissues (Schraudolf, 1989; Matthäus and Özcan, 2002), as happens with most glucosinolate-containing species (Rosa *et al.*, 1997). Methyl glucosinolate was reported to be present at levels in the range of 38–268 mg/kg in capers treated with dry salt, brine or oil (Sannino *et al.*, 1991). Interference in the determination of dithiocarbamate residues in capers has been reported and seems to be due to the presence of methyl glucosinolate (Sannino *et al.*, 1991). However, thiocyanates and isothiocyanates (odoriferous breakdown products of glucosinolates), as well as other volatile compounds, do not interfere in those pesticide tests (Brevard *et al.*, 1992).

The flavour volatile profile of capers is complex. Analysis of the volatiles present in the pickled flower buds indicated at least 160 different components (Brevard *et al.*, 1992). The nature of the volatiles involved is also very diverse and includes esters, aldehydes, alcohols and other chemical groups. Elemental sulphur (S_8) was identified in the volatile fraction of capers, in addition to sulphur-containing compounds (e.g., thiocyanates and isothiocyanates) and raspberry-like components (α-ionone, β-ionone, frambinone, zingerone). Also, the main constituents of the caperberry volatile oil are isopropyl isothiocyanate (~52 %) and methyl isothiocyanate (~42 %) (Afsharypuor *et al.*, 1998).

10.3 Cultivation of capers and caperberries

10.3.1 Environmental requirements

The caper bush requires a semi-arid climate. Mean annual temperatures in areas under cultivation are over 14 °C and rainfall varies from 200 mm/year in Spain to 460 in Pantelleria Island and 680 in Salina Island (Barbera, 1991). The caper bush can withstand strong winds and temperatures over 40 °C in summer, but it is sensitive to frost during its vegetative period. It survives low temperatures and has been found at 1000 m above sea level in the foothills of the Alps, although it is usually grown at lower altitudes (Barbera *et al.*, 1991).

The caper bush is a rupiculous species adapted to xeric areas. It is widespread on rocky areas and is grown on different soil associations, including alfisols, regosols and lithosols (Barbera, 1991; Fici and Gianguzzi, 1997). In different Himalayan and trans-Himalayan locations, *C. spinosa* tolerates both silty clay and sandy, rocky or gravelly surface soils, with less than 1 % organic matter (Ahmed, 1986; Kala and Mathur, 2002). It grows on bare rocks, crevices, cracks and sand dunes in Pakistan (Ahmed and Qadir, 1976), the Adriatic region (Lovric, 1993) and Egypt, Libya and Tunisia (Ayyad and Ghabbour, 1993), in transitional zones between the littoral salt marsh and the coastal deserts of the Asian Red Sea coast (Zahran, 1993), in the rocky arid bottoms of the Jordan valley (Turrill, 1953), in calcareous sandstone cliffs at Ramat Aviv, Israel (Randall, 1993) and in coastal dunes of Australia (Specht, 1993) and Israel (Levin and Ben-Dor, 2004). It also grows spontaneously in wall joints of buildings, antique constructions and monuments (Sozzi, 2001, and references cited therein).

Deep and well-drained soils with sandy to sandy-loam textures are favoured (Barbera and Di Lorenzo, 1982, 1984; Ahmed, 1986; Özdemir and Öztürk, 1996), although caper bush adapts to calcareous accumulations or moderate percentages

of clay (González Soler, 1973). It shows a good response to volcanic (Barbera and Di Lorenzo, 1982) or gypseous soils (Font Quer, 1962) but is sensitive to poorly drained soils. Soil pH between 7.5 and 8 is optimum (Gorini, 1981), although pH values from 6.1 to 8.5 are tolerated (Duke and Terrel, 1974; Duke and Hurst, 1975; Ahmed, 1986). The caper bush is usually not considered to be a halophyte, but it has been detected in the loamy solonchacks of the coastal lowlands of Bahrain, where the conductivity may reach 54 dS/m (Abbas and El-Oqlah, 1992).

Aerosols from sea-water-fed cooling towers produced leaf chlorosis or necrosis, probably due to chloride toxicity (Polizzi *et al.*, 1995). In contrast, caper bush withstands chronic levels of some other toxic gaseous pollutants. Krishnamurthy *et al.* (1994) reported an unusual 93 % retention of leaves when caper bush was exposed to a mixture of sulphur dioxide, oxides of nitrogen, ammonia and suspended particulate matter, although the photosynthetic area per leaf was reduced by 61 % and the fresh weight by 67 %.

The caper bush has developed a series of features and mechanisms that reduce the impact of high radiation levels, high daily temperature and insufficient soil water during its growing period (Rhizopoulou, 1990; Levizou *et al.*, 2004). *C. spinosa* has devolved a very effective system to offset limited water resources (deep roots and highly conductive wood). It is a stenohydric plant (Rhizopoulou *et al.*, 1997) with a highly specialized conducting tissue (Psaras and Sofroniou, 1999) and also thick amphistomatous and homobaric leaves bearing a multi-layered mesophyll, thick outermost epidermal cell walls and small leaf intercellular cell space percentage (Rhizopoulou and Psaras, 2003). Levizou *et al.* (2004) found that *C. spinosa* assimilates up to 3.4 times more CO_2 per m^2 during its growth period than other species in Mediterranean ecosystems. Caper bush also displays characteristics of a plant adapted to poor soils (Pugnaire and Esteban, 1991). Its high root/shoot ratio and the presence of mycorrhizae serve to maximize the uptake of minerals in poor soils. Different N_2-fixing bacterial strains have been isolated from the caper bush rhizosphere playing a role in maintaining high reserves of that growth-limiting element (Andrade *et al.*, 1997).

10.3.2 Reproductive biology

Caper bush is a perennial plant with a relatively short juvenile period. The biotype Mallorquina can yield 1 kg/plant in the second year of cultivated growth. Temperature is the main environmental factor affecting caper bush flowering. A positive correlation between temperature and productivity has been observed (Luna Lorente and Pérez Vicente, 1985). Fertility of the nodes is maximum (close to 100 %) during the hottest periods and lower at the beginning and end of the season (Barbera *et al.*, 1991). *C. spinosa* is night flowering (Petanidou *et al.*, 1996). The white petals open concomitantly with increasing relative humidity and declining temperature and exposure to sunlight (Rhizopoulou *et al.*, 2006). It blossoms for approximately 16 hours, from *c.* 18:00 h to *c.* 10:00 h the next morning (Ivri, 1985; Petanidou *et al.*, 1996) and most nectar secretion is nocturnal.

Caper flowers attract different insects, among them hawk-moths and bees (Kislev *et al.*, 1972; Eisikowitch *et al.*, 1986; Dafni *et al.*, 1987; Dafni and Shmida, 1996). In Greece, flowers are mainly pollinated by bees (Petanidou, 1991). *C. spinosa* has not

evolved specific mechanisms to prevent self-pollination. Nevertheless, the flower architecture, anthesis, colour and odour indicate that self-pollination is not regularly found in caper bush. *C. spinosa* is an important nectar source for pollinators in semi-arid ecosystems (Eisikowitch *et al.*, 1986), since it grows and flowers entirely during the most stressful period of the year, when the surrounding flora exhibits minimum growth rates. This performance provides *C. spinosa* with a competitive advantage against other species (Rhizopoulou *et al.*, 2006). Flower reward in genus *Capparis* is affected by the location and year (Petanidou *et al.*, 1996) and differs significantly among taxa. *C. aegyptia* has a higher pollen grain weight and its nectar is richer in total amino acids (Eisikowitch *et al.*, 1986). On the other hand, higher nectar concentration and volume are found in *C. ovata* (Eisikowitch *et al.*, 1986; Dafni *et al.*, 1987). Amino acid content and concentration, as well as hexose concentration, increase with flower age while sucrose concentration decreases (Petanidou *et al.*, 1996).

The juicy fruit is consumed by birds (Seidemann, 1970; Danin, 1983) like *Sylvia conspicillata*, *Oenanthe leucura* (Hódar, 1994) and *Chlamydotis* (*undulata*) *macqueenii* (van Heezik and Seddon, 1999) that disperse the seeds. Harvester ants (Luna Lorente and Pérez Vicente, 1985; Li Vigni and Melati, 1999) and lizards like *Lacerta lepida* (Hódar *et al.*, 1996) feed on the fruit and carry off fragments together with the hardcoated seeds. Wasps are attracted by mature caperberry scent and also act as dispersal agents (Li Vigni and Melati, 1999).

10.3.3 Propagation

Caper bush yields a large amount of seeds per generative shoot. Poor caper seed germination performance has been observed in Argentina (Sozzi and Chiesa, 1995), Armenia (Ziroyan, 1980), Cyprus (Orphanos, 1983), India (Singh *et al.*, 1992), Italy (Cappelletti, 1946; Barbera and Di Lorenzo, 1984; Macchia and Casano, 1993), Spain (Reche Mármol, 1967; Luna Lorente and Pérez Vicente, 1985; Pascual *et al.*, 2003, 2004), Turkey (Yildirim, 1998; Söyler and Arslan, 1999; Tansi, 1999) and the USA (Stromme, 1988; Bond, 1990). However, caper bush propagation is usually carried out by seed owing to the serious rooting problems associated with cuttings. Low germination percentages (5–15 %) are obtained within 2–3 months of seeding. Different treatments have been used to improve the germination percentage, including mechanical scarification (sand paper, ultrasound, etc.), stratification, soaking in concentrated H_2SO_4 or H_2O_2, or in 0.2 % $KMnO_4$, 0.2 % KNO_3, gibberellin (GA_4+7) or gibberellic acid (GA_3) aqueous solutions, and manipulation of the environmental conditions (light/dark, temperature) (Reche Mármol, 1967; Ministerio de Agricultura, 1980; Orphanos, 1983; Singh *et al.*, 1992; Macchia and Casano, 1993; Sozzi and Chiesa, 1995; Yildirim, 1998; Söyler and Arslan, 1999; Tansi, 1999). A soaking period of 30 days or longer enhances seed germination: final germination values range from 95–99 %, reducing the time to reach 50 % of final germination and consequently the duration of germination tests (Pascual *et al.*, 2009).

Caper seed germination depends on the covering structures (Sozzi and Chiesa, 1995). The seed of the genus *Capparis* is bitegmic (Corner, 1976). The testa is 0.2–0.3 mm thick, with all its cell walls somewhat lignified; its tegmen consists of an outer fibrous, lignified layer four to ten cells thick, with a lignified endotegmen

composed of contiguous cuboid cells, with strongly thickened radial walls. Only the mesophyll between exo- and endotegmen is unlignified (Guignard, 1893a; Corner, 1976). As the integrity of the covering structures is very important for dormancy persistence in caper seeds, the seed coats are very likely to be the main cause for the seed low germination rate (Sozzi and Chiesa, 1995). A physiological dormancy could also explain the response to GA_3 (Pascual *et al.*, 2004). Nevertheless, the viable embryos germinate within 3–4 days after partial removal of the lignified seed coats (Sozzi and Chiesa, 1995), while GA_3-treated seeds germinate within 20–70 days (Pascual *et al.*, 2004).

The seed coats and the mucilage surrounding the seeds may be ecological adaptations to avoid water loss and conserve seed viability during the dry season (Scialabba *et al.*, 1995). Seeds lie without order in the pericarp, each of them surrounded by an adherent layer of pulp. They can be obtained by rubbing and washing followed by drying in the shade. Large or medium-size fruits set in the central or apical region of the stems are adequate sources of dull brown mature seeds (Pascual *et al.*, 2003). Those seeds are over 90 % viable (Orphanos, 1983; Sozzi and Chiesa, 1995; Tansi, 1999) for 2 years if held at 4 °C and low relative humidity. Seeds obtained from small not-yet-opened fruits are generally light brown and immature. The final germination percentage is also affected by fruit position on the plant and fruit weight (Pascual *et al.*, 2003). Commercial lots of seed are usually pre-germinated in February or March in boxes or bins (Luna Lorente and Pérez Vicente, 1985). Seeds are packed in moist river sand, or compost made of two parts turfy loam and one part leaf mould and sand, or in mixtures with vermiculite or perlite (Foster and Louden, 1980; Kontaxis, 1989). Small lots can be pre-germinated in boxes; moderate to large lots are usually pre-germinated in bins located in a protected place. Two to four layers of seed are packed in each bin and covered with a sand layer. Seeds are sprinkled with water and treated with captan or captafol. Sprouted seeds are obtained and planted after 25–50 days. After proper cultivating, seeds (1.5–2 g/m) are planted about 1.5 cm deep, in rows 30 or 40 cm apart. Yields of 45–50 seedlings per metre may be obtained after 30 days.

Caper bush is a difficult-to-root woody species and successful propagation requires careful consideration of biotypes and seasonal and environmental parameters. Rooting percentages up to 55 are possible when using 1-year-old wood, depending on cutting harvest time and substrate utilized (Pilone, 1990a). Propagation from stem cuttings is the standard method for growing 'Mallorquina' and 'Italiana' in Spain and 'Nocella' in Salina. Hardwood cuttings vary in length from 15–50 cm and the diameter of the cuttings may range from 1–2.5 cm. Another possibility is to collect stems during February through the beginning of March, treat them with captan or captafol and stratify them outdoors or in a chamber at 3–4 °C, covered with sand or plastic. Moisture content and drainage should be carefully monitored and maintained until planting (Luna Lorente and Pérez Vicente, 1985). Softwood cuttings are prepared from 25- to 30-day shoots, each cutting containing at least two nodes. Cuttings are planted in a greenhouse under a mist system with bottom heat; 150–200 cuttings m^{-2} may be planted. Dipping the cutting basal end into 1500–3000 mg/l auxin solution may enhance rooting (Pilone, 1990b), but results depend on the type of cutting. Hardwood cuttings do not seem to respond to indole-3-butyric acid or α-naphthaleneacetic acid (NAA) pre-treatments. On the other

hand, dipping the herbaceous cutting base in a 2000 ppm NAA yielded rooting percentages of 83 % (Luna Lorente and Pérez Vicente, 1985).

Successful *in vitro* culture was achieved from nodal shoot segments. 6-benzylaminopurine stimulated proliferation and shoot development; when combined with indoleacetic acid (IAA) and GA_3, formation of proliferating clusters was enhanced (Rodríguez *et al.*, 1990). High rooting response was obtained by using 30 μM IAA (Rodríguez *et al.*, 1990). The presence of abnormal vitrified shoots was observed in some cases and could be prevented by means of alternate culture in cytokinin-enriched and hormone-free media, or normalized by using sucrose-enriched medium (Safrazbekyan *et al.*, 1990). Because of the difficulties of caper bush conventional propagation, micropropagation may be a promising alternative technique. Micropropagation of caper has been standardized by Chalak *et al.* (2003) and Carra *et al.* (2007) with a high rooting percentage. Grafting is a less common method of propagation for caper bush. In Spain, acceptable results (60 % scion take) were obtained using bark grafting in plantings. Nurseries generally whip-graft with survival rates of 70–75 % (Luna Lorente and Pérez Vicente, 1985).

10.3.4 Orchard establishment

Caper plantings over 25–30 years old are still productive. Thus, physical properties of the soil (texture and depth) are particularly important. Mouldboard ploughing and harrowing are usual practices prior to caper plant establishment (Luna Lorente and Pérez Vicente, 1985). Soil-profile modification practices, such as slip ploughing operating 0.6–1 m deep, can ameliorate some restrictions (Massa Moreno, 1987).

In Pantelleria, digging backhoe pits for each shrub was found to be the most effective means of cultivating caper in rocky soils (Barbera, 1991). Two planting designs are used: square/rectangle and hedgerow system. Spacing is determined by the vigour of the biotype, fertility of the soil, equipment to be used and the irrigation method, if any. Bush spacing of 2.5 × 2.5 m (Barbera and Di Lorenzo, 1982) or 2.5 × 2 m (Bounous and Barone, 1989) is common in Pantelleria. In Salina, 3 × 3 m is satisfactory for 'Nocella'. In Spain, 4 × 4 or 5 × 5 m is satisfactory for 'Mallorquina'. Spacing of 2–2.5 m is appropriate if *C. spinosa* is used to control soil erosion on slopes.

Nursery plants, propagated as seedlings or rooted cuttings, are dug in the nursery row during the dormant season. Caper bush may be transplanted either bare-root or containerized. Most plants are handled bare-root and replanted immediately in their permanent location or heeled-in in a convenient place with the roots well covered. Containerized plants are used only where lack of irrigation is the chief factor limiting transplanting success.

10.3.5 Pruning and trellising

Caper bush is usually dormant pruned. After removal of dead tissue, it must be pruned of weak, non-productive wood and water sprouts. The caper bush benefits from a short and heavy spur pruning which reduces branches to a length of 1–3 cm or 5–10 cm when the plant is young and vigorous (Barbera and Di Lorenzo, 1982, 1984; Luna Lorente and Pérez Vicente, 1985). It is important to leave several buds

on the spur as only the 1-year-old stems will bear flower buds for the current season. Early summer pruning involves thinning out weak stems when the caper bush is in active shoot growth, 30–40 days after budding. Summer pruning also involves heading back a few of the new shoots to induce flower bud formation.

If the caper plants could be trellised rather than allowed to sprawl on the ground, picking and management would be easier (Trewartha and Trewartha, 2005). The choice of a caper-support method is an economic decision. Trellising would keep plants off the ground, increase usable space and lessen harvest difficulties. The primary disadvantages of all trellis systems are the high cost of establishment and the necessary commitment to extensive, detailed canopy manipulations.

10.3.6 Plant nutrition

Fertilization should begin 20–30 days before planting. At that time, 100 kg/ha ammonium sulphate, 400 kg/ha single superphosphate and 150 kg/ha potassium chloride have been suggested in Spain (Massa Moreno, 1987). Fertilizers may be broadcast on the surface and incorporated by tilling or cultivating, or applied in a surface band. In Pantelleria, plots are enriched with organic or inorganic fertilizers applied to the backhoe pits (Barbera, 1991).

The types of fertilizer used and application rates should be related to plant age and soil nutrient content (Sozzi, 2001). Measurement of the total concentration of a nutrient in the plant and extraction of different elements from soil are useful to diagnose mineral deficiencies (Sozzi, 2001). Phosphate and potassium fertilizers are generally applied every 2–3 years. Instead, ammonium fertilizers are incorporated annually into the soil, late in winter before sprouting. In Pantelleria and Salina, N–P–K fertilizers are applied during winter (December and January) at a rate of 200–300 g/plant (Barbera and Di Lorenzo, 1982; Barbera, 1991). Bounous and Barone (1989) suggested that fertilizations with 150–200 kg/ha of ammonium sulphate and additional P–K applications would be appropriate for mature plantings.

10.3.7 Irrigation

Caper bush is cultivated mostly in poorly-irrigated soil. Irrigation is, however, specially important during the first year when the caper bush is highly sensitive to water stress. In Pantelleria and Salina, irrigation is impossible due to the lack of water (Barbera and Di Lorenzo, 1984). Nevertheless, a type of mulching – which may include placing stones around the young plants – is utilized to protect them from wind action and thus reduce evaporation. In Spain and Argentina, additional water is usually provided during the first year. The caper bush shows its productive potential under irrigation (longer vegetative cycle, larger bud production that begins earlier and shorter intervals between harvests), although the plant tends to be more prone to diseases (Jiménez Viudez, 1987). In Spain, irrigation begins in January when caper bush is grown with almond trees, or in February or March when grown alone, and it ends in August in either case (Jiménez Viudez, 1987). Yields were doubled and even tripled when irrigation was used in Almería (it rains 96 mm from February through August), Jaén (284 mm) and Murcia (156 mm). In 1984, the

average yield in Spain was 1365 kg/ha in irrigated plantings and 650 kg/ha in non-irrigated plantings (Ministerio de Agricultura, Pesca y Alimentación, 1989). In 1988, 837 ha were irrigated in Almería, Murcia, and Jaén (Ministerio de Agricultura, Pesca y Alimentación, 1988). In 1995, only 41 ha (mainly in Murcia, Córdoba and Valencia) were still under irrigation due to the increasing competition from caper grown in Turkey and Morocco (Ministerio de Agricultura, Pesca y Alimentación, 1997). A point source sprinkler system may be utilized. Total volumes of 12–140 l/plant week, depending on the climatic conditions, are supplied under irrigation (Jiménez Viudez, 1987).

10.4 Pests and diseases

C. spinosa is not very sensitive to pest damage when growing wild. Nevertheless, some phytophagous species attack caper in its main production areas. Insecticide treatments are restricted by the short interval between harvests (7–10 days): only low-persistence active principles can be used.

In Pantelleria, the caper moth (*Capparimyia savastanoi* Mart.) and the caper bug (*Bagrada hilaris* Bm.) are considered the most important pests. The control of caper moth relies on the removal of infested leaves, combined with the use of poisoned hydrolyzed protein baits in summer when populations are high (Longo and Siscaro, 1989; Longo, 1996). The caper bug was first found on wild plants (Carapezza, 1981) and, later on, attacking cultivated caper plantings (Genduso, 1990). The pale creamy oval eggs, which turn to orange as the insect develops (Mineo and Lo Verde, 1991), are laid singly on the ground, in the cracks of the bordering field walls and, more rarely, on the leaves. At the beginning of spring it attacks different wild plants, among them caper bush which grows weak and rapidly yellows. Pyrethroid formulations are used to control this insect. The chemicals are applied either to the walls or to the plants after harvest is finished (Barbera, 1991). The painted bug (*Bagrada picta* Fabr.; Pentatomidae) is a pest of cruciferous oilseed crops and has been reported to thrive on caper bush at Tandojam during summer (Mahar, 1973).

The larval form of the weevil *Acalles barbarus* Lucas causes damage to the root system (Liotta, 1977). In general, its targets are weak adult plants previously affected by other insects. The only effective control is the removal of the attacked plants. Other insect pests in Italy are *Phyllotreta latevittata* Kutsch (Chrysomelidae) which causes oval to round erosions in leaves, leaf yellowing and stem decay, and *Asphondylia spp.* (Cecidomyiidae) and *Cydia capparidana* Zeller (Tortricidae) which alter the morphology of buds (Harris, 1975; Orphanides, 1975, 1976). The braconid *Chelonus elaeaphilus* Silv., a promising parasite of *Prays oleae* (an olive pest), was also recovered from *C. capparidana* infesting caper bush (Fimiani, 1978). Rapisarda (1984–5) reported the occurrence of *Aleurolobus niloticus* Priesner & Hosny (Aleyrodidae), a polyphagous species that feeds only on caper bush leaves in Sicily.

Caper bush is the only larval host plant available in southern Spain during the dry season for different Pieridae: cabbage small white (*Pieris rapae* L.) and large

white (*Pieris brassicae* L.) butterflies, and desert orange tip (*Colotis evagore* Klug.) (Fernández García, 1988; Jordano *et al.*, 1991). *P. rapae* also attacks in California (Kontaxis, 1990) and in the Badkhyzskii Reserve, Turkmen (Murzin, 1986). The larvae of *P. rapae* and *P. brassicae* usually use cruciferous plants in the rainy season and caper bush in summer when Brassicaceae are dry (Fernández García, 1988). Oviposition takes place preferentially on the ground or on dried material around the host plant. *C.evagore* larvae are unable to survive on alternative cruciferous hosts (Jordano and Retamosa, 1988; Jordano *et al.*, 1991), but they complete their lifecycle successfully in certain coastal enclaves where caper bush provides sufficient resources throughout the year. The adult lays red eggs singly, on young leaves, stems and inert supports next to the food plant (Fernández *et al.*, 1986; Fernández Haeger and Jordano Barbudo, 1986).

Caper bush and other related species are also the commonest food plants of other *Pieridae* in Saudi Arabia, such as *Anaphaeis aurota* F., *Colotis fausta fausta* Olivier and *Colotis liagore* Klug. (Pittaway, 1979, 1980, 1981, 1985). These species deposit the eggs on isolated bushes in rocky scarps and cliffs. Eventually, caper plants may be completely stripped of foliage, the resulting bare branches carrying pupae and larvae. Pyrethroids can be used to control all of these *Pieridae* pests (Massa Moreno and Luna Lorente, 1985). Larvae of *Lampides boeticus* L. (Lycaenidae), which have anthophagous and carpophagous habits, have also been found to feed on caper buds (Jordano Barbudo *et al.*, 1988).

The pentatomid bug *Eurydema ornata* L. attacks caper bush leaves and may cause serious damage (Fernández *et al.*, 1986). The green stink bug *Nezara viridula* L. has caused some damage in Spain and Argentina. All these Hemiptera can be controlled by using trichlorfon, endosulphan, dimethoate or chlorpyriphos. Other insect pests detected in caper include *Ceuthorhynchus* sp. (*Curculionidae*) and *Heliothis-Helicoverpa* (Noctuidae). Many ant species (*Camponotus* spp., *Plagiolepis pygmaea*, *Crematogaster auberti*, *C. sordidula*, *Formica subrufa*, *Tetramonium hispanica* and *Cataglyphis viaticoides*) have been found feeding on caper plants (Fernández *et al.*, 1986). In California, caper bush can be damaged by cabbageworm, black vine weevil and flea beetle, as well as gophers, snails and slugs (Kontaxis, 1998).

Damping-off diseases, caused by several fungi (*Pythium* spp., *Fusarium* spp. *Verticillium* spp., etc.), may be severe. Frequently, caper seedlings are completely destroyed either when they are placed in seedbeds or after being transplanted. Seedlings are usually attacked at the roots or in the stems at or below the soil line, and the invaded areas soon collapse. These diseases can be controlled through the use of sterilized soil and chemically treated seeds.

The most important fungus attacking caper leaves and flowers is probably the white rust disease (*Albugo capparidis* De By.). A list of fungi affecting caper bush was given by Ciferri (1949). *Neoramularia capparidis* spec. nov. produces small greyish white leaf spots with narrow brown margin in India (Bagyanarayana *et al.*, 1994). Caper bush is also a host of *Leveillula taurica* (Lev.) G. Arnaud, causal agent of the powdery mildew (Gupta and Bhardwaj, 1998; Kavac, 2004). Caper plants were reported to have been infected with *Botrytis* spp. and *Pythium* spp. in California (Kontaxis, 1990). A caper vein banding virus (CapVbV) was reported in Sicily and was tentatively assigned to the carlavirus group (Majorana, 1970). Gallitelli and Di Franco (1987) showed that this virus infects caper plant symptomlessly and

suggested the name caper latent virus (CapLV, genus *Carlaviruses*, family Flexiviridae). The real causal agent of vein banding may be a rhabdovirus, the caper vein yellowing virus (CapVYV), that may infect caper bush simultaneously to the CapLV (Di Franco and Gallitelli, 1985). New serological tests have shown that CapVYV is indistinguishable from the pittosporum vein yellowing virus (PVYV, genus *Nucleorhabdovirus*, family Rhabdoviridae) (Nuzzaci *et al.*, 1993). *C. spinosa* is also a natural host of the cucumber mosaic virus (CMV, genus *Cucumovirus*, family Bromoviridae) (Tomassoli *et al.*, 2005).

10.5 Main cultivars and world production and trade

10.5.1 Main cultivars

The commercial product known as 'caper' is actually being obtained from different species (*C. spinosa*, *C. orientalis*, *C. sicula*, etc.) with intermediate biotypes and similar genetic background (Inocencio *et al.*, 2005). This fact complicates quality control and challenges researchers to develop new simple methods to discriminate different cultivars or species (Inocencio *et al.*, 2002). The main caper germplasm collections are located in Italy and Spain.

Many biotypes have been chosen by growers owing to some advantageous characteristics. Features of interest in caper bush improvement programmes are: (i) high productivity (long stems, short internodes and high node fertility, short and uniform flowering periods); (ii) deep green spherical flower buds, with close non-pubescent bracts and late opening; (iii) absence of stipular spines and easy stalk separation to simplify harvest and post-harvest operations; (iv) processed product with an agreeable appearance; (v) capacity for agamic reproduction; (vi) resistance to water stress, cold and pests; (vii) oval fruit with light green pericarp and few seeds; (viii) thick and tender stem tip (food use).

Caper biotypes are commonly referred to as *C. spinosa*, but many of them belong to other taxa (Inocencio *et al.*, 2005). The most attractive Italian commercial biotypes are 'Nocellara' or 'Nuciddara' (a cultivar within *C. orientalis*) and 'Nocella' or 'Nuccida' (Barbera *et al.*, 1991; Fici and Gianguzzi, 1997). Both are highly productive and yield high-quality capers (almost spherical shape, mustard green colour, strong aroma and conserved integrity after brining). 'Nocellara' does not bear spines and 'Nocella' has very small harmless ones. On the other hand, 'Nocella' does not resist drought. Other Italian biotypes are 'Senza spine' and 'Inermis' – Italian selection forms, without stipular spines –, 'Ciavulara' (Barbera *et al.*, 1991; Fici and Gianguzzi, 1997), 'Testa di lucertola' (Barbera *et al.*, 1991), 'Spinoso di Pantelleria' (Barbera *et al.*, 1991; Fici and Gianguzzi, 1997) and 'Spinosa comune' or 'Spinoso di Salina' (a cultivar within *C. sicula* subsp. *sicula*; Barbera *et al.*, 1991; Fici and Gianguzzi, 1997; Rivera *et al.*, 2003).

'Ciavulara' is less productive and its buds tend to open precociously; capers are flatter and flake easily during post-harvest treatments, giving a poor aspect to the final product. 'Testa di lucertola' ('Lizard's head') produces capers with a lengthened pyramid shape. 'Spinoso of Pantelleria' and 'Spinoso of Salina' have conspicuous axillary spines. In 'Spinoso of Pantelleria', the leaf tips also bear a small thorn. 'Spinoso of Salina' is less productive; its capers are flattened pyramidal and tend to

flake during post-harvest curing. Other Italian biotypes are 'Tondino' (Caccetta, 1985), grown in Pantelleria and Salina, 'Aculeata' and 'Dolce di Filicudi e Alicudi' (Alkire, 2001). A complete description of all cultivars can be found elsewhere (Rivera *et al.*, 2003).

The most important Spanish biotypes are 'Común' or 'del País' and 'Mallorquina' (Luna Lorente and Pérez Vicente, 1985; Rivera *et al.*, 1999). 'Común' is a heterogeneous population with spiny stems which dry out completely in winter. 'Mallorquina' has long spiny stems, bright green leaves and small seedy fruit. 'Mallorquina' is highly productive, presents a vigorous growth and has extraordinary yields under irrigation. Other biotypes within *C. spinosa* are cultivated to a lesser extent in the Balearic Islands: 'Redona', 'Roses', 'De las Muradas', 'Figues Seques' and 'Peluda' (Rivera *et al.*, 1999). 'Redona' is a spiny but highly productive biotype, yielding high-quality capers. On the other hand, 'Fulla Redona' is a biotype within *C. orientalis*, with no spines. It is considered a promising biotype by the quality and quantity of its produce.

10.5.2 World production and yield

The economic importance of the caper bush led to a significant increase in both the area being cultivated and production levels during the late 1980s. Global trade in capers involves around 60 countries, and the average annual production is estimated to be around 10000 t: 3500–4500 t are produced in Turkey, 3000 t in Morocco, 500–1000 t in Spain and 1000–2000 t in other countries. Turkey is the leading caper-exporting country. The USA was one of the most important caper consumers during the 1990s. Harvest represents two-third of the total labour in the crop management process as it is done manually, and it is time-consuming due to: (i) the decumbent character of the branches; (ii) the presence of stipular spines in some biotypes; (iii) high temperatures and solar radiation during summer in caper-producing areas; (iv) the small diameter of flower buds. Since flower buds are arranged along twigs which have an indeterminate growth habit, twigs should not be cut.

Caper bush yields are highly variable depending on the growing environment, cultural practices and biotype, but a maximum yield is expected in the fourth year. A mature caper plant may produce 4–5 kg/year. According to Lozano Puche (1977) a wild growing plant yields 2–3 kg/year in Spain, but the same caper bush has the potential to produce 6–9 kg/year when cultivated in irrigated fertile soils (Jiménez Viudez, 1987). Great differences in yield are attributed to genetic variations. A 3-year-old 'del País' planting yields 1–1.5 t/ha year, but this production may be doubled and even tripled by using 'Mallorquina'. Bounous and Barone (1989) indicated average annual yields of 1–1.5 kg/plant and yields as high as 4 kg/plant in the third and fourth years of cultivated growth. Barbera and Di Lorenzo (1982) reported average annual yields of 1–1.5 kg/plant in Pantelleria (maximum yields of 4–5 kg/plant) and 2–3 kg/plant in Salina in 3-year plantings (average annual yields of 3–4 t/ha). On the other hand, Caccetta (1985) estimated annual yields of 1.2–2.5 t/ha in Pantelleria and 1.8–2.6 in Salina. Global growth in caper trading is estimated to be around 6 % per annum. In some countries such as Australia, opportunities exist in import replacement of high-quality capers for a niche market as well as in export (Trewartha and Trewartha, 2005). The caper crop can create new jobs in harvesting

as well as in the processing and distribution industries. Every hectare of capers planted is estimated to produce six to eight permanent jobs (Trewartha and Trewartha, 2005).

10.6 Post-harvest technology and uses in food processing

10.6.1 Post-harvest technology

Different physicomechanic characteristics of capers and caperberries have been assessed, and this information will help to develop more efficient handling and processing systems (Özcan and Aydin, 2004; Özcan *et al.*, 2004). After harvest, capers are placed in shallow vats. In Spain, post-harvest conditioning is generally performed by local traders, cooperatives or producer associations. After removing the leaves and pedicels, a first selection of capers takes place and blemished and open buds are discarded. Then, capers are subjected to a first sieving, which generally grades them into two size groups, with diameters lower or higher than 8–9 mm. Capers are valued in proportion to the smallness of their size. This first classification provides an incentive for re-collection of smaller capers and makes the subsequent industrial steps easier. Fresh capers have an intensely bitter taste, and one of the purposes of the pickling process, besides preservation, is to remove this unpleasant flavour. This is due to the presence of the glucoside glucocapparin, which is readily hydrolyzed to by-products completely lacking the bitter taste. After aeration in a well-ventilated place, capers are packed in wooden or polyvinyl chloride (PVC) barrels, fibreglass tanks or large casks and treated with high salt brine (*c.* 16 % NaCl w/v at the equilibrium, increasing to 20 % after changing the first brine). After filling, the casks are hermetically closed and placed in the sun. In order to reach the equilibrium in salt concentration, barrels are rolled during the early stage of brining. Periodical salt checks should be performed, also ensuring that the brine completely covers the material. This 'wet' curing process lasts 20–30 days (Luna Lorente and Pérez Vicente, 1985), but capers may be stored under such conditions for several months, until final industrial conditioning takes place.

Capers may be classified as fully brined vegetables (Ranken, 1988). Brines with a high salt content are increasingly being objected to (Alvarruiz *et al.*, 1990; Rodrigo *et al.*, 1992). Organoleptic characteristics and preservation of the final product proved to be the same over at least 27 months when capers had been pretreated with 10, 15 or 20 % NaCl at equilibrium (Alvarruiz *et al.*, 1990). High salt concentrations inhibit both the growth of undesirable microorganisms and the activity of lactic acid bacteria. Lower NaCl brines (i.e. 5 %) are more likely to permit growth of coliform bacteria, yeasts and moulds (Özcan and Akgül, 1999a).

Fermentation takes place at a higher rate when pickling small (≤ 8 mm) buds (Özcan and Akgül, 1999a). In Italy, growers arrange capers in cement tanks, PVC or wooden barrels, or open drums, between layers of solid salt (10–15 % w/w). This promotes the extraction of water from the raw product by osmosis and generates saturated brine. This treatment lasts 7–8 days. Then, the brine is removed and the capers are submitted to the same process once or twice more (Barbera, 1991). Capers are also pickled in vinegar (at least 4 % acidity as acetic acid) in a 1:1 (w/v) ratio (Reche Mármol, 1967). Regular topping up with vinegar ensures that all the

Table 10.2 Caper grading system

Diameter (mm)	Commercial denomination	Number of flower buds/kg	
		According to Barbera (1991)	According to Luna Lorente and Pérez Vicente (1985)
< 7	Non Pareil	5500	7000
7–8	Surfine	4000	4000
8–9	Capucine	3250	4000
9–10	Capote	2600	2000
10–11	Capote	2200	2000
11–12	Fine	1900	1300
12–13	Fine	1600	1300
13–14	Grosse	–	800

capers remain covered. This pickling process lasts 30 days. Only 10 % of vinegar is absorbed by the product, the remainder being discarded at the end of the period.

Following the completion of the curing period, the industrial processing is completed in three steps. First, capers are drained and rinsed with several changes of water to dislodge and remove all sediment. Second, damaged buds are disposed of and capers are carefully size-graded according to a grading system (Table 10.2). Finally, capers are prepared in a variety of ways and packed as a finished product. Pasteurization (80 °C, 15 minutes) of the final product is used to prevent the development of pathogens. These heat treatments can further prevent the development of certain spoilage-causing microorganisms (Ranken, 1988; Alvarruiz *et al.*, 1990).

Without pasteurization, 6–10 % NaCl and 1 % acidity as acetic acid (w/v) are required in the final product to avoid the risk of spoilage (Alvarruiz *et al.*, 1990; Özcan and Akgül, 1999b). In some cases, NaCl is avoided and covering capers with diluted acetic acid or distilled malt vinegar (4.3–5.9 % acetic acid) serves as an alternative. In Italy, the final product is treated with dry salt. Such preparation decreases the cost of transportation and gives a more intense flavour. In Spain, a similar treatment is carried out with capers of large diameter. Capers are drained and mixed with dry salt (20 % maximum). The caper industry discontinued the use of olive oil in caper preparations due to its high cost. Other special preparations, including wine vinegar, with or without the addition of tarragon, *Artemisia dracunculus* L. (Vivancos Guerao, 1948), are also expensive and exclusively utilized with capers of small diameter. Sweetening ingredients like sugar are added to those capers exported to Denmark or some northern European countries (González Soler, 1973).

Capers are generally packed in PVC or wooden barrels of 180–200 kg for the pickle industry but 40 kg barrels are used for packing 'non pareil' and 'surfine' capers, depending on the country importing them. For retail sale, capers are packed in various kinds of glass or plastic flasks containing 20 g to 5 kg, or translucent sachets of 0.1–1 kg. Five-kilogram flasks and sachets are usually sold to restaurants and coffee shops.

Traditionally, caperberries are fermented by dipping in water for 4–7 days. This immersion produces a strong fermentation accompanied by a colour change (from green to yellowish) and loss of texture due to flesh breakdown and gas accumulation. This step affects the value of the product and has proven to be unnecessary (Sánchez *et al.*, 1992). Lactic acid bacteria show faster growth rates at low NaCl concentrations (Sánchez *et al.*, 1992) but, as for capers, undesirable microorganisms can grow in 5 % NaCl brines (Özcan, 1999a). In order to protect caperberries from spoilage during fermentation, 4–5 % NaCl brines may be adequate (Sánchez *et al.*, 1992), but fermentation must be continuously controlled (Özcan, 1999a). Fermentation should last 20–25 days. Brines with 10 % (Sánchez *et al.*, 1992) to 15 % (Özcan, 1999a) NaCl at equilibrium create a favourable environment for pickled caperberry storage. Sorbic and benzoic acids, as well as their corresponding sodium and potassium salts, are used as preservatives during final packing. A method combining steam distillation (extraction) and high-performance liquid chromatography (HPLC) determination could be used to control the levels of those preservatives in caperberries (Montaño *et al.*, 1995).

10.6.2 Uses in food processing

Consumption of capers and caperberries has a long history. Direct evidence of the consumption of *Capparis* spp. from 18 000–17 000 years ago was obtained by archaeological excavations from Palaeolithic sites (Wadi Kubbaniya, west of the Nile Valley, Upper Egypt) (Hillman, 1989). Prehistoric remains of wild caperberries were also recovered from sites in south west Iran and in Iraq (Tigris) and dated to 6000 BC (Renfrew, 1973). Also, remains of caper seeds were recovered in quantity from different archaeological sites and dated to 9000–8000 BC (van Zeist and Bakker-Heeres, 1982, 1986; Willcox, 1996). A Bronze Age jar bearing carbonized flower buds and unripe fruit was found at Tell es Sweyhat (Syria) and suggests the consumption of pickled capers during the Bronze Age (van Zeist and Bakker-Heeres, 1988). The caper bush was utilized by ancient Greeks, Hebrews and Romans (reviewed by Sozzi, 2001; Rivera *et al.*, 2002), and both capers and caperberries are recognized as safe products when used as spices for natural seasoning.

There are almost 550 recipes that include capers (CondéNet, 2005), most of them compiled from specialized journals (Gourmet, Bon Appetit). Capers have a sharp piquant flavour and are mainly used as a seasoning to add pungency to: (i) sauces (e.g., tartare, remoulade, ravigote, vinaigrette, sauce gribiche, tarragon sauce and caper sauce); (ii) dressings and salads (e.g., caponata, a cold eggplant salad with olives and capers); (iii) cold dishes (vithel tohnné), or sauces served with salmon, herring, whiting or turbot; (iv) pasta, pizzas and canapés; (v) cheeses (e.g., liptauer cheese); and (vi) lamb, mutton, pork or chicken preparations (Hayes, 1961; Knëz, 1970; Machanik, 1973; Nilson, 1974; Baccaro, 1978; Stobart, 1980). A complex organoleptic profile is responsible for caper flavour (Brevard *et al.*, 1992). Caperberries and tender young shoots of the caper bush are also pickled for use as condiments, as previously described. The unripe seeds or pickled buds of other species (*Tropaeolum majus* L., *Caltha palustris* L., *Cytisus scoparius* (L.) Link., *Zygophyllum fabago* L., *Euphorbia lathyrus* L.) are sometimes suggested as

substitutes for capers (Redgrove, 1933; Vivancos Guerao, 1948; Seidemann, 1970; Mitchell and Rook, 1979; Stobart, 1980; Bond, 1990).

10.7 Functional properties and health benefits

Different organs of the caper plant have been used as folk remedies for various diseases (Pernet 1972; Kirtikar and Basu, 1975; Boulos, 1983; Duke, 1983; Jain and Puri, 1984; Abbas *et al.*, 1992; Husain *et al.*, 1992; Al-Said, 1993; Ghazanfar and Al-Sabahi, 1993; Ghazanfar, 1994; Bhattacharjee, 1998). It is traditionally utilized in diabetes control and treatment in Morocco (Jouad *et al.*, 2001; Eddouks *et al.*, 2002). Liv.52, an Indian traditional polyherbal formulation that contains different plant extracts, among them 24 % of *C. spinosa*, is a 'liver stimulant' with some protective action against hepatotoxic substances (ethanol, acetaldehyde and carbon tetrachloride), radiation sickness and dermatitis. The health benefits of Liv.52 related to *C. spinosa* have been extensively reviewed (Sozzi, 2001), and recent studies confirm its efficacy on liver cirrhotic patients (Fallah Huseini *et al.*, 2005).

Caper has been used in folk medicine as carminative, anti-escorbutic, antispasmodic, diuretic and vermifuge. The decoction of caper bush has hypoglycaemic properties and may be useful in antidiabetic therapy (Ageel *et al.*, 1985; Yaniv *et al.*, 1987). Aqueous extracts of *C. spinosa* have a potent anti-hyperglycaemic activity in streptozotocin diabetic rats (Eddouks *et al.*, 2004). No changes were observed in basal plasma insulin concentrations following treatment of normal or diabetic rats with *C. spinosa* aqueous extracts, thus indicating that the underlying mechanism of its pharmacological activity seems to be independent of insulin secretion (Eddouks *et al.*, 2004). Another beneficial effect observed in diabetic rats being administered *C. spinosa* extract was the reduction in plasma cholesterol which is usually high in patients with diabetes mellitus (Eddouks *et al.*, 2005). High levels of plasma lipids represent a risk factor for coronary heart disease.

The oral administration of a caper root decoction or tincture to guinea pigs revealed strong desensitizing effects against various plant and animal allergens (Khakberdyev *et al.*, 1968). Cappaprenol-12, -13 and -14 in ethanol extracts of caper leaves are anti-inflammatory compounds (Al-Said *et al.*, 1988; Jain *et al.*, 1993). It has recently been shown that methanolic extracts of *C. spinosa* flowering buds possess a marked anti-allergic and antihistaminic effect (Trombetta *et al.*, 2005). *C. spinosa* is also used in phytomedicine as antifungal (Ali-Shtayeh and Abu Ghdeib, 1999), antihepatotoxic (Gadgoli and Mishra, 1995, 1999), anti-inflammatory (Ageel *et al.*, 1986) chondroprotective/antidegenerative (Panico *et al.*, 2005) and antileishmania (Jacobson and Schlein, 1999). A role for the plant in the epidemiology of leishmaniasis has been suggested (Schlein and Jacobson, 1994a, b). In fact, extracts of *C. spinosa* caused extensive parasite agglutination, apparently due to caper plant lectins (Jacobson and Schlein, 1999). Methanolic extracts of *C. spinosa* showed some antimalarial activity when assayed *in vitro* against a multi-drug resistant strain of *Plasmodium falciparum* (K1) (Marshall *et al.*, 1995). Extracts of the whole plant or its aerial part also exhibited variable degrees of antimicrobial activity, as well as antifungal activity (Ali-Shtayeh *et al.*, 1998).

A number of caper extracts have anticarcinogenic activity. The hydrolysis products of some glucosinolates have anticarcinogenic effects (Mithen *et al.*, 2000) and different antioxidant compounds (e.g. quercetin, rutin) may also contribute to cancer prevention. A methanolic caper extract showed strong antioxidant/free radical scavenging effectiveness in different *in vitro* tests and, when topically applied, afforded significant *in vivo* protection against UV-B light-induced skin erythema in healthy human volunteers (Bonina *et al.*, 2002).

Antidermatophytic activity in caper extracts is comparable with that of griseofulvin preparations (often used as a standard in evaluating antibiotic potential), suggesting a possible use against dermatophytic infections in humans (Ali-Shtayeh and Abu Ghdeib, 1999). In contrast, the green parts of caper plant have been considered to be potentially irritating to the skin because of its glucosinolates (Mitchell, 1974; Mitchell and Rook, 1979; Cronin, 1980; Foussereau *et al.*, 1982). Caper leaf and fruit extracts, applied as wet compresses to inflamed skin, may produce acute contact dermatitis (Angelini *et al.*, 1991). Nevertheless, Lemmi Cena and Rovesti (1979) pointed out that caper extracts may be used for treating enlarged capillaries and dry skin. Barbera (1991) suggested that they could be utilized for cosmetic preparations (creams, shampoos, lotions and gels), due to the presence of some active principles: rutin and quercetin (flavonoids that produce effects similar to those of vitamin P), glucocapparin (rubefacient action), pectins (moisturizing and protecting effects), phytohormones and vitamins.

10.7.1 Health-promoting and therapeutic characteristics

C. spinosa bud extract may be considered as an interesting source of antioxidants and antibiotics and as a strong scavenger against free radicals for therapeutic or nutraceutical industries (Tlili *et al.*, 2011). Phytochemical studies of caper have shown the presence of many beneficial compounds such as spermidine, rutin, quercetin, kaempferol, stigmasterol, campesterol, tocopherols and carotenoids. Biological studies reveal significant antimicrobial, antioxidative, anti-inflammatory, immunomodulatory and antiviral properties.

Considering the effect of different preservation treatments on *C. spinosa* buds, the antiradical activity decreases in the following order: fresh capers > pickled capers > buds dried at 55 °C > salt-dried buds. The highest retention of antiradical activity is observed when capers are treated with vinegar (62 % of the activity in fresh material). Results indicate that both flower buds and leaves can be considered a promising source of flavonoids in general and rutin in particular, even after the preservation treatments (Gonzalez *et al.*, 2010).

Sher and Aleymeini (2010) pointed out the ethnobotanical and pharmaceutical importance of *C. spinosa* and explored its agro-industrial potential for the Kingdom of Saudi Arabia. *C. spinosa* proved to be a multipurpose plant used for curing various human ailments including gastrointestinal problems, inflammation, anaemia, liver dysfunction and rheumatism. It has been used as an antispasmodic analgesic; anthelmintic; antihaemorrhoidal; aperient; deobstruent; depurative; diuretic; expectorant; and general body tonic in indigenous, Ayurvedeic, Chinese and Unani systems of medicine. This study concluded that *C. spinosa* had economic significance for Saudi Arabia.

Table 10.3 Nutritional value of caperberries

Serving size	100 g of caperberries	
% Daily requirements		
Total calories	23	1 %
Calories from fat	7.2	
Total fat	0.9 g	1 %
Saturated fat	0.4 g	1 %
Mono-unsaturated fat	0.1 g	
Polyunsaturated fat	0.4 g	
Trans fat	0 g	
Cholesterol	0 g	0 %
Total carbohydrate	4.9 g	2 %
Dietary fibre	3.2 g	13 %
Sugars	0.4 g	
Protein	2.4 g	5 %
Minerals		
Calcium	40 mg	4 %
Iron	1.7 mg	9 %
Magnesium	33 mg	8 %
Phosphorus	10 mg	1 %
Potassium	40 mg	1 %
Sodium	2964 mg	123 %
Zinc	0.3 mg	2 %
Copper	0.4 mg	19 %
Manganese	0.1 mg	4 %
Selenium	1.2 mcg	2 %
Vitamins		
Riboflavin	0.1 mg	8 %
Niacin	0.7 mg	3 %
Folic acid	23 mcg	6 %
Vitamin A	138 IU	3 %
Vitamin C	4.3 mg	7 %
Vitamin E	0.9 mg	4 %
Vitamin K	24.6 mcg	31 %
Phytosterols	48 mg	

Caperberries are high in vitamin content (Table 10.3) and are recommended for good health for the following reasons:

- They are very low in calories, have minimal amounts of fats and no cholesterol.
- They are a good source of B-group vitamins like thiamine, riboflavin, niacin, B6 and folic acid that are essential to enhance the energy production from food.
- They are a good source of vitamin C, a natural water-soluble antioxidant that enhances the immune system, and vitamin K which prevents internal and external bleeding.
- They are a moderate source of vitamin A, which enhances the eyesight, and vitamin E and selenium, natural antioxidants that scavenge the free radicals that oxidize fats, preserve the integrity of cell membranes and protect the body.

- They are a good source of minerals like calcium, iron, potassium, phosphorus, magnesium, zinc and manganese, which play a very important role in maintaining proper metabolic activities.
- They are a good source of soluble dietary fibre, that adds roughage to the contents of the intestines, promotes satiety, promotes the health of the colon and also helps in relieving constipation, haemorrhoids, diverticular disorders, etc.
- They are a very good source of rutin and quercetin (180 mg/100 g), second only to tea leaf. Both compounds are powerful antioxidants. Rutin strengthens capillaries and inhibits platelet clump formation in the blood vessels. Both actions help in smooth circulation of blood in very small vessels. Rutin has been used for haemorrhoids, varicose veins and in bleeding conditions such as haemophilia. It has been found to reduce low-density lipoprotein (LDL) cholesterol levels in obese individuals. Research studies suggest that quercetin has antibacterial, anticarcinogenic, analgesic and anti-inflammatory properties.

10.8 Quality issues and future trends

Consumer satisfaction and repeat purchases of food are dependent upon flavour and nutritional quality. Many studies exalt the nutritional value of caper flowering buds, which are widely used as a source of flavour. Capers are rich in antioxidant compounds. Moreover, caper isothiocyanates are well known as cancer preventive agents and different caper extracts have hypoglycaemic properties and protective effects against hepatotoxic substances. In addition, capers and caperberries could be part of new therapeutic strategies based on natural products. Increasing amounts of capers are being consumed in different countries, and this trend appears likely to be sustained for coming years, the interest in new tastes presumably accounting for most of the increase.

Success in caper bush cultivation depends mainly on five fundamental points: (i) biotypes of high quality and production; (ii) adequate propagation; (iii) good control of cultivation practices, particularly harvest; (iv) adequate post-harvest processing and storage; and (v) efficient marketing systems and strategies. Caper yields are much higher in irrigated plantings, with N–P–K fertilization, although much more research is required to determine the optimal cultivation conditions for this species. Diseases and pests do not seem to be a great problem in general but need to be researched. Two major expenses are expected, implantation and harvesting. The latter may be the stumbling block in high-input systems, and the possibility of a semi-mechanical operation should be considered in order to remove this limiting factor. Moreover, further improvement in caper quality may be obtained by regulating harvesting dates. There is an assortment of opportunities for plant breeders to contribute to domestication of caper bush for agricultural purposes. Determination of the genetic bases for productivity, ease of propagation, absence of stipular spines and flower bud quality and conservation are high-priority research needs. In Australia, Trewartha and Trewartha (2005) consider that research and development could support the expansion of a viable caper industry, undertaking investigation in order to reduce picking costs (through harvest management, mechanization and

trellising), select optimum varieties and diversify and add value through product innovation. Finally, marketing research remains an area of great importance. Marketing of capers without prearranged contract with processing or exporting companies could be very risky. Market promotion and the ability of handlers to provide a high-quality product at times that will yield a competitive price have become essential factors. Producers and handlers will be challenged to develop new and expanded markets for capers.

10.9 References

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