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Broad overview of the subtropical banana industry

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Abstract

Bananas are cultivated in different countries in the subtropics, including Australia, Southern Brazil, Egypt, Israel, Morocco, Portugal (Madeira and Azores), South Africa, Spain (Canary Islands) and Turkey. Despite climatic constraints which cause undesirable physiological effects and long cropping cycles, subtropical banana yields can be quite high. Although 'Grand Nain' is the cultivar most planted in the subtropics, 'Williams' and some Dwarf Cavendish clones, like 'Gruesa', a Canary Islands selection, are also planted. Climatic constraints and water scarcity have led to protected cultivation of bananas, particularly in Morocco, Canary Islands, Turkey and more recently in Israel where all new plantings are established in greenhouses. Management of pests and diseases is generally easier and cheaper compared with the tropics, due to the limiting effect of low temperatures and humidity on pest and pathogen activities. Most of the subtropical belt is free of black leaf streak (*Pseudocercospora fijiensis*) and the burrowing nematode (*Radopholus similis*), although the incidence of Fusarium wilt and, particularly, the rapid spread of tropical race 4 (TR4) is a serious concern for the future. Although proximity to the market is an advantage for subtropical countries like Israel, Turkey or Morocco which sell their bananas locally, market difficulties are present for Canary Islands or Madeira which export their fruits to the Iberian Peninsula where they face the market competition of the so-called 'dollar bananas' arriving from Latin American countries. The actual importance of and future prospects for developing banana in the subtropics are analysed in this paper.

Keywords: climatic constraints, cultivars, diseases, Fusarium wilt, protected cultivation, pests, Tropical Race 4

INTRODUCTION

According to the Cambridge English Dictionary, the subtropics are 'the parts of the world that are immediately south or north of the tropics and have very hot weather at some times of year. Within this region, bananas are cultivated in different countries, including Turkey, Israel, Egypt, Lebanon, Pakistan, India, China, Spain (Canary Islands), Australia, Morocco, South Africa, Portugal (Madeira and Azores), Argentina and the south of Brazil. Although the majority of the banana-growing areas of the world are geographically situated between the equator and the latitudes 20°N and 20°S, there are commercially profitable plantings at latitudes close or even slightly higher than 30°N and 30°S and these areas with mild subtropical climates, such as the Canary Islands, Israel or Turkey, where the best yields for bananas are obtained, especially under greenhouse cultivation (Robinson and Galán Saúco, 2010).

CLIMATIC CONSTRAINTS FOR BANANA CULTIVATION IN THE SUBTROPICS

The most common problems occurring in the subtropics are primarily related to cold temperatures in winter, but also to temperatures higher than 38°C (Ganry, 1973; Aubert, 1971) which are common during summer in several countries in the subtropics, among others, in Israel, Morocco and Egypt. These specific problems have been summarized by Robinson and Galán Saúco (2010) and Galán Saúco and Robinson (2013) as follows:

a) Frost damage

b) Winter chilling of leaves
c) Growth cessation with leaf emission rate (LER) dropping sharply at temperatures below 20°C to less than 1 leaf/month during winter in the subtropics compared with 4-5 leaves/month in the tropics or during summer in the subtropics; the plant has no visible damage, but its cycle length is considerably increased
d) Root growth also ceases or is reduced by low winter temperatures
e) Choke throat problems
f) Winter flower initiation, known as 'November dump' in the Southern Hemisphere or 'May bunch' in the Northern Hemisphere, which can cause small and malformed bunches
g) Underpeel discolouration
h) Winter leaf photo-oxidation due to a combined effect of high (>30°C) daytime temperatures, low night time temperatures, low (<25%) relative humidity, high light intensity and a depleted feeder root system due to growth cessation
i) Other climatic problems such as wind damage, hail and lightning are also characteristic of subtropical climates, imposing specific growth, yield and fruit quality constraints.

Some of the problems mentioned above, particularly (e), (f) and (g), may be avoided through suitable cultural practices orientated towards obtaining flower initiation and flower emergence during the summer and harvesting prior to the onset of low temperatures. Appropriate fertilization, irrigation and wind protection practices, and adequate site selection, choosing locations with appropriate temperatures and other environmental factors, may also reduce some of these problems. The choice of planting date, usually done in spring or summer, planting density and appropriate sucker selection to time the crop harvest as well as successive annual crops to coincide with high market prices and to benefit from, or to avoid, certain climatic conditions will also offer great benefits for successful cultivation of bananas in the subtropics.

Besides common considerations regarding soil and wind exposure, sites for open-air banana cultivation in the subtropics should be carefully selected according to temperature records, avoiding places with minimum winter temperatures below 10°C and maximum summer temperatures above 38°C. In places such as Egypt, with peak summer temperatures ranging between 40 and 45°C, and in Israel or Morocco, with winter temperatures sometimes in the range of 1 to 8°C, bananas can also be cultivated by modifying management practices, in particular through protected cultivation. Cultivation of banana in greenhouses, now increasingly practised in different parts of the subtropics, is of greater help to reduce not only climatic constraints, but also to reduce irrigation needs and improve yield. The main advantages of greenhouse cultivation, as indicated before by Robinson and Galán Saúco (op. cit.) and listed below, deserves however some comments here:

a) Increased number of days with mean temperature above 16°C resulting in more hours in winter with temperatures above the threshold limit of 14.5°C below which the growth of 'Dwarf Cavendish' (DC) banana plants is completely stopped (Green and Kuhne, 1970; Robinson and Anderson, 1991). This threshold is also valid for other close Cavendish cultivars such as 'Grand Nain' (GN) or 'Williams'.
b) Protection against wind and other weather conditions (frost, sunburn, hail). Frost protection can also be undertaken with the use of thermal nets like those that have been evaluated in Israel in the last 3 years with excellent results (N. Galpaz, 2018, pers. commun.).
c) Reduction in water consumption, as evapotranspiration is reduced by up to 25% as shown by Tanny et al. (2012) in Israel who obtained equivalent or better yields in bananas under screenhouses with water savings of 20-30% compared to open field cultivation.
d) Increased leaf surface area leading to higher photosynthetic capacity.
e) Shortened crop cycles, which permits a quicker recovery of the investment allowing the first harvest in the same year of planting, which is not possible in open-air

plantings in the subtropics.

f) Production of larger and heavier bunches. In some parts of Canary Islands, bunch weights have increased 62% (Galán Saúco et al., 1998a), leading to yields exceeding 80 t/ha (exceptionally 100 t/ha/year) in comparison with 60 t/ha/yr average for well-managed open field plantations. Differences in yield have been also reported in Turkey with average bunch weights of 40 kg in greenhouse-produced banana versus 27 kg in banana produced under open-field conditions (Gubbuk et al., 2018).
g) Increased size of banana fruits, generally an advantage but not in the case of the Spanish mainland market which prefers the small size DC bananas traditionally produced in the Canary Islands which explains why cultivars like 'Gruesa' or 'Brier' (DC local selections) are preferred in the Canary Islands for greenhouse cultivation while GN is only planted at open air plantings in the cooler areas of the islands (see Table 2).
h) Prevention of diseases transmitted by wind such as Sigatoka leaf diseases and lower incidence of virus transmission through insect vectors as in the case of banana streak viruses (BSV) or Banana bunchy top virus (BBTV).

Special care should be taken in greenhouse cultivation with the practice of removing healthy leaves at flowering which has proven to be useful to accelerate ratoon sucker growth in the subtropics, because under greenhouse cultivation light can be restricted to the suckers, as leaf laminas are not disturbed or damaged by wind and the leaf remains intact. While a minimum of 12 healthy leaves should be present at flowering and 9 at harvest in open field plantings to obtain maximum bunch filling and green life extension (Turner, 1970; Robinson et al., 1992; Daniells et al., 1994) a minimum of 8 leaves at flowering are enough under greenhouse cultivation (Robinson and Galán Saúco, op. cit.).

Despite the use of greenhouse cultivation being considered environmentally sound, especially in arid and semi-arid regions, this practice may have some negative consequences as a result of:

a) Negative visual impact which is why banana greenhouse cultivation is prohibited in places like Madeira Island
b) The need for and difficulties with properly recycling the plastic material from the periodic replacement of covers, either because of degradation of the material or due to damage.
c) The high initial investment cost and the cost of periodic cover renovations
d) Possibility of sunburn damage due to excessive high temperatures during summer.

Little can be done through research to reduce the visual impact, but there have been advances regarding cover efficiency and greater durability (Cabrera Cabrera and Galán Saúco, 2012). Cultivation of bananas under greenhouse, especially under polyethylene covers, requires careful ventilation management during summer to avoid temperatures that can burn banana leaves and strategies to reduce or avoid sunburn damage such as the installation of overhead sprinkler systems or whitening the covers with an application of calcium carbonate solution during summer, currently used in countries with hot summers, like Morocco and Turkey (Gubbuk et al., 2018, Lavigne, 1996). Overhead sprinklers are also used on cold winter nights in Morocco where temperatures can reach 4°C to avoid the death of the banana leaves, but are only useful if greenhouses are well constructed and can be appropriately sealed.

OVERVIEW OF BANANA CULTIVATION IN THE SUBTROPICS

To complement the literature information about banana cultivation in the subtropics, a survey was conducted in 2018 addressed to researchers in all these countries to obtain the key data about cultivated area both in open field and under greenhouse, total production, and importance of organic cultivation, cultivars, cultural techniques, occurrence of pests and diseases, market considerations and future prospects. A summary of key information on subtropical banana production extracted from both literature review and the survey is discussed below.

Importance of banana production in the subtropics

As shown in Table 1, almost all the bananas produced in the subtropics are destined to local markets with only small quantities exported to neighbouring countries. High import taxes as in Turkey (Gubbuk et al., 2017) or phytosanitary reasons as in Israel make it difficult for bananas to be imported into these countries. Consumer preferences and quality issues derived from proximity to market as well as traditional preference for smaller-sized bananas, as in the case of the Spanish mainland and the Canary Islands, explain the success of locally produced bananas. In addition, lack of export infrastructure in some other countries and the difficulties of competing in an already saturated international market (Loeillet, 2018a) explain why bananas produced in the subtropics are seldom exported to foreign markets.

Table 1. Importance of banana production in the subtropics. (Source: banana survey, except for Lebanon (FAOSTAT 2017).

Country	Open field (ha)	Under cover (ha)	Total (ha)	Total production ($x10^3$ T)	Organic production	Market
China	320,000	/	320,000	96,000	Very small	Mostly local
India	178,000	/	178,000	6,444	Negligible	Mostly Local
Brazil	115,186	/	115,186	2,320	0.34%	Local and Mercosur
Egypt	35,085	100	35,085	1,500	Nil	Mostly local
Pakistan (1)	26,300	/	29,500	≈ 115 (*)	Negligible	Mostly local
Spain (2)	8,967	≈2,600	≈6,367	438	(<1% but growing	Local + Spain and Portugal
South Africa	9,000	/	9,000	350	Nil	Local
Morocco	234	8,386	8,634	338	Nil	Local
Turkey	2,145	4,080	6,225	306	Nil	Local
Argentina	3,000	/	3,000	79	Nil	Local
Lebanon	1,965	/	1,965	63	Nil	Local
Israel	≈220	≈ 2,350	2,984	147	10-15 ha	Local
Australia	≈1500	/	≈1,500	39	<1%	Local
Portugal (3)	1,020		1,020	29	20 ha	Local + Portugal

(1) Sindh Province, (2) Canary Islands, (3) Madeira and Azores. (*) Estimated.

Greenhouse production is limited to Morocco, Turkey, Israel and Spain (Canary Islands) and a few hectares in Egypt. All these countries have or have had government subsidies for establishing greenhouses which are justified on the basis of water savings as in the case of Israel, and/or because of qualitative and quantitative yield improvement in the other countries.

Organic production of banana is almost negligible in the subtropics and will probably not increase, because, even though the international organic banana market is growing, the forecast price increase is not happening and prices are even falling and approaching those obtained by conventional produced bananas (Loeillet, 2018b).

Cultivars grown in the subtropics

As shown in Table 2, 'Dwarf Cavendish' (DC), 'Grand Nain' (GN) and 'Williams' (W) are the cultivars almost exclusively planted in the subtropics, with the exceptions of 'Prata Ana' (AAB) in Brazil and 'Lady Finger' (AAB) and 'Ducasse' (Pisang Awak, ABB) in Australia. Similar to the Cavendish cultivars mentioned above, these alternative cultivars are well adapted to the cooler environment of the subtropics (Robinson and Galán Saúco, 2010). Local selections of both DC and GN types, like 'Gruesa' and other clones in the Canary Islands (Cabrera Cabrera and Galán Saúco, 2006) or 'Zelig', a W selection from Israel and other selections from this country have proven better than either DC or GN in certain situations (Galán Saúco et al., 1998 a and b, Cabrera Cabrera et al., 2005; Cabrera Cabrera and Galán Saúco, 2006) and are being commercially planted, not only in their country of origin, but also in moderate scale in other subtropical countries.

Table 2. Banana cultivars grown in the subtropics. (Source: banana survey, except for Pakistan (Laghari, undated) and Lebanon (FA0, 2007).

Country	Cultivars
China	Williams B6 (98%)
India	Grand Nain (95%)
Brazil	Cavendish (Williams, Grand Nain, Naniçao) (50%), Prata (Prata Ana and Prata Ana SCS-451 Catarina) (40%)
Pakistan	Basrai (Dwarf Cavendish type) (98%), Grand Nain, Williams
Egypt	Grand Nain (78%), Williams (10%), Hindi (10%), Maghrebi, Basrai
Spain	Gruesa, Brier and other Dwarf Cavendish types (80%) in open air and under greenhouse, Grand Nain for open air cooler locations (20%)
South Africa	Williams
Morocco	Grand Nain in greenhouse, Dwarf Cavendish in open air
Turkey	Grand Nain and Asman (Robusta?) for greenhouse, for open air plantings Dwarf Cavendish and Asman in protected areas
Argentina	Grand Nain, Williams, Congo (similar to Williams) Manzano (very few)
Lebanon	Grand Nain and local cultivar Baladi (or Abou Nekta)
Israel	Grand Nain and local selected Cavendish (Gal, Zelig, Adig and other Grand Nain types)
Australia	Williams (50%), Lady Finger (40%), Ducasse (Pisang Awak, 10%)
Portugal	Dwarf Cavendish (90%), Williams Ricasa (Canary Island selection)

Planting density and spacing

Planting density in most subtropical countries is around 1,600-2,600 plants/ha (see Table 3) which is close to the density (1,500-2,000) recommended by Robinson and Galán Saúco (op. cit.) for mild subtropical climates and Cavendish cultivars in order to maximize cumulative gross margin per hectare and annum over the plantation life. In Israel, where great care is devoted to cultural practices such as fertilization, irrigation and sucker management, planting density for Cavendish cultivars can reach 3,000 plants/ha, and in Carnarvon in Western Australia, planting densities of 3,333 plants/ha are common. Higher densities are also used in cooler conditions of Morocco and South Africa and also for 'Prata Ana' in Brazil, while 'Lady Finger' in Australia is planted at a lower density, approximately half than for Cavendish. 'Ducasse' planting densities in Australia are similar to Cavendish.

Planting design in the subtropics is generally rectangular which is in agreement with results obtained in South Africa (Robinson et al., 1989) indicating that overall productivity for GN at densities of 1,666 plants/ha was higher with rectangular (3 × 2 m) spacing than with hedgerow (4 × 1.5 m) or tramline (6 × 2 × 1.5 m) plantings.

Planting material and irrigation system

Egypt and Israel are the only countries in the subtropics using almost exclusively tissue culture (TC) plants for commercial banana plantings, while the remaining subtropical countries using both TC and conventional planting materials, either suckers or rhizomes (Table 3).

Table 3. Planting density, planting design and planting material in the subtropics. (Source: banana survey).

Country	Planting density (pl/ha)	Planting design (m)	Planting material
China	1,900-2,200	2.6 x 2.0 – 2.5 x 1.8	TC and conventional
India	1,600-2,600	1.8 x 2.0 – 3.0 x 2.0	TC and conventional
Brazil	Cavendish 2,000-2,500 Prata Ana 1,333-3,333	Prata Ana 3 x 2.5 (2 or 1.5) Cavendish 2.5 (or 2.0) x 2.0 4 x 2 x2 (double row) both	TC and rhizomes
Egypt	1,900	Open field 3 x 3.5 (2pl/hole) Greenhouse 3.5 x 1.5	TC
Pakistan	1,800-2,200	2.4 x 2.4 or 2.1 x 2.1	Conventional (99%) and TC (1%)
Spain	1,600 - 2500	DC 22 x 2.2 or 2.0) or 3 x 1 GN 5 x 1.67 (2pl/hole)	TC and suckers
South Africa	2,200 (but higher densities in cooler situations)	3 x 1.5	TC and suckers
Morocco	1,800-2,000 (greenhouse) 3,000-3,500 (open field)	Greenhouse 1.6 x 1.5 x 4.5 (Double row)	TC and suckers
Turkey	1,800- 2000	Open air 2.5 x 2 Greenhouse 3 x 1.8	TC (*) and conventional
Argentina	2,500	4 x 4 (4 plants 2nd year)	TC and conventional
Lebanon	No data	No data	No data
Israel	2,000-3,000	4 x 2.5 (2-3 pl/mat)	TC
Australia	1,600 Williams 750 Lady Finger 1,600 Ducasse	3 x 2 Williams and Ducasse 3.6 x 3.6 Lady Finger	TC and conventional
Portugal	2,000	2 x 2.5	TC and conventional

TC= Tissue culture, pl = plants, DC = Dwarf Cavendish, GN = Grand Nain.
(*) Tissue culture plants in greenhouses and conventional in open fields.

With the exception of the Azores, parts of Brazil and Eastern Australia, where rainfall distribution during the year is appropriate for banana cultivation, all other countries use either drip micro-sprinkler or overhead sprinkler irrigation. Drip irrigation is preferred in Israel, Morocco, Turkey, Egypt or the Canary Islands where saving water is important due to shortage of good quality water. The only exceptions are Pakistan, some valleys in Egypt and some parts of the Madeira Island, where flood irrigation is the main irrigation system.

The situation of pests and diseases in the subtropics, and the menace of TR4

The burrowing nematode (*Radopholus similis*) and the banana weevil (*Cosmopolites sordidus*) are considered as the major pests affecting bananas. Black leaf streak (*Pseudocercospora fijiensis*) and Sigatoka leaf spot (*Pseudocercospora musicola*), Moko bacterial wilt, *Banana bunchy top virus*, banana streak viruses and Fusarium wilt (a.k.a. Panama disease), with the rapid spread of tropical race 4 (TR4), are the major banana diseases. The incidence of these pests and diseases, as discussed below, is lower in the subtropics than in the tropics, due to unfavourable climatic conditions, but also due to isolation from other banana-producing countries as in the case of the Canary Islands, Madeira or the Azores, or strong phytosanitary and quarantine policies (Israel and Australia) and exclusive use of TC plants (Israel).

Despite the presence of the burrowing nematode in many subtropical countries (Table 4), it has not been reported as a main problem for banana cultivation in any of the surveys. Burrowing nematode prefers a temperature range between 24 and 32°C and does not reproduce below 16-17°C or above 30°C (Sarah et al., 1996). It is not a serious problem in the subtropics, except in south-eastern banana production areas in Australia. Although the banana weevil (BW) is a more widespread pest in subtropical countries, it has been only reported as a main pest in India, Madeira, the Canary Islands and subtropical Australia (Table 5), where it is considered a much greater problem than in tropical Australia. This is just the opposite of the burrowing nematode, which is only a main pest in tropical North Queensland and in south-eastern banana production areas. Two factors contribute to the damage caused by the BW: i) the slower plant growth rate in subtropical conditions which allow the BW to cause more damage to the newer part of the mat, and ii) TC plants (most frequently used as planting material in these countries) seem to be more susceptible to the BW during early establishment because the growing point is more easily accessed and readily attacked than sucker/bit material and TC plants lack corm reserves (Daniells et al., 1996). However, with appropriate management practices, like sanitation, biological control, strict quarantine practices and the use of TC plants, neither of these two pests are serious impediments to the cultivation of bananas in the subtropics (Robinson and Galán Saúco, op. cit.).

The speed of infection of *Pseudocercospora fijiensis*, the fungus causing black leaf streak (BLS), is linked to temperature, and the disease may become more aggressive at higher temperatures, as growth of the germination tube of the spores increases in direct response to temperature increase. However, the presence of high relative humidity >98% for ascospore and >88% for conidia is necessary for spore germination (Jacome et al., 1991; Jacome and Schuh, 1992). Probably because of the negative impact of cold temperatures for the growth of ascospore germination tubes (Pérez Vicente et al., 2006) and the fact that BLS only occurs in the presence of leaf wetness, this disease is virtually absent in the subtropics, with the exception of the humid subtropical areas of China and Brazil (Table 4), and only in the latter has it been listed as a main leaf disease. Sigatoka leaf spot, which has a lower impact on banana and is easier to manage compared to BLS, was reported as an important disease for subtropical banana production in Argentina, Australia, Brazil and South Africa, generally linked to places with high rainfall, high humidity exceeding 90% and minimum night temperatures reaching 18°C (Galán Saúco et al., 2012).

Banana streak viruses are present in many subtropical countries (Table 5), but they have not been cited as a pest in any of the survey reports, probably because the impact of these viruses in the yield of Cavendish cultivars, even in tropical areas is small, less than 11% in tropical North Queensland (Daniells et al., 2006).

Similarly, Moko, once introduced to tropical Australia in imported *Heliconia* plants from Hawaii and quickly eradicated (Jones, 2009), was also not reported as a pest in any of the surveys from the different subtropical countries, as it only has restricted distribution in India and Brazil (Table 4).

Banana bunchy top virus (BBTV), which is endemic to Southeast Asia, is also present in Morocco, Egypt and Australia (Table 5). BBTV remains a major constraint in smallholder plantings in India and Pakistan, but the problem can be kept under control with the use of TC plants, an appropriate management program, as done in Australia (Vézina, 2013), or in greenhouse cultivation, like in Morocco which makes the insect transmission via *Pentalonia nigronervosa* more difficult.

Table 4. Incidence of the main pests and diseases in subtropical countries. (Source: CABI, 2018 except for banana streak, Mourichon et al. (1997) and for Sigatoka leaf spot data from banana survey).

Country	BN	BW	Sigatoka leaf spot	Banana streak	Moko	Bunchy top	Fusarium wilt
China		x	xxx (B)	x		Rd	x
India	Rd	x	xxxx (Y)	x	Rd	Rd	Rd
Brazil	x	x	xx (Y, B)	x	Rd		Rd
Egypt	x		x (Y)	Rd		Rd	x
Pakistan		x				Rd	x
Spain	x	x					x
South Africa	Rd	x	x (Y)	x			x
Morocco	x			x			
Turkey							
Argentina		x	x (Y)				
Lebanon	x						x
Israel	A	Confined					
Australia	Rd	x	x (Y)	x		Rd	Rd
Portugal		x		x			Rd

BN = Burrowing nematode; BW = Banana weevil, B = Black; Y = Yellow; Rd= Restricted distribution.

Although Fusarium wilt was not reported as a major disease in countries like Israel, Turkey, Morocco, Argentina, Portugal (Azores) or Brazil (Table 5) and it has not been reported to be present on Cavendish cultivars in any of these countries except for Brazil (Table 4), it is probably present in most areas where bananas are grown due to previous movement of infected planting material. Until the appearance of TR4, the incidence of Fusarium wilt in Cavendish cultivars was linked to unfavourable growing conditions, including low temperatures, poor soil conditions or other predisposing factors. However, TR4, more specifically the vegetative compatibility group of the pathogen VCG 01213-01216, can destroy Cavendish plantations even under optimum environmental conditions and cultural practices in the absence of any predisposing factor (Ploetz, 2015b). Although TC plantlets have been found to be more susceptible to Fusarium wilt attack than conventional planting material (Smith, 1998), they are the most reliable source of clean planting material and use of TC planting material is strongly recommended to reduce the risk of TR4 introduction. After decades of research on managing Fusarium wilt of banana, no alternative to the use of resistant cultivars has been found to control this disease (Ploetz, 2015a). As more than 95% of the marketed dessert bananas, also in the local markets of the subtropics, are Cavendish cultivars, this indicates clearly the extremely serious threat TR4 poses to subtropical banana production. Fortunately, TR4 has not yet been detected in many areas of the subtropics, though it is already present in subtropical China (Qi, 2001), including Taiwan (Su et al.,1986), Pakistan (Syed et al.,2015), Jordan (García et al., 2015), Lebanon, (Ordonez et al., 2016) and its presence has been reported in India, though not formally published (Damodaran et al., 2018). TR4 was recently (2016) detected in Israel (Maymon et al., 2018)), but was officially declared eradicated by June 2018 (Anon., 2018).

Table 5. Incidence of the main pests and diseases in subtropical countries. (Source: banana

survey and author own data for Spain).

Country	BN	BW	Sigatoka (*)	Banana streak	Moko	Bunchy top	Fusarium wilt
China	-	-	-	-	-	x	x
India	-	x	-	-	-	x	x
Brazil	-	-	x	-	-	-	x
Egypt	-	-	-	-	-	x	-
Pakistan	x	x	-	-	-	x	x (Rare)
Spain (CI)	-	x	-	-	-	x	x
South Africa	-	-	x	-	-	-	x
Morocco	x	-	-	-	-	x	-
Turkey	-	-	-	-	-	-	-
Argentina	-	x	x	-	-	-	-
Lebanon	Nd	Nd	Nd	Nd	Nd	Nd	x
Israel	-	-	-	-	-	-	x
Australia	x	x	x	-	-	-	x
Portugal	-	x	-	-	-	-	x (only in Madeira)

BN = Burrowing nematode; BW = Banana weevil; (*) Sigatoka leaf spot (black leaf streak only reported for Brazil). x = reported as main pest or disease; - = Not reported as main pest or disease. Nd = No data obtained.

FUTURE PROSPECTS

The future of marketing bananas produced in the subtropics may be promoted by the advantage of lower pest and disease incidence which will favour organic cultivation together with reduced costs of fungicides/insecticides. Another benefit can come from the rising concern about the carbon footprint, which is much reduced in the case of subtropical production in the Mediterranean countries or subtropical European regions due to the proximity to the European Union (EU) market. Most of the bananas produced in the subtropics are consumed locally in markets more tolerant of minor quality blemishes. Proximity to the markets gives subtropical bananas considerable advantages regarding taste, maturity and freshness, because bunches can be left on the plant until nearly mature and fruits reach the ripening rooms within two or three days of harvest, thus increasing quality and yield. However, banana production in the subtropics faces marketing problems due to the strong competition from tropical producing countries dominated by multinational companies and in fact, as seen below, there has not been much increase in banana plantings in the subtropics in recent years.

From the information gathered in the survey sent to the different banana producing countries in the subtropics, Turkey, with 4,492 ha in 2012 and 6,225 ha in 2016, is the only country in which banana plantings are increasing. The reason for this increase is the existence of very high import taxes (over 140%), the government incentives for banana farmers, no over-production pressure and an undersupplied local market with stable prices (Gubbuk et al., 2017). Due to greater net return per ha than other fruit crops, banana is also an emerging fruit crop in Pakistan but poor availability of good quality water and the lack of proper packhouse and postharvest systems limits large-scale cultivation. Prices for bananas in South Africa are also very attractive but, despite this strong incentive to grow bananas, the incidence of Panama disease subtropical race 4 restricts the potential of the industry to grow. Egyptian banana plantations, which produce for local markets and also exports to Syria and United Arabs Emirates have expanded in recent years - 5,000 ha were planted in 2017 – but the recent prohibition of planting bananas in this country because of the high water requirement of this crop will impede future growth. The prospects in Israel, which produces virtually only under netting greenhouse structures in order to save water, are for an increase of 70-80 ha/year to cope with Israeli population growth. Banana plantings in the Canary Islands, Madeira and Morocco are not expected to increase, or may even slightly decrease due to the strong competition of imported bananas, in the case of the Spanish and Portuguese markets, from the so-called dollar bananas and, in the case of Morocco, from bananas entering from West African countries. The area devoted to bananas in the subtropical belt of Australia is in decline, with Australian demand being supplied by the production of bananas in the tropical areas of that country, however there is still strong demand in Australia's subtropical banana producing regions for locally produced fruit. Banana cultivation in China which produces for its local markets and exports bananas to Russia, Japan and Kazakhstan, is in decline both on the mainland and in Hainan and Taiwan due to low prices and Fusarium wilt incidence. Prospects for the rest of the subtropical countries, are also limited to supply the local market and no further increase in banana production is expected, even if Panama and other pests and diseases can be excluded or controlled.

Finally, it should be mentioned that the predicted climatic changes regarding increased global temperature and drought may be more or less conducive to banana production under irrigation in the subtropics by diminishing some of the main problems for cultivation of bananas in this part of the world. Exceptions may be in places like Salta in Argentina, Sindh in Pakistan and Uttar Pradesh in India, which already have extremely high summer temperatures that are marginal for banana cultivation (Calberto et al., 2015). Theoretically the projected temperature increases may boost the incidence of Burrowing nematode and Moko, pests not currently prevalent in the subtropics. Climate projections until 2070 indicate that rainfall distribution on average will not change over the projected period for any of the 24 sites studied, 6 of which are subtropical. Therefore, the incidence of Black Leaf Streak will continue to be a challenge only in the actual wet subtropical areas, as per the current situation. More problems may be expected in the case of Panama disease. The optimum range of temperature for Foc growth is between 23 and 27 °C but the pathogen can grow in vitro up to 38°C (Pérez et al, 2003), and the disease become usually more intense during the warmer and wet months of the year (Pérez-Vicente et al., 2014). While the increase of temperature may reduce the incidence of milder strains of Fusarium, the development of which is linked to unfavourable conditions such as low temperature in the subtropics, TR4 may become even more aggressive at higher temperature than those presently occurring in the subtropics. As the main future challenge for subtropical banana scientists, managing this threat will require either strong quarantine measures or the breeding of new cultivars resistant to TR4 which are well accepted by the market.

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