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RELATIONSHIPS BETWEEN WINTER HARDENING TEMPERATURES AND SPRING BUD BREAK IN *CITRUS* AND RELATED SPECIES

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Abstract. **Spring leaf and flower bud break characteristics of *Citrus*, *Citrus* hybrids, and related species were evaluated under natural conditions from 1974 to 1978. Included were *Eremocitrus glauca*, *Poncirus trifoliata*, *Fortunella* sp., *Eremocitrus* hybrids, *P. trifoliata* hybrids, sour orange, grapefruit, 'Calamondin', and rough lemon. Under natural conditions, spring leaf bud break was latest on *Poncirus*, *Eremocitrus*, and *Fortunella*, followed by *Eremocitrus* hybrids. *Citrus* selections had the earliest leaf bud break. *Eremocitrus glauca* appeared to impart later spring leaf bud dormancy than did *P. trifoliata* to their *Citrus* hybrids. Spring flower bud break occurred prior to leaf bud break on *P. trifoliata* and *E. glauca* and subsequent to leaf bud break on their hybrids and *Citrus* selections. In general, leaf bud break required more time after growth temperatures occurred following mild winter hardening temperatures (147 hours at or below 7.2°C) than following cold winter-hardening temperatures (752 and 762 hours at or below 7.2°). Flower bud break followed similar trends.**

Under controlled environmental conditions, bud break was delayed in 7 of 10 cultivars at 21°C growing conditions when plants were preconditioned to 21°/10° day/night temperatures for 4 weeks compared to longer and colder conditioning regimes.

Midwinter or early spring bud growth in response to warm temperatures happens more frequently with *Citrus* cultivars in mild climates. Young shoots and flowers are very tender to cold, and when present during the winter or early spring are likely to be exposed to subfreezing temperatures. Although several reports have related air and soil temperatures to the extent of flushing and flowering of citrus[4,5] and to dormancy of *Poncirus trifoliata* (L.) Raf.[7,8,17] and *Citrus* cultivars and hybrids,[17] studies relating spring bud break to winter temperatures have not been reported. Current knowledge of spring bud break of *Citrus* cultivars and related species has been gained primarily through observations. Swingle[9] states that *P. trifoliata*, a relative of *Citrus*, is deciduous and has a deep winter dormancy, whereas *Eremocitrus glauca* (Lindl.) Swing., a xerophytic relative, has a greater winter dormancy than *Citrus* but does not equal *Fortunella* for both dormancy and cold hardiness.

One of the objectives of the citrus cultivar improvement program of the U. S. Department of Agriculture is to increase the winter and spring dormancy and cold hardiness of new citrus cultivars. Currently *P. trifoliata*, *Eremocitrus*, and *Fortunella* are being used as sources of dormancy and cold hardiness. Knowledge of midwinter or spring bud break characteristics of *Citrus* and related species, particularly in a mild climate like Florida's, is useful to the citrus geneticists in selecting suitable parental sources of dormancy and in developing new cold-hardy cultivars.

The purpose of this paper is to relate winter hardening temperatures to spring bud break characteristics of selected *Citrus* cultivars, hybrids, and related species.

Materials and Methods

Plant materials

Observations were made on mature seedling trees of the following: *P. trifoliata* cvs. English Dwarf, Argentina, Flying Dragon, Pomeroy, Kryder 15-3, Kryder 25-4, Rubidoux 55-124, Marks Small 54-76-4, Swingle, Kryder 55-1, Rubidoux 55-123, Large Flower, Marks 54-96-13, English Large, Kryder 43-3, Ronnse, Rich 16-6, Marks 54-96-11, Davis A, Yamaguchi, Chambers, Rich 21-3, Christian, Jacobson 56-5, Kryder 5-5, Rich 7-5, Gainesville, 3F-14, Rubidoux 56-6, English Small, Town G, Rich 5-2, Kryder Medium, Marks 54-96-1, Rich 22-2, Small Flower, Benecke, and Kryder 15-5; *Eremocitrus glauca; E. glauca* × *C. reticulata* Blanco hybrids: *E. glauca* × *C. sinensis* (L.) Osbeck hybrids; hybrids of *E. glauca* × *C. reticulata* var. austera; *Fortunella margarita* (Lour.) Swing. cv. Nagami; *Fortunella* hybrid cv. Meiwa; *P. trifoliata* × *C. limon* hybrid citremon 46216; *Fortunella margarita* × *(P. trifoliata* × *C. sinensis)* cvs. Thomasville and 48032 citrangequats; *P. trifoliata* × *C. sinensis* cvs. Troyer, Savage, Carrizo, Yuma, Norton, Rustic, and Phelps citranges; *C. paradisi* Macf. × *P. trifoliata* cv. Swingle citrumelo and citrumelo hybrids 4590, 4481, and 4551; *C. limon* cv. rough lemon; *C. paradisi* Macf. cv. Ruby grapefruit; *C. aurantium* L. cv. sour orange; and *C. reticulata* ? × *Fortunella* sp.? cv. Calamondin. These field-grown plants were located at the USDA A. H. Whitmore Foundation Farm near Leesburg, Florida.

Controlled-environment studies included 1-year-old seedlings of 'Flying Dragon' trifoliate orange, 'Meiwa' and 'Nagami' kumquats, 'Carrizo' citrange, 'Thomasville' citrangequat, 4481 and 'Swingle' citrumelos, 'Cleopatra' mandarin (*C. reticulata*), rough lemon, and 'Duncan' grapefruit (*C. paradisi*).

Bud break observations

Under natural environmental conditions, observations of incipient leaf and flower bud break were made weekly, by visual observations of the first recognizable new leaf and flower buds starting each year in January in 1975, 1976, 1977, and 1978. The dates for both leaf and flower bud break were recorded for each tree. Results are reported on the basis of averages of classification groups, i.e. *P. trifoliata*, citranges, kumquats, etc., since replications/cultivar were limited to 1 or 2 trees. Because winter temperatures varied greatly from year to year, we devised a standard system with which to compare the yearly observations by calculating the number of days between the time at which the average weekly minimum air temperatures stayed above 10°C in the spring and the actual date of leaf or flower bud break. Although other temperatures could have been selected for this purpose, 10°C was chosen because it was near the minimum growth temperature reported for some *Citrus* cultivars.[17]

Leaf bud break was also recorded from daily observations of seedling plants placed in environmental growth chambers at 21°C after exposure to hardening temperatures.

Controlled environment studies

One-year-old nucellar seedlings, which were grown in greenhouse conditions, were selected in a quiescent bud-growth stage and with foliage fully extended and mature. None had been exposed to temperatures less than 21°C. Plants, in 3.7-liter containers, were placed in an environmental growth chamber where temperatures were maintained at 21°/10° day/night. After 4 weeks, 5 seedlings of each cultivar were removed and placed in a growth chamber at 21° for bud-break observations. The remaining seedlings were exposed to 15.5°/4.4° and 10°/–1.1°, 2 weeks each, and then exposed to 21° in a growth chamber for bud-break observations. Relative humidity was maintained at 55 ± 2.5 % and day length at 12 hours.

Results

Winter-spring temperature variations

Average monthly maximum and minimum air temperatures varied greatly among the winters of 1974–75, 1975–76, 1976–77, and 1977–78 (Table 1). In the 1974–75 winter, air temperatures were the warmest of the 4 years studied. Average maximum air temperatures ranged from 25° to 19°C, while average minimum temperatures ranged from 13° to 9°. The 1976–77 and 1977–78 winters were the coldest. In 1976–77, maximum air temperatures ranged from 25° to 15°; in 1977–78, they ranged from 24° to 16°. Minimum air temperatures for the same 2 winters ranged from 13° to 2° and 17° to 4°, respectively.

Year	Nov.	Dec.	Month Jan. (°C)	Feb.	Mar.	Hours at or below 7.2°C
1974–75						
Max	25	19	22	24	25	147
Min	13	9	10	12	12	
1975–76						
Max	24	21	18	23	26	394
Min	14	8	6	9	13	
1976–77						
Max	21	19	15	19	25	752
Min	9	7	2	5	13	
1977–78						
Max	24	20	17	16	24	762
Min	17	7	5	4	11	

Table 2. Average monthly maximum and minimum soil temperatures (10 cm) in Lake Alfred, Florida.

Year	Nov.	Dec.	Month Jan. (°C)	Feb.	Mar.
1974–75					
Max	24	19	21	24	26
Min	19	14	16	19	19
1975–76					
Max	23	18	17	21	27
Min	18	14	12	14	21
1976–77					
Max	19	19	16	18	24
Min	18	14	11	12	19
1977–78					
Max	25	19	18	18	25
Min	18	13	11	11	14

The number of days when subfreezing temperatures occurred were: 1 in 1974–75, 7 in 1975–76, 16 in 1976–77, and 13 in 1977–78. Accumulative hours at or below 7.2° were 147, 394, 752, and 762, respectively.

Soil temperatures were not measured at the USDA research farm in Leesburg, but were available from the citrus experiment station in Lake Alfred, 50 miles south (Table 2). Although these temperatures were likely to be 1° to 2°C warmer than at Leesburg, they illustrate the differences which occurred among the 4 winters. Warmest temperatures at the 10-cm soil depth occurred in the 1974–75 winter, whereas the coldest occurred in the 1976–77 and 1977–78 winters. Average minimum soil temperatures ranged from 19°C to 14° in 1974–75, to 18° to 11° in 1977–78. Average minimum soil temperatures never reached 10° at Lake Alfred, but it is likely that they did in January and February in the 1976–77 and 1977–78 winters in Leesburg. The number of days when soil temperatures were 10° or lower were 3 in 1974–75, 17 in 1975–76, 21 in 1976–77, and 37 in 1977–78.

The coldest month of the 1974–75 winter was December, while in succeeding years the coldest months were January and February. This was reflected not only in the average monthly minimum temperatures, but also when the average minimum weekly air temperatures stayed above 10°C, which was December 18, 1974; February 13, 1976; February 28, 1977; and March 13, 1978.

Leaf bud break under natural conditions

In the 1974–75 winter, the warmest of the 4 winters in this study, *E. glauca* was the latest in the spring to begin leaf bud growth (bud break). *P. trifoliata*, *E. glauca* hybrids, and *Fortunella* began spring leaf bud growth just prior to *E. glauca* (Table 3). Citremon, citrangequats, citranges, and citrumelos, all hybrids of *P. trifoliata*, were intermediate in regard to spring leaf bud break, whereas the earliest in the spring to begin leaf bud growth was rough lemon, grapefruit, sour orange, and 'Calamondin'. In each of the succeeding 3 years, which were progressively colder, the differences among these major groupings were greatly reduced. *E. glauca*, *P. trifoliata*, *Fortunella*, and *E. glauca* hybrids

Cultivar or type of hybrid	No. trees	Leaf bud break (days) 1974–75	1975–76	1976–77	1977–78
E. glauca	1	125	26	7	9
P. trifoliata	74	82	28	14	13
Fortunella	3	61	26	14	16
E. glauca × mand.	3	65	30	10	5
E. glauca × Rang.	4	66	23	12	4
E. glauca × Swt. Or.	7	51	21	10	6
Citremon	2	48	6	0	0
Citrangequat	4	39	6	0	8
Citrange	19	38	11	2	1
Citrumelo	18	33	8	0	0
Rough lemon	1	22	6	0	2
Grapefruit	2	22	6	0	2
Sour orange	1	22	6	0	0
Calamondin	1	22	6	0	0
Mean		50	15	5	5
Year mean LSD 5% = 6					

Table 4. Number of days between the time the average weekly minimum air temperatures stayed above 10°C in the spring and the date of flower bud break.

Cultivar	No. trees	Flower bud break (days) 1974–75	1975–76	1976–77	1977–78
E. glauca	1	–	–	–	2
P. trifoliata	74	37	20	4	5
E. glauca × mand.	3	–	–	–	16
E. glauca × Rang.	4	–	–	9	14
E. glauca × Swt. Or.	7	–	–	9	16
Citremon	2	48	13	7	2
Citrangequat	4	42	16	10	14
Citrange	19	33	13	1	5
Citrumelo	18	30	12	2	5
Rough lemon	1	–	20	14	28
Grapefruit	2	39	26	7	0
Sour orange	1	37	13	7	2
Calamondin	1	22	0	0	–
Mean		36	15	6	9

were similar, although *E. glauca* tended to begin leaf bud growth sooner than *P. trifoliata* and the *Fortunella*. Citremon, citrangequats, and citrumelos, all behaved similar to *Citrus* cultivars. Leaf yellowing and abscission occurred each year on *P. trifoliata* but not on the other cultivars.

On a yearly basis, the actual date of leaf bud break among all cultivars ranged from January 9 toApril 22, 1974–75; February 19 to March 14, 1975–76; February 27 to March 14, 1976–77; and February 27 to March 29, 1977–78. The actual leaf bud break period for the cultivars studied was more compressed and later in the spring of the colder winters. Of *P. trifoliata*, the citranges, and the citrumelos where numerous cultivars were available, variability within the *P. trifoliata* group was greatest but, in general, leaf bud break of most trees in each of the 3 groups occurred within ±7 days of the mean. Greatest variability occurred following the mild winter.

The number of days between the time the average weekly minimum air temperatures stayed above 10°C in the spring and the actual date of leaf bud break in the 1974–75 winter ranged from 22 to 125, averaging 50. In the 3 succeeding and progressively colder winters, the mean for the same cultivars was 15, 5, and 5 days, respectively.

Flower bud break under natural conditions

Eremocitrus glauca and *E. glauca* hybrids, because of a younger age, did not flower until after the winters of either 1976–77 or 1977–78 and, consequently, little information was obtained. *Fortunella* flowered late in the spring (after April 1), when observations were terminated, so the actual dates were not recorded.

Flower bud break on *P. trifoliata* and *E. glauca* always occurred prior to leaf bud break, but subsequent to leaf bud break on all *Citrus* cultivars and the *P. trifoliata* and *E. glauca* hybrids studied (Table 4). Flower bud break on *P. trifoliata* occurred at least a week before leaf bud break, and with the *Citrus* cultivars and hybrids, it occurred concurrently with or up

Table 5. Time required for leaf bud break at 21°C following conditioning at 21°/10° day/night temperatures for 4 weeks followed by 15.5°/4.4° and 10°/–1.1° for 2 weeks each.

Cultivar	Bud break at 21°C (days)	
	21°/10°	21°/10° + 15.5°/4.4° + 10°/–1.1°
P. trifoliata cv. Flying Dragon	31	22
Fortunella cv. Meiwa	17	12
Citrange cv. Carrizo	16	9
Citrangequat cv. Thomasville	15	10
Fortunella cv. Nagami	15	10
Cleopatra mandarin	14	8
Citrumelo cv. Swingle	12	12
Citrumelo No. 4481	11	15
Rough lemon	9	5
Duncan grapefruit	4	6
Treat. mean LSD 1% = 4		

to 4 weeks subsequent to leaf bud break. Except for *E. glauca* and its hybrids, where data were missing, flower bud break patterns generally followed trends similar to those of leaf bud break. Mean days to flower bud break were 36, 15, 6 and 9, respectively, for the 4 years. But these means were not completely accurate because significant data were missing, primarily from the first 2 years of study.

Leaf bud break under controlled evironments

Seedlings of *P. trifoliata*, 2 *Fortunella* cultivars, a citrangequat, a citrange, 2 citrumelos, a mandarin, a lemon, and a grapefruit were exposed to 2 hardening regimes following which leaf bud break was determined at 21°C. Seven of the 10 cultivars evaluated required fewer days for leaf bud break at 21° following exposure to 21°/10°C, 15.5°/4.4°, and 10°/–1.1° as compared to exposure to 21°/10° only. These were *P. trifoliata*, 'Nagami' and 'Meiwa' kumquats, 'Cleopatra' mandarin, 'Thomasville' citrangequat, Carrizo citrange, and rough lemon (Table 5). *P. trifoliata* required the most days for leaf bud break to occur, whereas rough lemon and 'Duncan' grapefruit required the least. Under the 21°/10° conditions, leaves of *P. trifoliata* turned yellow and abscised, but leaf coloring and abscission did not occur on the other cultivars at any of the temperatures.

Discussion

Swingle[9] reported that *E. glauca* did not equal *Fortunella* cultivars for both winter dormancy and hardiness, while *P. trifoliata* was superior to both. In our studies over a 4-year period, including 1 mild and 2 cold winters, spring leaf bud break of *E. glauca* was 64 days later following the mild winter than that of *Fortunella*, and 0 to 7 days earlier following colder winters. Except for the mild winter, when *E. glauca* was 43 days later than *P. trifoliata*, spring leaf bud break was 2 to 7 days earlier than for *P. trifoliata*. Spring leaf bud break was similar among the 3 species following the 3 winters when colder temperatures prevailed; and only following the very mild winter of 1974–75 were spring leaf bud break characteristics of the 3 species greatly different. Yelenosky *et al.*[12] found *E. glauca* and several *E. glauca* hybrids to be more cold hardy than *Fortunella* under both natural and artificial hardening conditions. We suspect that *E. glauca*, under Florida conditions, is in fact as cold hardy and exhibits similar winter dormancy to *Fortunella*. *P. trifoliata* is definitely more cold hardy than *Fortunella*,[9] but direct comparisons of *P. trifoliata* with *E. glauca* have not been reported. The earliest spring leaf bud break was on the *Citrus* cvs. rough lemon, grapefruit, sour orange, and 'Calamondin', as expected. Of particular interest was the *E. glauca*-transmitted later spring leaf bud break tendencies to mandarin, sweet orange, and Rangpur lime hybrids compared to that transmitted by *P. trifoliata* to lemon, grapefruit, and sweet orange hybrids. This later spring dormancy and increased cold hardiness of F_1 hybrids of *E. glauca*[12] and the knowledge that the fruit are nearer to being palatable than F_1 hybrids of *P. trifoliata*[1] indicate that *E. glauca* is an excellent parental candidate for use in the development of new cold-hardy scion cultivars.

Spring flower bud break occurred prior to leaf bud break on *P. Citrus* cultivars and *Fortunella*, including their hybrids. *Fortunella* was the latest to flower in the spring. *P. trifoliata* actually exhibited bud break activity (flowers) prior to that of several cultivars, including *Fortunella* and the *E. glauca* hybrids. Presumably, had *E. glauca* flowered between 1975 and 1977, it also would have been earlier than several cultivars.

Winter temperatures had a pronounced effect on spring bud break. Spring bud break occurred (chronologically) the latest in 1977 and 1978, the coldest years, and the earliest in 1975, the warmest. This was true of both leaf and flower buds. Based on average monthly maximum and minimum air and soil temperatures, the coldest months were January and February in the 1976-77 and 1977-78 winters, and December and January in the 1974-75 winter. In the colder winters, coldest temperatures occurred later in the spring and the later bud break which occurred in 1977 and 1978, compared to 1975, was expected.

However, because the data when favorable growth temperatures occurred varied greatly each year, the actual bud break date could not be used in comparing responses from year to year. To overcome these yearly variations, we devised a standard whereby the number of days between the time the average weekly minimum air temperatures stayed above 10°C in the spring and the actual date of leaf or flower bud break was calculated. The 10° standard was selected on the basis of previously reported minimum growth temperatures for several cultivars.[17] If 12.8° were used as the standard for *P. trifoliata*, which has a higher minimum growth temperature, the time required for spring bud break in any given year was similar to that of grapefruit or sour orange, for example. It was apparent by using this procedure that the cultivars studied required a longer time for bud break after 10° minimum temperatures (or 12.8° in the case of *P. trifoliata*) were reached in the spring following a mild winter than following 2 very cold winters. These results suggested that colder winter temperatures predisposed trees of *Citrus* and related species to a quicker resumption of spring bud growth once growth temperatures were reached. Examination of temperature records indicated no unusual patterns in the spring after the 10° minimum was reached. Average weekly maximum air temperatures ranged from 21° to 27° for each of the 4 years studied. Soil temperatures were warmer during the 1974-75 winter and apparently not a factor in the much later bud break.

Further evidence that colder hardening temperatures affected leaf bud break was obtained in controlled environments. Seven of 10 cultivars exposed to mild or cold hardening temperatures resumed bud growth sooner at 21° following the colder hardening conditions.

Bud break observations seemed to suggest that the resumption of bud growth in the spring was not through a simple mechanism of dormancy release once temperatures were above the minimum for growth. For example, leaf bud break on *E. glauca* started April 22 following the mild winter of 1974-75 when average minimum air temperatures were above 10°C after January. And, although air and soil temperatures around seedlings were kept at 21° in environmental chambers for bud-break observations, well above minimum growth temperatures, differences in the time required for bud break occurred among cultivars and from colder hardening temperatures. Stathakopoulos and Erickson[8] suggested that chilling is not required for bud break on *P. trifoliata*, but that soil temperature above 12.8° was an influential factor controlling dormancy release provided the plants had been exposed to a certain amount of accumulated degree hours above a threshold temperature. Although the present studies were not designed to address the subject of chilling per se, observations indicated that colder winter temperatures predisposed plants to a more rapid dormancy release than did mild temperatures. Accumulated hours at or below 7.2°C (a factor associated with chilling requirements of peaches) appeared to be inversely related to the time required for spring bud break.

Cooler air and soil temperatures are reported to increase dormancy[2,3,16] and cold hardiness.[11,13] Associated with winter hardening of citrus are shifts in various metabolites including sugars,[10,13,14] proline,[10,11] and abscisic acid and gibberellins.[6]

Differences among cultivars in dormancy release in the spring associated with colder winter temperatures may be related to changes in these or other metabolities. Further characterization may provide the basis for a chemical control mechanism for dormancy release.

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CITRUS CULTURE IN THE HIGH ALTITUDE AMERICAN TROPICS

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Abstract. **Most major citrus plantings are at altitudes below 1000 m. Nevertheless, there are many trees at higher altitudes producing fruit mainly for local markets. Few observations have been accumulated on citrus behavior at high altitudes. This paper presents information on the behavior of several citrus species in the high altitude American tropics. Changes in altitude determine changes in the environment, which in turn determine vegetational variation. The environmental parameter most influenced by altitude is temperature. Light intensity and quality are also influenced directly by altitude. Rainfall, winds and ambient humidity are mostly affected by the type and direction of the slope and by the general movement of the atmosphere. Citrus culture in the high altitude American tropics occurs in valleys with microclimates differing in mean temperature, rainfall and humidity. Most of those valleys are free of strong winds, hail and heavy frost. Citrus culture for commercial purposes may go as high as 2,400 m. But for ornamental use several species are grown up to 2,800 m in areas close to the equator. Temperature appears to be the major environmental factor limiting citrus growth and production at high altitudes. Probably the largest citrus collection located at the highest elevation in the world is at the Granja Tumbaco, Quito, Ecuador, at 2,350 m. Some data on growth and tree size, and other observations on 24 cultivars of 18 species included in this collection are presented, plus observations on insect pests and cultural practices.**

Citrus fruit species are native to a large area extending from the Himalayan foot-hills of north-east India to north-central China, the Philippines in the east and Burma, Thailand, Indonesia and New Caledonia in the south-east. The only exception is the grapefruit (*Citrus paradisi* Macf.) which appeared in the West Indies (Barbados) about 1750.[5]

The first citrus fruit known to Western civilization, the citron was found cultivated in Iran some 2,300 years ago by the Greek botanist Theophrastus. Surely citrus species were cultivated several thousands of years before in their centers of origin. Early distribution of citrus was slow, and was carried out by Arab sailors and the caravans from the east. In this way citrus spread to the Sea of Oman, Egypt and later Europe. Christopher Columbus brought sweet orange, lemon, citron and other citrus to America from the Canary Islands in his second trip in 1493. Sweet orange came to South Africa in 1654. Captain George Vancouver brought the orange to Hawaii in 1792. The Bahía orange or navel orange was taken to Australia from Brazil in 1824 and later to North America and other countries.[24]

Thus original distribution of citrus around the world took place mostly by sea and the first plantings in every country, outside its center of origin occurred at sea level. Further, in most countries where citrus production is an important industrial activity, it is located at low altitudes below 1,000 m. Burke, [3] in his description of the commercial citrus regions of the world, mentions only one country (Mexico) where commercial citrus culture occurs at high altitudes, namely up to 1,800 m. Very few references, if any, deal with the behavior and culture of citrus trees at altitudes higher than 1,500 m. This paper intends to present some information on the culture and behavior of citrus at high altitudes in tropical America.

The Tropics

The tropics lie between the Tropics of Cancer and Capricorn on either side of the equator. Within the tropical area, however, there are high mountains which modify the climate considerably. The term "tropical areas" is applied mainly to areas where a tropical climate is found. That is, the areas of the world where frost never occurs. This definition implies both an altitudinal and a latitudinal limit for the tropics. On the other hand, the subtropics are those areas where frost occurs occasionally, and are located at latitudes North and South adjacent to the tropics. Subtropical climates, however, are also found in the tropics in areas at certain altitudes.[23]

Regardless of the altitude, the climate of any given site in the tropics, close to the equator, differs from that of sites at different latitudes in 2 major characteristics. First, the photoperiod or daylength. This climatic parameter includes the number of hours with sunlight, based on time of sunrise and sunset. Since the light intensities that control photoperiodic reactions in plants are considerably lower than levels occurring during hours of sunlight, apparently the time of twilight should be included to define daylength.[9] There is negligible to low daylength variation from