PLANT HEAT ZONES OF MEXICO

L. E. Giddings[¶]; M. Soto-Esparza
Instituto de Ecología, A. C. m. 2.2 Carretera Antigua a Coatepec Núm. 351, A. P. 63, Xalapa Veracruz, C. P. 91070. MÉXICO.
Correo-e: giddings@ecologia.edu.mx. ([¶]Corresponding author).

ABSTRACT

A Plant-Heat Zone Map of Mexico is presented, equivalent to the "Plant Heat-Zone Map" of the United States of America (USA). It presents the average number of days per year with maximum temperature over 30 °C (86 °F). Its principal use is to evaluate the potential for cultivating an ornamental plant in a given locality, as does the corresponding USA map, prepared by the American Horticultural Society. In an electronic form it may also be used for calculating potential distributions of wild plants. It was derived from data in the Eric II CD-ROM, which contains daily and monthly records for a large majority of Mexican meteorological stations. Data for individual stations were analyzed for the number of days over 30 °C per year, and average values were compiled. Stations with fewer than 20 years were eliminated, as were years with fewer than 360 days of data in a year. A comprehensive effort eliminated errors of various kinds. The corrected data were used to form a heat-zone map of all of Mexico using kriging (an interpolation technique). Large format maps and electronic data are available from the authors.

ADDITIONAL KEY WORDS: ornamental plants, distribution of plants, databases

ZONAS DE CALOR DE PLANTAS DE MÉXICO

RESUMEN

Se presenta un Mapa de Zonas de Calor para México equivalente al "Plant Heat-Zone Map" de los Estados Unidos de América (EEUU), el cual muestra el número de días promedio que en el año presentan temperatura máxima mayor a 30 °C (86 °F). Su uso principal es para evaluar el potencial para cultivar plantas ornamentales en un lugar dado, al igual que el mapa correspondiente de EEUU, preparado por la American Horticultural Society. También puede ser usado para determinar la distribución potencial de especies silvestres. Fue derivado a partir de los datos de Eric II, CD-ROM que tiene registros diarios y mensuales de un gran número de estaciones meteorológicas de México. Los datos de temperatura máxima extrema de cada estación fueron analizados para detectar el número de días con más de 30 °C en el año, compilándose los promedios. Las estaciones con menos de 20 años de observaciones fueron eliminadas, al igual que los años con menos de 360 días de datos. Se diseñó un proceso para suprimir posibles tipos de errores de la fuente de datos. A partir de los datos depurados y empleando el proceso de kriging (una técnica de interpolación) se elaboró el Mapa de Zonas de Calor para la República Mexicana. El mapa impreso o en formato digital así como los datos están disponibles a través de los autores.

PALABRAS CLAVE ADICIONALES: plantas ornamentales, distribución de plantas, bases de datos

INTRODUCTION

Gardeners in the United States of America (USA) have traditionally used the Plant Hardiness Zone Map (USDA, 1990) to predict the viability of plants in a given area. This important publication, originally published in 1960 and revised in 1990, uses the average minimum temperature to indicate whether plants will "winter over" (survive the coldest part of the year). This has always furnished a valuable indication of the viability of ornamental plants.

The map was further extended to Mexico and is available over the Internet but apparently is not available on paper. It is explicitly available for any use: "This map is not copyrighted, and permission for reproducing it is not required" (USDA, 1990).

Of course, minimum temperature is only one of the many variables that control distribution. Plants also vary in their ability to withstand high temperatures. Recognizing

Recibido: 17 de febrero, 2004
Aceptado: 23 de junio, 2005

this, Dr. H. Marc Cathey, former director of the National Arboretum of the USA, promoted the preparation of a comparable map of heat zones. The American Society for Horticultural Science (ASHS), of which he is President Emeritus, contracted the preparation of the Plant Heat-Zone Map and published it (ASHS, 1997) and its description (Cathey, 2001). This map presents the annual number of days with highs over 30 °C (86 °F), which is said to be the point at which plant proteins may experience damage. Whereas the Plant Hardiness Zone Map indicates the most extreme winter conditions, the Plant Heat-Zone Map indicates the most extreme summer conditions. The combination of the two can give valuable information for the gardener.

Recognizing that both the Plant Hardiness Zone Map and the Plant Heat-Zone Map are useful for gardeners in the USA, we decided to complete them for Mexico. Since the current version of the former includes Mexico, but the latter does not, we decided to prepare the Plant Heat-Zone Map for Mexico. We feel that furnishing new sources of information to gardeners in Mexico would help their competitive advantages as they face integration into the process of globalization.

MATERIALES AND METHODS

The source of all meteorological data used here is the CD-ROM, Eric II (Eric II, 2000). Eric is the most complete compilation of daily and monthly meteorological data currently available for Mexico (Quintas, 2000). The maximum daily temperature data were extracted using the program included on the CD. Corrections for the state of Chiapas were furnished by the author, who also graciously added some additional years of data for some stations.

A Fortran program was prepared to calculate the number of days with highs over 30 °C for each year of data and count the total number of days with data. A second program assembled the data, eliminated years with fewer than 360 days with data, and eliminated the stations with fewer than 20 years of usable data, producing a record for each usable station. This program calculated the average, and also, for diagnostic purposes, the standard deviation of the results.

These data were imported into an Excel worksheet and examined for apparent errors. The Excel data were imported into Surfer (Golden, 1999) and interpolated into a grid using a kriging algorithm, and then converted to a contour map and a residual map. The residuals are the difference between the generated surface and the original data; large values sometimes indicated erroneous input data.

There are many potential sources of errors. The data in Eric were simply copied by hand from original records and sometimes included errors, mostly of transcription. Elimination of errors was pursued in several ways, including searching individual errant years as identified by the standard deviation, identification of deficient areas indicated by the residual map, and others.

It is obvious that there is some relation of heat days to temperature, in particular to maximum temperature, and that temperature in general is related to elevation and to latitude. To see whether the final map could be improved by these relations, regression of heat days *vs.* maximum temperature, elevation, and latitude were calculated for different zones, and maps calculated on their basis. However, none of these relations showed promise for increasing the precision of the final map, probably because of the great density of meteorological stations in Mexico (Figure 1). None were incorporated into the map.

The final map (Figure 2), was the result of an iterative process of elimination of errors and recalculation of the grid.

The ASHS map was prepared before daily data were available for Mexico. As a result, data across the border in Mexico were not used in its preparation. By the same token, USA data were not used in the preparation of this map. As a result, there are small discrepancies between the two maps; the USA map can be seen on the Internet. However, it is apparent that in no case do discrepancies exceed a single zone, and in general, the equivalence at the border is quite acceptable.

It is evident, however, that the map necessarily loses precision over the highest areas in the country, since very few have meteorological stations. The description of the corresponding map of the USA (ASHS, 1997b) specifically states that "... data from weather stations at or near mountain peaks in sparsely populated areas were not incorporated")

RESULTS AND DISCUSSION

The final map is presented in colors similar to the ASHS Heat-Zone Map of the USA. It was necessary to add additional zones for the temperatures in Mexico, which are considerable higher than in the USA.

It's interesting that the zones with the highest number of days with temperatures over 30 °C do not coincide with the hottest parts of the country, those with greater than 44° C in maximum extreme temperature. These areas are located in northwest Mexico in the states of Sonora and Baja California Norte (Figure 3).

The zones with the greatest number of heat days, that is, from 271 to 301, correspond in some cases to areas where the extreme maximum reaches 40 to 44 °C, That is the case of the zone to the south of the state of Sonora and the north of Sinaloa (not on the shore). On the Yucatan Peninsula, this same number of heat days corresponds to

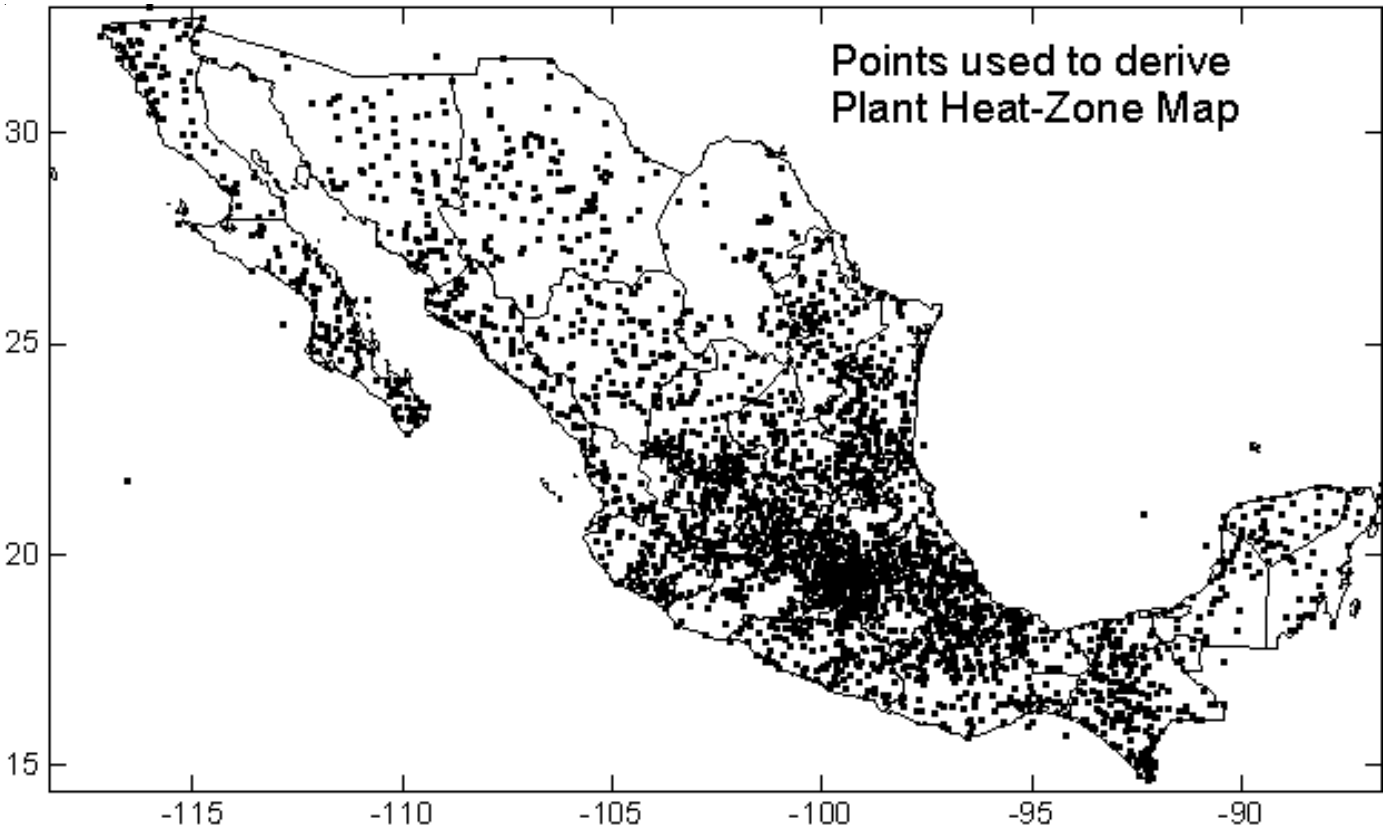

FIGURE 1. Meteorological Stations Used

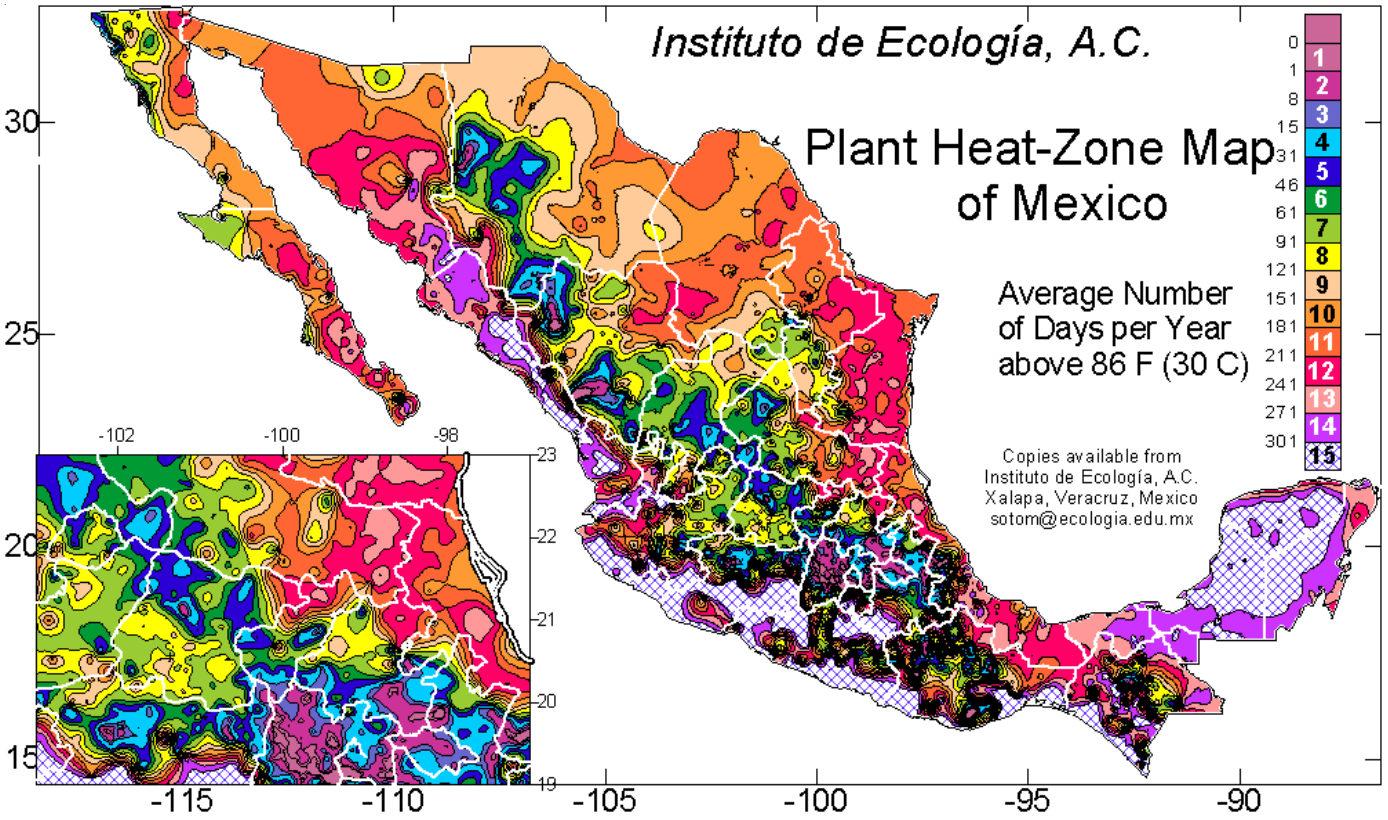

FIGURE 2. Plant Heat-Zone Map of Mexico

lower extreme maximum temperatures, from 36 to 40 °C. We should note that on the north and east of the Peninsula, the number of heat days is of the order of 211 to 241, and the extreme maximum temperature is lower, from 36 to 40 °C. This can be attributed to the thermoregulating effect of the sea.

On the coast of the Pacific Ocean, from 25°N to 15°N, there are 271 to more than 300 heat days and the maximum extreme temperature varies from 36 to 40 °C, with the exception of the Rio Balsas basin where the maximum temperatures can reach 40 to 44 °C. These high temperatures are reflected in the name given to this area, “Tierra Caliente” (“Hot Land”). Here is found the meteorological station, Huetamo, where the average temperature of the coldest month is greater than 26 °C.

Temperatures similar to the coast are found in the Central Depression of the state of Chiapas. In the southeast at altitudes less than 200 m are found the Papaloapan Basin and the Tabasco Plains, all with 211 to 271 heat days (Figure 3).

As expected, zones with fewer than 100 heat days are found in the highest parts of the various mountain systems, such as the Sierra Madre Oriental, Sierra Madre Occidental, Sierra Madre del Sur, the Neovolcanic Axis, the Sierra de Chiapas, the mountains to the north of Chiapas and in general, the zones above 1000 or 1500 m. The gradient of lessening of the number of heat days in general follows the well known relation of temperature with altitude and latitude.

In general, the largest zone of Mexico has 121 to 150 heat days, with 13 % of the area. About 23 % has more than 210 heat days.

As has been noted, the information on the Heat-Zone Map has its principal uses in the cultivation of ornamental plants. Of course, it can clearly be applied to growing other plants. With no pretension of showing practical applications, we can see that zones of production of oranges tends to occur in zone 12 (211 to 241 heat days), although they can also be found in zone ll and even to zone 15. In the case of lemon, they appear to be concentrated in zone 15, but there is also production from zones 10 to 15. Given such large intervals, it is possible that the zone depends on the variety cultivated and the management of the crop.

Other crops apparently have smaller production ranges, such as cacao in zones 13 and 14, coconut en 14 and 15, an “henequen” only in zone 15, although there are other important factors such as the soil.

It is important to mention that the geographical locations of the USA and Mexico cause the difference in temperature regimes. The most notable is the Heat Zone 12 and above, which includes less than 1 % of the area of USA

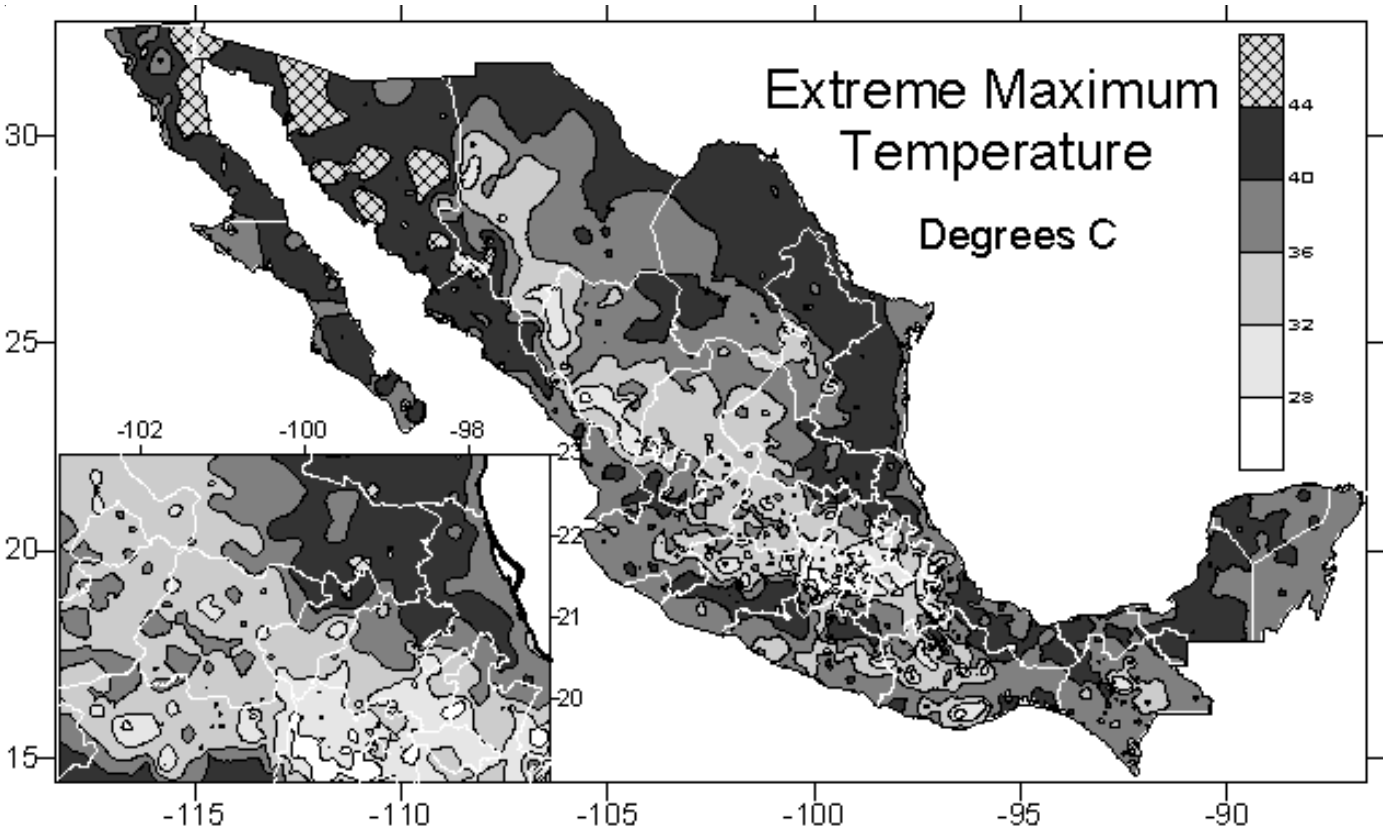

FIGURE 3. Extreme Maximum Temperature

and almost a quarter of Mexico, showing that Mexico is a tropical country.

CONCLUSIONES

The map presented here is an additional information tool which can help characterize the environmental variables that lead to the success of a cultivated plant. Although its principal use, at least in the USA, is for the cultivation of ornamental plants, its use can extend to the cultivation of other crops, and even to the distribution of wild plants.

As horticulturists have more environmental information, they will have more elements for their decisions on methods of cultivating plants. They should therefore be in better condition to compete in global markets.

We trust that the Plant Heat-Zone Map of Mexico will be as useful to Mexican gardeners as the USA map is to gardeners in the USA. We believe that these data, imported into geographical information systems, will also support studies of the potential distribution of native plants.

To a certain extent, the use of the ASHS map of the USA has been limited by its copyright, which states that "The ASHS Heat-Zone map is a copyrighted document that is wholly owned by the American Society for Horticultural Science. Any reference to, reproduction of, or attempt to code plants using the map's information without written consent by ASHS is a violation of the copyright" (ASHS, 1997)

By contrast, this heat-zone map of Mexico, although copyrighted, may be used and copied for non-commercial use, provided only that its source is cited in the following form: "This map is the property of the Instituto de Ecología, A.C., Xalapa, Veracruz, 91070 Mexico." Copies on paper and in digital form are available from the authors.

LITERATURE CITED

ASHS. 1997. Plant Heat-Zone Map (60 x 90 cm., color). American Society for Horticultural Science. Virginia, USA.

ASHS. 1997b. ASHS Resource Bulletin. American Society for Horticultural Science. Virginia, USA.

CATHEY, H.M. 2001. Heat-Zone Gardening; How to Choose Plants: That Thrive in Your Region´s Warmest Weather. Time-Life, USA.

ERIC II. 2000. Extractor rápido de ifnromación climatológica. CD-ROM del IMTA, Instituto Mexicano de Tecnología del Agua. Morelos, México.

GOLDEN SOFTWARE. 1999. Surfer 7, Program and User´s Guide. Golden Software Inc., Colorado, USA.

QUINTAS, I. 2000. ERIC II, Documentaicón de la base de datos climatológica y del programa extractor. Instituto Mexicano de Tecnología del Agua, Morelos, México.

USDA.1990. United States Department of Agriculture Miscellaneous Publication No. 1475. January, 1990, Washington, USA.