



Temporal responses of peak citrus flowering to climate change in Iran: 1960-2010

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Recent studies investigating floral and faunal phenological responses to climate change have highlighted the extent to which these relationships are species and location specific. This study investigates temporal responses of citrus peak flowering to climate change in the cities of Kerman, Shiraz and Gorgan, Iran. Phenological data comprise peak flowering dates of five citrus types: orange (*Citrus x sinensis*), tangerine (*Citrus x tangerine*), sweet lemon (*Citrus limetta*), sour lemon (*Citrus x limon*) and sour orange (*Citrus x aurantium*). These were collected daily from government heritage gardens located within each of the three cities, and archived by a private Iranian company, for the period 1960-2010. For the same period, daily Tmax, Tmin, rainfall and sunshine hour data were acquired from the Iranian Meteorological Organization. Time trend analyses were undertaken for both the phenological and meteorological data, followed by linear regression to determine the nature and extent of any relationships between these variables. We find that the mean peak flowering dates, and their long-term trends over the 51-year period, are very similar amongst the five citrus types within each city, but demonstrate significant differences between cities. Flowering date advances of 0.12-0.17d/yr are recorded for Kerman, and more rapid advances of 0.56-0.65d/yr for Shiraz. Notable progressive delays in flowering dates occur in Gorgan (0.05-0.1d/yr). The peak flowering dates of citrus in the former two cities demonstrate strong relationships with mean annual Tmin, ranging from $r = 0.46-0.61$ ($p = 0002$; $p < 0.0001$) for Kerman to $r = 0.53-0.67$ ($p = 0.0386$; $p < 0.0001$) for Shiraz, and equating to peak flowering advances of 3.15-3.39d/°C and 4.34-5.47d/°C respectively. By contrast, the strongest relationships between peak flowering dates and climate in Gorgan are with rainfall ($r = 0.02-0.3$, $p = 0.8874-0.0528$), indicating a weak phenophase response of 0.1d/mm. Gorgan also provides a somewhat rare situation of delayed citrus flowering during a time of regional and global warming. Our study highlights the importance of considering location-specific phenophase shifts within given regions, as dissimilar trends may occur within a country; this has important implications for future agricultural planning and fruit crop supply to local and international markets.