Review: Weak radiofrequency radiation exposure from mobile phone radiation on plants
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ABSTRACT
Aim: The aim of this article was to explore the hypothesis that non-thermal, weak, radiofrequency electromagnetic fields (RF-EMF) have an effect on living plants. Subject and methods: In this study, we performed an analysis of the data extracted from the 45 peer-reviewed scientific publications (1996–2016) describing 169 experimental observations to detect the physiological and morphological changes in plants due to the non-thermal RF-EMF effects from mobile phone radiation. Twenty-nine different species of plants were considered in this work. Results: Our analysis demonstrates that the data from a substantial amount of the studies on RF-EMFs from mobile phones show physiological and/or morphological effects (89.9%, \( p < 0.001 \)). Additionally, our analysis of the results from these reported studies demonstrates that the maize, roselle, pea, fenugreek, duckweeds, tomato, onions and mungbean plants seem to be very sensitive to RF-EMFs. Our findings also suggest that plants seem to be more responsive to certain frequencies, especially the frequencies between (i) 800 and 1500 MHz \( (p < 0.0001) \), (ii) 1500 and 2400 MHz \( (p < 0.0001) \) and (iii) 3500 and 8000 MHz \( (p = 0.0161) \). Conclusion: The available literature on the effect of RF-EMFs on plants to date observed the significant trend of radiofrequency radiation influence on plants. Hence, this study provides new evidence supporting our hypothesis. Nonetheless, this endorses the need for more experiments to observe the effects of RF-EMFs, especially for the longer exposure durations, using the whole organisms. The above observation agrees with our earlier study, in that it supported that it is not a well-grounded method to characterize biological effects without considering the exposure duration. Nevertheless, none of these findings can be directly associated with human; however, on the other hand, this cannot be excluded, as it can impact the human welfare and health, either directly or indirectly, due to their complexity and varied effects (calcium metabolism, stress proteins, etc.). This study should be useful as a reference for researchers conducting epidemiological studies and the long-term experiments, using whole organisms, to observe the effects of RF-EMFs.

Introduction
The number of mobile phones users was increased from about 2.2 to 5.9 billion between 2005 and -2011 (Key global telecom indicators, 2012). Approximately four mobile phone service providers exist in a given geographical area (Hyland, 2005). Consequently, the number of base stations was also increased to support the tremendous growth of mobile phone users (World Health Organisation, 2006). According to the International Telecommunication Union (ITU), this leads to high concentrations of radiofrequency electromagnetic fields (RF-EMFs) in the environment, besides high utilization of broadband technologies (International Telecommunication Union, 2012).

The World Health Organization (WHO) and International Agency for Research on Cancer (IARC) classified RF-EMFs from mobile phones as a “Possible Human Carcinogen” (Group 2B) (World Health Organisation, 2011) (May 2011) based on scientific results presented in the literature. The Interphone study (INTERPHONE Study Group, 2010) (some evidence to suggest increased risk of glioma in heavy adult users > 1640 hours) and the study by Hardell et al. (2006) indicate the growing risk of malignant brain tumors for users of cellular and cordless phones. The results from these studies have not been without controversy. The analysis presented in the another study by Swerdlow et al. (2011) proposes that there is no increase in risk, with accumulating evidence suggesting the fact that mobile phone use is safe for adults. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) report (International Commission on Non-Ionizing Radiation Protection, 1998) indicates that many of the experiments...