Oecologia Australis
24(1):185-190, 2020
https://doi.org/10.4257/oeco.2020.2401.16

NEGATIVE INFLUENCE OF LOW RAINFALL LEVELS ON FRUIT RIPENING OF *Miconia calvescens* DC. (MELASTOMATACEAE JUSS.)

Mariana Abrahão[1] & Maria Alice Santos Alves[2]*

[1] Universidade do Estado do Rio de Janeiro, Instituto de Biologia Roberto Alcantara Gomes, Programa de Pós-Graduação em Ecologia e Evolução, Rua São Francisco Xavier, nº 524, PHLC, 2º andar, sala 224, Maracanã, CEP 20550-011, Rio de Janeiro, RJ, Brazil.

[2] Universidade do Estado do Rio de Janeiro, Instituto de Biologia Roberto Alcantara Gomes, Departamento de Ecologia, Rua São Francisco Xavier, nº 524, PHLC, 2º andar, sala 220, Maracanã, CEP 20550-011, Rio de Janeiro, RJ, Brazil.

E-mails: mariana.abrahao@yahoo.com.br (*corresponding author); masaalves19@gmail.com

Abstract: Fruit ripening is the stage that most demands water. Here we report the negative influence of a shortage of water on the ripening of *Miconia calvescens* (Myrtales, Melastomataceae) fruits. In 2014 rainfall levels in Ilha Grande, municipality of Angra dos Reis, state of Rio de Janeiro, Brazil, were low in comparison with the historical means (2003-2013), leading to dry-season conditions during the peak of the wet season. The low rainfall levels may have caused the abortion of the first unripe fruit crop. Fruit development and ripening started again by the increase of the rainfall levels. The results indicate that water stress is a limiting factor for fruit ripening in this species, given that its fruits have high water content.

Keywords: Atlantic forest; fruiting; phenology; water stress.

Phenological studies determine the patterns of occurrence of repetitive biological events (Talora & Morellato 2000), which provide insights into the dynamics of the ecology of plant species and contribute to the understanding of ecosystem function and the temporal distribution of resources (Rosemartin *et al.* 2014). Climate seasonality is generally considered to be the most important factor determining the phenological patterns of plant species (Morellato *et al.* 2016).

In tropical environments with pronounced rainfall seasonality, the dry period typically determines plant phenology patterns by limiting growth and reproduction (Van der Sleen *et al.* 2015). However, some studies have shown that the variation in day length and temperatures also often influence plant phenology, given that most species present periodicity in phenological events, even in non-seasonal regions (Talora & Morellato 2000, Morellato *et al.* 2013). As fruit development and maturation are the stages that most demand water (des Gachons *et al.* 2005), a shortage of water during this period should have a negative effect on fruiting patterns, especially in species that produce pulpy fruit with high water content (Maruyama *et al.* 2007).

The phenological patterns of tropical plants are heterogeneous, and will often vary among populations, and even within a population, in relation to the age and structure of the plants, and differences in micro-habitats (Calle *et al.* 2010). Data on the dynamics of the phenological patterns of a plant species can contribute to the understanding of its survival and reproduction strategies (Chambers *et al.* 2013). While many phenological studies are available, few evaluate the influence of microclimatic conditions, such as rainfall levels, on the different phenophases (Marques *et al.* 2004).

Miconia is the largest genus of the family Melastomataceae (Myrtales), with more than 1000 registered species (Goldenberg *et al.* 2013). In areas where many *Miconia* species coexist, they typically fruit sequentially, resulting in prolonged fruit availability (Snow 1965). *Miconia* is relatively common in the Atlantic Forest (Allenspach *et al.* 2012). Most species produce abundant fruit crops throughout the year, providing a keystone resource for many frugivores (Borges 2010).

We investigated the influence of rainfall levels on the fruit ripening of *Miconia calvescens* DC, a relatively abundant species in tropical forests which lacks information about the influence of rainfall on fruit development. *Miconia calvescens* is a shrub or tree, growing to a height of up to 15 m (Meyer 1998), with a high germination capacity, tolerance of low levels of luminosity, and relatively high growth rate. It typically begins fruiting at 4-5 years of age, when grown from seed, which are dispersed by birds and small mammals (Meyer & Florence 1996). This species is a serious invader in the tropical Pacific, including the Hawaiian and Tahitian Islands, where it may form extensive monospecific stands and dense thickets that have essentially taken over large tracts of rainforest habitat (Meyer 1998).

Ilha Grande is a continental island in the municipality of Angra dos Reis (23º15' S, 44º15' W), on the southern coast of the Brazilian state of Rio de Janeiro. The island has one of the largest continuous remnants of Atlantic Forest found in the state. The field survey was carried out in a protected area, the Ilha Grande State Park, which covers more than half of the island. The vegetation consists of Atlantic Forest formations, together with areas of coastal Restinga and mangroves. The weather is tropical, with a mean annual temperature of approximately 23°C and high rainfall levels, especially during the austral summer, with a mean annual precipitation of around 1700 mm (Alho *et al.* 2002).

Fieldwork was conducted monthly between January and December, 2014. We tagged 20 trees of *M. calvescens* along a patch of Atlantic Forest, 200 m distant from one another. The Fournier index was used to estimate the intensity of the phenophases (*i.e.*, buds, flowers, unripe fruits and ripe fruits) in each individual (Fournier 1974). To estimate the availability of ripe fruit on each individual, the number of fruits of five infructescences was registered and multiplied by the total number of infructescences found on the tree (Chapman *et al.* 1992). Rainfall data were obtained from the National Institute of Meteorology (INMET) meteorological station at the municipality of Angra dos Reis, on the coast of the state of Rio de Janeiro, Brazil. In addition to the monthly precipitation values for the study period, historical means were calculated for the last 10 years (2003-2013). The relationship between monthly rainfall and ripening fruits was tested using Pearson's correlation.

The phenophases overlapped in April, May, July, and August. Flowering was discontinuous and short, with buds appearing in January-February, April-May, and July, and flowers in January-February, April-May, and July-August. The emission of buds and flowers peaked in February (Figure 1). Fruiting was prolonged, with unripe fruit being observed between March and December, and ripe fruit from May through December. Fruiting peaked in March, declining considerably in April and May, coinciding with the appearance of buds and flowers, which are consistent with the conclusion that the unripe fruit crop was aborted (Figure 1).

Monthly rainfall at the municipality of Angra dos Reis in 2014 was relatively low in comparison with the historical means for the last 10 years (Figure 2). Precipitation in January and February 2014 were comparatively lower than historical means, being comparable to levels typical of the dry season.

The *M. calvescens* trees bore an average of 91 ± 33 (SD) infructescences per individual, bearing thousands of small fruits (less than 1 cm). The number of ripe fruits began to increase considerably in August (Figure 3), although there was a decrease in precipitation in August and September, which coincided with a decrease in the presence of ripe fruits in September (Figure 3). The fruits began to ripe in May, but the number of ripe fruits began to increase noticeably only in October, peaking in November and December (Figure 3).

Unripe fruit began to appear in March, but this crop was aborted, and the quantity of unripe fruits recorded in April and particularly in May decreased considerably. The proportion of juvenile fruits that ripe depends on many factors, such as weather conditions, seed predation and the ability of the maternal parent to provide the resources necessary

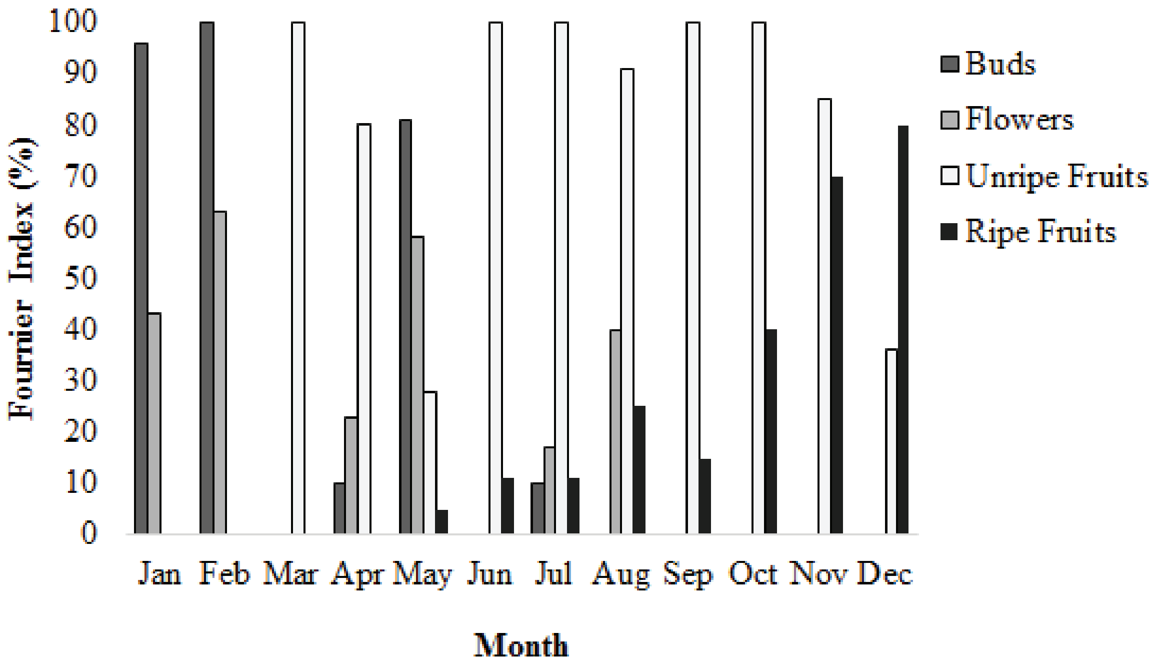

Figure 1. Fournier index recorded monthly in 2014 for the phenophases of *Miconia calvescens* (Myrtales, Melastomataceae) trees monitored in a fragment of Atlantic Forest at Ilha Grande, state of Rio de Janeiro, Brazil.

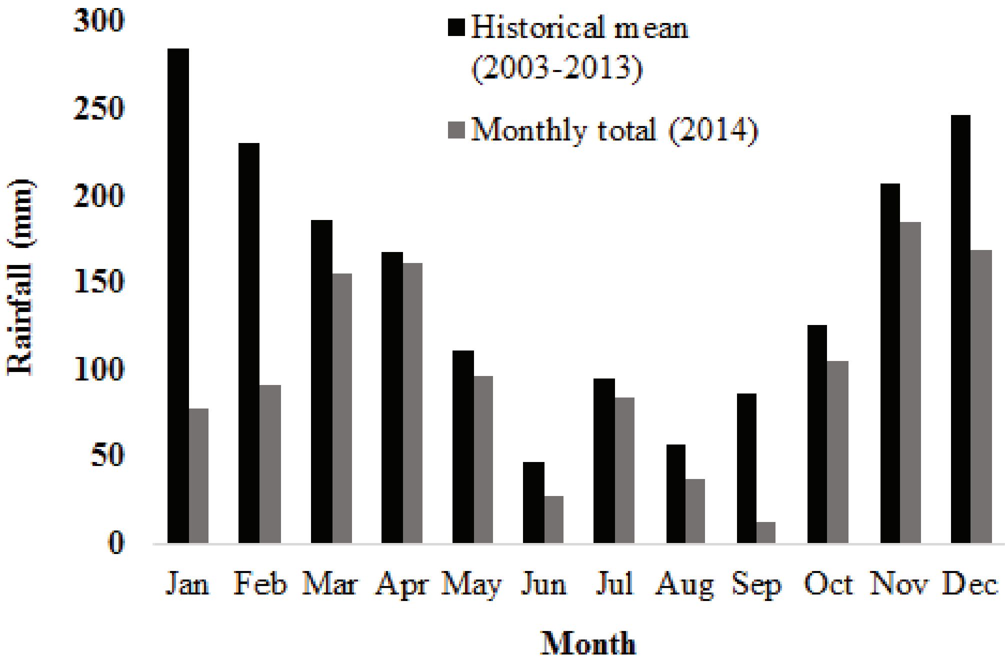

Figure 2. Monthly rainfall recorded at the municipality of Angra dos Reis, state of Rio de Janeiro, Brazil: 10-year historical means (2003–2013) and monthly total precipitation recorded during 2014. Source: COPPES /DIGAT/INEA/INMET.

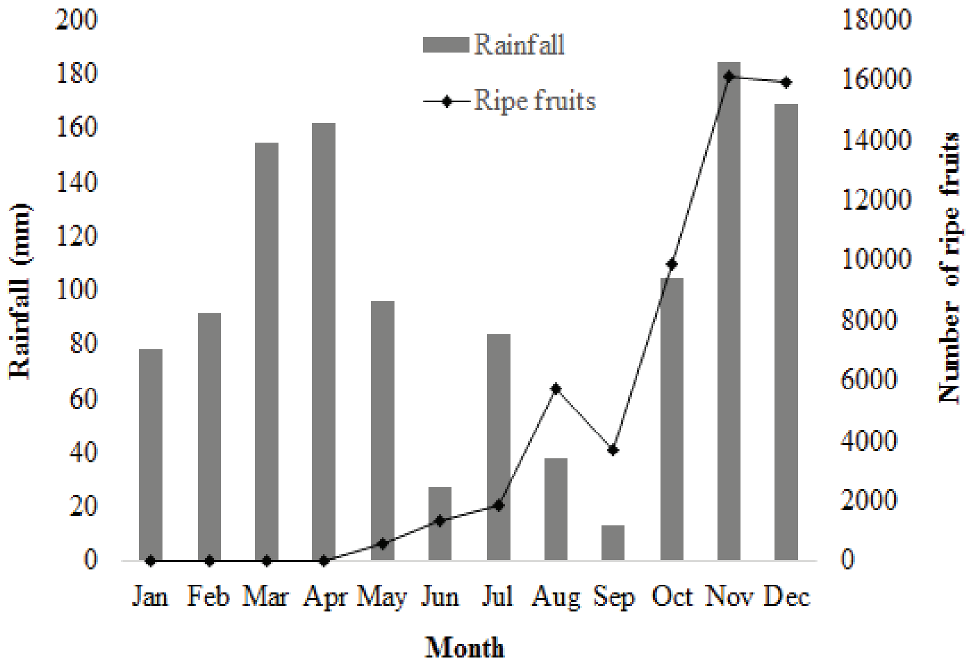

Figure 3. Estimated number of ripe fruits recorded monthly in *Miconia calvescens* (Myrtales, Melastomataceae) trees during 2014, and the precipitation recorded during the same period at the municipality of Angra dos Reis, state of Rio de Janeiro, Brazil.

for growth and development (Marcelis *et al.* 2004). Resource conservation theory predicts that the maternal plant should abort those fruits furthest from maturity in order to conserve scarce resources (Marcelis *et al.* 2004). Water stress is a limiting factor for fruit development (Carpentieri-Pípolo *et al.* 2008). The ripening period is the one that most demand water resources, to ensure the adequate development of the fruit tissue (Martins & Silva 1997). Given this, it seems likely that the abortion of this first crop was related to the low rainfall levels recorded in January and February.

There was a positive correlation between fruit ripening with rainfall (Pearson's correlation test = 0.44; $p < 0.01$), which indicates that rainfall could influence ripening in this species. The increased rainfall recorded in July, was followed by a minor peak in ripe fruits in August (Figure 3). However, rainfall decreased in August, and was followed by a decrease in the records of ripe fruits in September. Despite the low rainfall levels registered in September, the number of ripe fruits began to increase considerably from October onwards. It is possible that the high levels of rainfall recorded in October had triggered ripening since the number of ripe fruits increased strongly in the following months, along with increasing levels of rainfall. The apparent influence of rainfall levels on fruiting patterns in *M. calvescens* is likely related to the plant's demand for water, given that the fruit's pulp is 80% water (Maruyama *et al.* 2007).

In a study of five *Miconia* species, Borges (2010) found that rainfall levels influenced the production of unripe fruit in different ways. In *M. chamissois* and *M. ibaguensis*, the rainfall levels in the months prior to the fruiting period are key, providing a trigger for the initiation of the emission of flower buds and the subsequent development of the fruits. In *M. theizans*, *M. affinis*, and *M. albicans*, however, the key period was the beginning of the fruit set. Cunha *et al.* (2016) found that low rainfall levels influenced the reproductive phenology of *Eugenia punicifolia* (Myrtales, Myrtaceae), with flowers being aborted after pollination. A similar process was recorded by Pezzopane *et al.* (2008), who observed that a water deficit during the flowering and fruiting period affected the development of *Coffea arabica* (Gentianales, Rubiaceae) fruits.

Rainfall levels are likely to affect fruit ripening of *M. calvescens* but may not be the only contributor. The combined influence of rainfall and temperature on phenophases is greater than each factor individually (Ferraz *et al.* 1999). Clearly, further research is required to provide a more systematic understanding of the simultaneous influence of abiotic factors and their variations on phenological patterns.

ACKNOWLEDGMENTS

We would like to thank the Center for Environmental Studies and Sustainable Development (CEADS/UERJ) for technical and logistical support, CNPq for the productivity and research grants to Maria Alice S. Alves (PQ processes #305798/2014-6 and #306.579/2018-9), Idea Wild for the equipment provided and the members of UERJ Bird Ecology Lab for their assistance. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001 (master's scholarship to Mariana Abrahão).

REFERENCES

Alho, C. J. R., Schneider, M., & Vasconcellos, L. A. S. 2002. Degree of threat to the biological diversity in the Ilha Grande State Park (RJ) and guidelines for conservation. Brazilian Journal of Biology 62(3), 375-385. DOI: 10.1590/S1519-69842002000300001

Allenspach, N., Telles, M., & Dias, M. M. 2012. Phenology and frugivory by birds on *Miconia ligustroides* (Melastomataceae) in a fragment of Cerrado, southeastern Brazil. Brazilian Journal of Biology. 72(4), 859-864. DOI: 10.1071/BT03098

Borges, M. R. 2010. Oferta de frutos e frugivoria por aves, em espécies do gênero *Miconia* Ruiz & Pav. (Melastomataceae) em duas áreas do Cerrado. Master thesis. Instituto de Biologia da Universidade Federal de Uberlândia. p. 85.

Calle, Z., Schlumpberger, B. O., Piedrahita, L., Leftin, A., Hammer, S. A., Tye, A., & Borchert, R. 2010. Seasonal variation in daily insolation induces synchronous bud break and flowering in the tropics. Trees Structure and Function, 24(5), 865-877. DOI: 10.1007/s00468-010-0456-3

Carpentieri-Pípolo, V., Neves, C. S. V. J., Bruel, D. C., Souza, S. G. H., & Garbúglio, D. D. 2008. Frutificação e desenvolvimento de frutos de aceroleira no Norte do Paraná. Ciência Rural, 38(7), 1871-1876. DOI: 10.1590/S0103-84782008000700011

Chambers, L. E., Altwegg, R., Barbraud, C., Barnard, P., Beaumont, L. J., Crawford, R. J., & Morellato, P. C. 2013. Phenological changes in the southern hemisphere. PloS One, 8(10), e75514. DOI: 10.1371/journal.pone.0075514

Chapman, C. A., Chapman, L. J., Wangham, R., Hunt, K., Gebo, D., & Gardner, L. 1992. Estimators of fruit abundance of Tropical trees. Biotropica, 24(4), 527-531. DOI: 10.2307/2389015

Cunha, L. L. T., Lucena, E. M. P., & Bonilla, O. H. 2016. Exigências térmicas da floração à frutificação de espécies de Myrtaceae em ambiente de Restinga. Revista Brasileira de Geografia Fisica, 9(3), 707-721

des Gachons, C. P., Leeuwen, C. V., Tominaga, T., Soyer, J. P., Gaudillère, J. P., & Dubourdieu, D. 2005. Influence of water and nitrogen deficit on fruit ripening and aroma potential of *Vitis vinifera* L cv Sauvignon blanc in field conditions. Journal of the Science of Food and Agriculture, 85(1), 73-85. DOI: 10.1002/jsfa.1919

Ferraz, D. K., Artes, R., Mantovani, W., & Magalhães, L. M. 1999. Fenologia de árvores em fragmento de mata em São Paulo, SP. Brazilian Journal of Biology, 59(2), 305-317. DOI: 10.1590/S0034-71081999000200013

Fournier, L. A. 1974. Un método cuantitativo para la medición de características fenológicas en árboles. Turrialba, 24(4), 422-423

Goldenberg, R., Almeda, F., Caddah, M. K., Martins, A. B., Meirelles, J., Michelangeli, F. A., & Weiss, M. 2013. Nomenclator botanicus for the Neotropical genus *Miconia* (Melastomataceae: Miconieae). Phytotaxa, 106(1), 1-171. DOI: 10.11646/phytotaxa.106.1.1

Marcelis, L. F. M., Heuvelink, E., Baan Hofman-Eijer, L. R., Den Bakker, J., & Xue, L. B. 2004. Flower and fruit abortion in sweet pepper in relation to source and sink strength. Journal of experimental Botany, 55(406), 2261-2268. DOI: 10.1093/jxb/erh245

Marques, M. C. M., Roper, J. J., & Salvalaggio, A. P. B. 2004. Phenological patterns among plant life forms in a Subtropical Forest in Southern Brazil. Plant Ecology, 173(2), 203-213. DOI: 10.1023/B:VEGE. 0000029325.85031.90

Martins, S. V., & Silva, D. D. 1997. Maturação e época de colheita de sementes de *Dalbergia* *nigra*. Revista Brasileira de Sementes, 19(1), 96-99.

Maruyama, P. K., Alves-Silva, E., & Melo, C. 2007. Oferta qualitativa e quantitativa de frutos em espécies ornitocóricas do gênero *Miconia* (Melastomataceae). Revista Brasileira de Biociências, 5(1), 672-674

Meyer, J. Y., & Florence, J. 1996. Tahiti's native flora endangered by the invasion of *Miconia calvescens* DC. (Melastomataceae). Journal of Biogeography, 23(6), 775-78.

Meyer, J. Y. 1998 Observations on the reproductive biology of *Miconia calvescens* DC (Melastomataceae), an alien invasive tree on the island of Tahiti (South Pacific Ocean). Biotropica, 30(4), 609-624. DOI: 10.1111/j.1744-7429.1998.tb00101.x

Morellato, L. P. C., Camargo, M. G. G., & Gressler, E. 2013. A review of plant phenology in South and Central America. pp. 91-113. In: M. D. Schwartz (Ed.), Phenology: an integrative environmental science. Dordrecht: Springer. DOI: 10.1007/978-94-007-6925-0_6

Morellato, L. P. C., Alberton, B., Alvarado, S. T., Borges, B., Buisson, E., Camargo, M. G. G., & Mendoza, I. 2016. Linking plant phenology to conservation biology. Biological Conservation, 195, 60-72. DOI:10.1016/j.biocon.2015.12.033

Pezzopane, J. R. M., Pedro-Júnior, M. J., Camargo, M. B. P., & Fazuoli, L. C. 2008. Exigência térmica do café arábica cv. mundo novo no subperíodo florescimento-colheita. Ciência e Agrotecnologia, 32(6), 1781-1786. DOI: 10.1590/S1413-70542008000600016

Rosemartin, A. H., Crimmins, T. M., & Enquist, C. A. F. 2014. Organizing phenological data resources to inform natural resource conservation. Biological Conservation, 173, 90-97. DOI: 10.1016/j.biocon.2013.07.003

Snow, D. W. 1965. A possible selective factor in the evolution of fruiting seasons in Tropical Forests. Oikos, 15(2), 274-281. DOI: 10.2307/3565124

Talora, D. C., & Morellato, P. C. 2000. Fenologia de espécies arbóreas em floresta de planície litorânea do sudeste do Brasil. Revista Brasileira de Botanica, 23(1), 13-26. DOI: 10.1590/S0100-84042000000100002

Van der Sleen, P., Groenendijk, P., Vlam, M., Anten, N. P. R., Boom, A., Bongers, F., Pons, T. L., Terburg, G., & Zuidema, P. A. 2015. No growth stimulation of tropical trees by 150 years of CO2 fertilization but water-use efficiency increased. Nature Geoscience, 8(1), 24-28. DOI: 10.1038/NGEO2313

Submitted: 07 March 2019
Accepted: 25 July 2019
Published online: 02 August 2019
Associate Editor: Bianca Ott Andrade