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MORE THAN A CENTURY OF CYTOGENETIC STUDIES IN CHILEAN PLANTS: HOW MUCH HAVE WE PROGRESSED?

MÁS DE UN SIGLO DE ESTUDIOS CITOGENÉTICOS EN PLANTAS CHILENAS: ¿CUÁNTO HEMOS PROGRESADO?

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ABSTRACT

An overview is provided on the cytogenetic of Chilean plants, highlighting information gathered from more than a century of work carried out by foreign and national researchers who have contributed to the study of native species. We briefly present the progress made to date and also emphasize some strategies that, in our opinion, could spur further advances in this second century of cytogenetic studies in Chilean plants.

Key words: Cytogenetics, cytogenomics, Chilean plants.

RESUMEN

Se presenta una visión general de la citogenética de plantas chilenas, destacando información recopilada durante más de un siglo de trabajo realizado por investigadores nacionales y extranjeros que han contribuido al estudio de las especies nativas. Presentamos brevemente los progresos realizados hasta la fecha y también destacamos algunas estrategias que, en nuestra opinión, podrían impulsar mayores avances en este segundo siglo de estudios citogenéticos en plantas chilenas.

Palabras clave: Citogenética, citogenómica, plantas chilenas.

INTRODUCTION

The cytogenetics of Chilean plants has had a fragmented development along its history, especially in its beginnings. In the last decades, however, it has made important contributions to the study of plant diversity, incorporating classical quantitative karyotype analysis and more recently modern cytogenomic methods. However, in the present, strategies to further progress have not yet been discussed among Chilean cytogeneticists.

The first study on the cytogenetics of Chilean plants reported the chromosome number of *Alstroemeria chilensis* Lem. (Syn. *Alstroemeria ligtu* L., Alstroemeriaceae), which was published by Strasburger (1882) almost at the end of the 19th century in the Archiv für Mikrobiologie und Anatomie in Germany. Later on, at the beginning of the 20th century, more studies on the cytogenetics of Chilean plants were published from 1929 onwards. Since then, relevant contributions have been made by foreign cytogeneticists such as Whyte (1929), Sato (1938, 1943), Goodspeed (1940), Titov de Tschicshow (1954) and Esponda (1970), who described chromosome number and morphology in species of several native genera (e.g., *Alstroemeria*, *Bomarea*, *Lapageria* and in back then *Hippeastrum*). At that same time, Sanz (1955, 1965, 1968, 1970), a Chilean cytogeneticist, made pioneering contributions applying cytogenetic methods to plants, focusing his work on native species of the genera *Alstroemeria*, *Calceolaria*, and *Leucocoryne*, among others. In later decades, a gradual increase in chromosome studies of four botanical divisions (Bryophyta, Pteridophyta, Pinophyta, and Magnoliophyta) including terrestrial and aquatic plants is observed, with major advances achieved since 2001 until now. Some reviews have discussed aspects on this subject which can be consulted for more details (Jara Seguel and Urrutia, 2012; Jara Seguel and Urrutia Estrada, 2018).

In this article we briefly present the progress on cytogenetic studies of Chilean plants made to date, and also suggest some strategies that, in our opinion, could spur further advances in this second century of cytogenetic studies.

HOW MUCH HAVE WE PROGRESSED?

At present, 122 publications on cytogenetics are available covering *ca.* 402 Chilean plant species (Jara Seguel and Urrutia Estrada, 2020). This number of studied species is equivalent to 6.5% of the total flora, according to statistics published in floristic reviews (*ca.* 6,103 land plant species; Villagrán, 2020). This percentage is alarmingly low compared to other regions around the world, with percentages ranging from 35.0% in Italy to 80.0% in New Zealand (Peruzzi *et al.* 2011). Unfortunately, in South America only Paraguay (with *ca.* 313 studied species; Jara Seguel and Urrutia, 2012) and Brazil (with *ca.* 699 species studied from the Cerrado Ecoregion; Roa and Telles, 2017) have estimations on the number of studied species, representing the only comparison parameter that we have to evaluate progress. The above paucity is coupled with scant funding for projects on this specific issue in Chile. Since 2007 only two government projects (FONDECYT) and one with academic funding were awarded to a research group of the Universidad de Concepción (Baeza C., Negritto M.; Repositorio ANID 2021). Our group (Jara Seguel P., Palma Rojas C.) receives financing annually from the Núcleo de Estudios Ambientales (project MECESUP UCT0804, 2011) of the Universidad Católica de Temuco, but the resources are mainly earmarked for operational expenses.

According to the number of species cytogenetically studied so far for Chilean plants, it is clear that in the initial century the progresses were few and intermittent (Jara Seguel and Urrutia 2012), experiencing difficulties such as the shortage of Chilean specialists, which led to a large part of the studies being carried out by foreign cytogeneticists. Publications recorded for the last decade show that two Chilean research groups (those mentioned above) maintain active productivity on the subject by focusing on various families and studying different cytogenetic features e.g., chromosome number, karyotype morphology, C-values, C and Ag-NOR banding, as well as cytogenomic markers e.g., 5S/45S rDNA localization through the application of fluorescent *in situ* hybridization (Baeza and Schrader, 2005; Baeza *et al.*, 2007; Cajas *et al.*, 2009; Jara Seguel *et al.*, 2012; Chacón *et al.*, 2012). Many of these chromosome data have been used to envisage phylogenetic and evolutionary hypotheses in some families (Chacón *et al.*, 2012; Jara Seguel *et al.*, 2021) with some species included in cytoevolutionary studies of global flora (Smarda *et al.*, 2014; Carta *et al.*, 2020). Plant taxonomy has also required cytogenetic support in the case of some families (Jara Seguel and Urrutia, 2012). Cytogeography is another incipient line of research in Chile which could be useful to understand patterns of distribution of cytogenetic diversity along the latitudinal and longitudinal gradients of the continent or in insular areas with different geographic locations and geological origins (Stuessy and Baeza, 2017; Jara Seguel *et al.*, 2020; 2021). Applications in conservation genetics can also be visualized as an interesting field of study in the near future (Jara Seguel and Urrutia, 2012; Jara Seguel *et al.*, 2020).

WHAT CAN WE DO IN THE FUTURE?

In this second century of cytogenetic studies in Chilean plants, much remains to be done and the challenges for the small Chilean community of cytogeneticists are great. According to the statistics *ca.* 93.5% of the Chilean native species have yet to be studied. In our opinion various strategies are required to make further progress, and we propose: i) the training of new specialists at the graduate and undergraduate level who are willing to address this discipline of genetics instead of other branches perhaps with a molecular approach, although obviously one does not exclude the other; ii) specialization may also be necessary for current researchers specifically in the fields of modern cytogenomics (Eykelenboom and Tanaka 2020) and cytoinformatics (e.g., chromEvol, Mayrose *et al.*, 2010), thus making it possible to increase the critical mass of highly specialized cytogeneticists; iii) the structuring of research groups necessarily has to be planned to ensure that they work in cooperation in order to streamline efforts and financial resources, either prioritizing endemic species (*ca.* 45% of the Chilean continental flora) or those with conservation problems (*ca.* 70 critically threatened species); iv) monetary resources could be raised from companies (mining, forestry, agricultural), charitable trusts, philanthropists and environmentalists, i.e. all those social groups that are linked to the direct use of native plants or that cause effects on them. The future advances in cytogenetic studies of Chilean plants require the contribution of various actors such as government, academia, research centers and economic groups. In this third millennium, in the middle of the post-genomic era, progress in cytogenetic studies is highly necessary for Chilean plants, especially with the advent of global climate change that is strongly affecting the flora and the ecosystems. In this scenario of biodiversity threat, it is necessary to understand evolutionary aspects of Chilean plants, allowing cytogenetics to contribute fundamental knowledge that could be included in modern phylogenomic studies (Posada, 2016), encompassing the analysis of different genome compartments (e.g., nuclear, plastidial, and mitochondrial).

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