CAPÍTULO 1

Secondary somatic embryogenesis and its potential biotechnological applications

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Abstract

Secondary somatic embryogenesis is a powerful biotechnological tool in the genetic improvement of plants. However, up to date, it has only been described in 148 species (7 Gymnosperms (G), 141 Angiosperms between 35 monocots (M) and 106 dicots (D)) in different explants, in particular zygotic embryos (G: 100%, M: 54%, D: 48%), mainly indirectly (G: 100%, M:67%, D: 66%), and asynchronous (G: 100%, M:100%, D: 96%), of unicellular origin (G: 63%, M: 63%, D: 67%); directly differentiating the secondary embryos in particular from the apical zone of higher stage primary embryos, plants regenerating in more than 90% of the species. The combination of growth regulators (single auxin, only cytokinin, or combination auxin + cytokinin) for the primary and repetitive embryogenesis stage varies with the species and explant type. However, in the second stage, the media is used without any hormones, with low auxin concentration, or increasing the cytokinin. The potential and avant-garde system used is poorly described; this review supports future research in this regard, given insights into the genetic improvements of many species with agro-ecological interest.

Keywords: *Agrobacterium*, biolistic, cyclic embryogenesis, repetitive embryogenesis, temporary immersion, unicellular origin.

1. Introduction

The system with the higher regenerative rate *in vitro* is somatic embryogenesis, and it is defined as the process in which develops a bipolar structure called embryos from a single somatic cell (without any cell fusion), being structurally and functionally identical to the derived zygotic embryo from the union of gametic cells in sexual embryogenesis. The first report was described using the dicotyledonous *Daucus carota* in the late 50s of the 20th century. More than 100 species have been reported (NEUMANN; KUMAR; IMANI, 2020). Frequently, it occurs in a larger proportion by the indirect way (presence of a transition phase called callus); it is given that exogenous hormonal stimuli must induce the competent cells. Consequently, these generate a morphogenic reprogramming for the plant's differentiation from the developed somatic embryos, and it can originate from one or more somatic cells, with subsequent implications in the genetic homogeneity of the developed plants (FEHÉR; BERNULA; GÉMES, 2016; NEUMANN; KUMAR; IMANI, 2020).

A relevant aspect in the micropropagation efficiency is the synchrony of the process, which in most species is asynchronous, as somatic embryos with the same stage are not seen at the same time (WÓJCIKOWSKA; GAJ, 2016).

In some species, this regenerative process has a high cyclic capacity. It is determined by establishing two types of somatic embryogenesis, where the first one called "primary" is distinguished in the formation of somatic embryos directly from the explant or indirectly through the callus. At the same time, the "secondary" is characterized in the differentiation of new somatic embryos, generally directly on the surface of the primary embryos, and this process can be repeated in more than one cycle (PÉREZ; CHAN; SÁENZ, 2006). Thus, repetitive somatic embryogenesis reports began at the '80s ending and the beginning of the '90s of the last century. In the "solo" bibliographic revision of this topic, up to date was indicating 82 species following 10 Gymnosperms; 72 Angiosperms divided into eight monocotyledons and 64 dicotyledons (RAEMAKERS; JACOBSEN; VISSER, 1995).

The regenerative system through somatic embryogenesis is an efficient biotechnological tool that can be applied in the genetic improvement of different species with agro-ecological interest since it can be coupled in the processes of micropropagation and genetic engineering (LOYOLA, 2016). However, up to date, the use of the system is limited to a few species, particularly forestal ones. In this regard, the objective of this review is to detail update all the important and inherent aspects of the regenerative process and its potential applications. Furthermore, after 25 years of the first review, to support future research not only in the described species but also in others, whose resources for a human could be improved and increased by this way.

2. Conceptualization of secondary somatic embryogenesis

The somatic embryogenesis (also known as asexual or adventitious embryogenesis) consists of the development of bipolar structures (with two vegetative apices, the apical of the stem and the subapical of the root) called "embryos", from somatic cells that form the tissues. So, these cells are not the product of sexual cells fusion of gametes during fertilization, similar in sexual or zygotic embryogenesis, where the zygotic embryo is differentiated, being structurally and functionally identical in both types of embryos (LOYOLA, 2016). Comparing organogenesis and somatic embryogenesis as regenerative systems *in vitro*, the last one had the highest replicative rate in most plant species; therefore, it is frequently used in mass micropropagation and conventional or genetic engineering breeding programs (LOYOLA, 2016).

Regarding the pathway can be two types, direct and indirect. The direct pathway is characterized by the direct differentiation of somatic embryos from the explant. While the indirect is the second where the somatic embryos develop from callus (a dedifferentiated cell mass), considered a transitional phase of the regenerative process, being able to imply the appearance of genetic variations in the regenerated plants to the high rates of cell division in the callus. Thus, this can lead to mutations or permanent genetic aberrations without molecular repair mechanisms. The genetic uniformity of the variety of elite cultivars in propagation is not ensured; however, this does not occur in most cases (FEHÉR; BERNULA; GÉMES, 2016).

Furthermore, another important aspect from the point of view of plant breeding is the origin of somatic embryos, which can be unicellular or multicellular, in epidermic or sub epidermic layers of the explant or callus of embryogenic nature (QUIROZ *et al*., 2006). In the first case, the embryos are formed from a single cell, which divides anticlinally, distinguishing perfectly at the end the embryo isolated from the maternal tissue, united only by the suspensor (WILLIAMS; MAHESWARAN, 1986). Although, in the second case, the embryos are observed without suspensor and fused to the tissue that gave them origin because these were initially the product of the anticlinal cell division of more than one cell, being visualized sometimes bodies of fused embryos (HACCIUS; BHANDARI, 1975). Thus, the probability of genetic mosaicism or chimeras is higher in the multicellular origin, not assuring the genetic homogeneity of the regenerated plants, an aspect that is feasible with the unicellular origin.

Concerning the synchronization during the differentiation of the somatic embryo, it can be synchronous or asynchronous. The synchronous is characterized for having only one type of stage observed simultaneously due to the cells that gave rise to them and divided at the same time. In contrast, the asynchronous refers to the differentiation of somatic embryos at different times, being observed simultaneously in different proportions of embryos according to the stage (WÓJCIKOWSKA; GAJ, 2016).

Regarding the cyclic capacity of somatic embryogenesis, two types can be defined as primary. Firstly, where only a series of somatic embryos are differentiated, and the second as secondary, repetitive, or cyclic, where somatic embryos are differentiated in more than one cycle, being denominated as primary to the somatic embryos that developed first from the explant or callus, and secondary to those that generally differentiate directly from the surface of the primary embryos, being able to repeat cyclically in the newest embryos (PÉREZ; CHAN; SÁENZ, 2006).

3. Cyclic somatic embryogenesis in Gymnosperms

Only seven forestal species of gymnosperms of the family Pinaceae are reported in this work. Although Raemakers *et al*. (1995) indicate ten species, after complete revision of different reports, it was determined in a conclusive and expressly way that currently, only this number of species described secondary somatic embryogenesis. Moreover, in this group of plants, only zygotic embryos were used as explant, with an indirect and asynchrony regenerative pathway at 100%, originating somatic embryos in a unicellular way in 63% of the species. In comparison, in two (25%), it was multicellular, and only in one (12%), both origins were reported (Table 1).

In the primary somatic embryo stage, where the cyclic embryogenesis occurs, 86% is torpedo and 14% in the cotyledon. While the zone of differentiation of secondary embryos was in greater degree (57%) in the hypocotyl, followed by the cotyledon (29%) and the meristem (14%), the regenerating plants (81-98%) only in 5 of the 7 species (Table 1).

Table 1. Gymnosperms with Cyclic embryogenesis somatic

SPECIES	EXPLANT	REGENERATIVE VIA	ORIGIN OF THE SOMATIC EMBRYOS	PRIMARY SOMATIC EMBRYOGENESIS (PSE)								DIFFERENTIATION ZONE AND TYPE FROM PSE TO SSE	SECONDARY SOMATIC EMBRYOGENESIS (SSE)								PERCENTAGE OF PLANT DIFFERENTIATION FROM SSE (%)	REFERENCES
				AUXIN (mg/l)				CYTOKININ (mg/l)					AUXIN (mg/l)				CYTOKININ (mg/l)					
				2,4-D	Picloram	NAA	IAA	BAP	K	TDZ	Z		2,4-D	Picloram	NAA	IAA	BAP	K	TDZ	Z		
Abies numidica De Lannoy & Carrieré **(P^{t})**	ZE	I	M	-	-	-	-	1	-	-	-	A/ C^{h}	-	-	-	-		-	1	-	90	Vooková *et al.*(2003); Vooková y Kortumák (2006)
Larix decidua x leptoeuropaea Mill. **(P^{t})**	ZE	I	M	2	-	-	-	0,5	-	-	-	A/ T^{h}	2	-	-	-	1	-	-	-	98	Saly *et al.*(2002)
Picea abies (L.) H.Karst **(P^{t})**	ZE	I	U M	2,2	-	-	-	1,1	-	-	-	A/ T^{h}		-	-	-	1,8	-	-	-	81	Nagmani *et al.* (1987); Von Arnold (1987); Mo *et al.* (1989); Mo & Von Arnold (1991)
P. glauca (Moench) Voss **(P^{t})**	ZE	I	U	2,2	-	-	-	1,1	-	-	-	A/ T^{m}		-	-	-	0.5	-	-	-	0	Nagmani *et al.*(1987); Kong & Yeung (1992)
Picea glauca x engelmanni **(P^{t})**	ZE	I	U	2,2	-	-	-	1,1	-	-	-	A/ T^{h}	1,1	-	-	-	0.5	-	-	-	0	Nagmani *et al.*(1987); Eatsman *et al.*(1991)
Pinus pinaster Ait. **(P^{t})**	ZE	I	U	0,5	-	-	-	0,5	-	-	-	A/ T^{e}	2	-	-	-	1	-	-	-	90	Klimaszewska *et al.*(2009)
Pseudotsuga menziesii (Mirb.) **(P^{t})**	ZE	I	U	0,5	-	-	-	0,5	-	-	-	A/ T^{e}	2	-	-	-	1	-	-	-	98	Lelu *et al.*(2018)

FAMILY. (P): Pinaceae. **HABIT.** (^{t}): tree. **EXPLANT. ZE**: zygotic embryo. **REGENERATIVE VIA**. **D**: direct; **I**: Indirect. **ORIGIN OF THE SOMATIC EMBRYOS.** (**U**): unicellular; (**M**): multicellular. **SOMATIC EMBRYO**. **PSE**: primary; **ESS**: secondary. **DIFFERENTIATION TYPE PSE TO SSE**. **G**; globular; **T**: torpedo; **C**: cotyledonal. **SYNCHRONIC OF THE SSE.** (**SIN**). **S**: Synchronic; **A**: asynchrony. **DIFFERENTIATION ZONE PSE TO SSE.** **(^{r}):** root; **(^{h}):** hypocotyl; **(^{e}):** epicotyl; **(^{m})**: meristem. **AUXINS. 2,4-D:** 2,4-dichlophenoxyacetic; **PICLORAM:** 4-amino-3,5,6-trichloropicolinic acid; **NAA:** 1-naphthaleneacetic acid; **IAA:** indole-acetic acid. **CYTOKININS: BAP**: 6-benzyl-amino purine; **K:** 6-furfuryaminopurinre or Kinetin; **TDZ**: thidiazurom; **Z**: zeatin.

Accordingly, the relationship of growth regulators in primary and secondary somatic embryogenesis (Table 1), it was found that only in *Abies numidica* was used cytokinins, in the primary (BAP) and the secondary (TDZ), while in the rest of the species (86%) used in the primary, auxin plus cytokinin (2,4-D+ BAP), but in the secondary in two species (29%; *Picea abies* and *Picea glauca*) was induced only with cytokinin (BAP). On the contrary, the remaining five species (71%) were induced by combining auxin and cytokinin (2,4-D+BAP). Secondary embryo maturation is another important aspect prior to the regeneration, which is achieved mostly with the growth substances used in the cyclic embryogenesis phase. However, it is used at that stage 10 mg/L of ABA, 3% maltose, and 10% polyethylene glycol for *Abies numidica* (VOOKOVÁ; MATUSOVÁ; KORMUTÁK, 2003). In this sense, in *Pseudotsuga menziesii*, ABA is used as the only hormonal inducer that increases the secondary embryogenic frequency by 62% using 10.5 mg/l of it (WALTHER; WAGNER; RASCHKE, 2022).

4. Cyclic somatic embryogenesis in Angiosperms: monocotyledons group

In the bibliographic review carried out by Raemakers *et al*. (1995), eight species of monocotyledons with herbaceous habit were indicated, 25 years later in this work, 35 species with repetitive somatic embryogenesis were reported, 86% herbaceous and 14% tree (palms), being 37% grasses, 14% palms (tree-like), 14% muses, 9% orchids, and the remaining 9 (26%) species of different families (Table 2).

The most used explant was the zygotic embryo (48%), followed by the inflorescence (15%) and then leaf (13%), with the indirect regenerative way in 68% of the species. The only way found in anther, inflorescence, ovary, corm, stem, and cotyledon, while the direct way was found exclusively in the meristem, unlike both ways was described in zygotic embryos and leaves. Likewise, the differentiation of somatic embryos was asynchronous, originating unicellular in 58% of the species, multicellular in 8 (20%) and four (10%) with both origins (Table 2).

On the other hand, the type of primary somatic embryo where cyclic embryogenesis occurs, globular is 94% and 3% for cotyledonary and 3% torpedo, differentiating 100% of the secondary embryos in the apex zone, regenerating plants in all species, in more than 70% in 24 of them (Table 2).

Table 2. Cyclic Somatic Embryogenesis in Angiosperms species (monocotyledons)

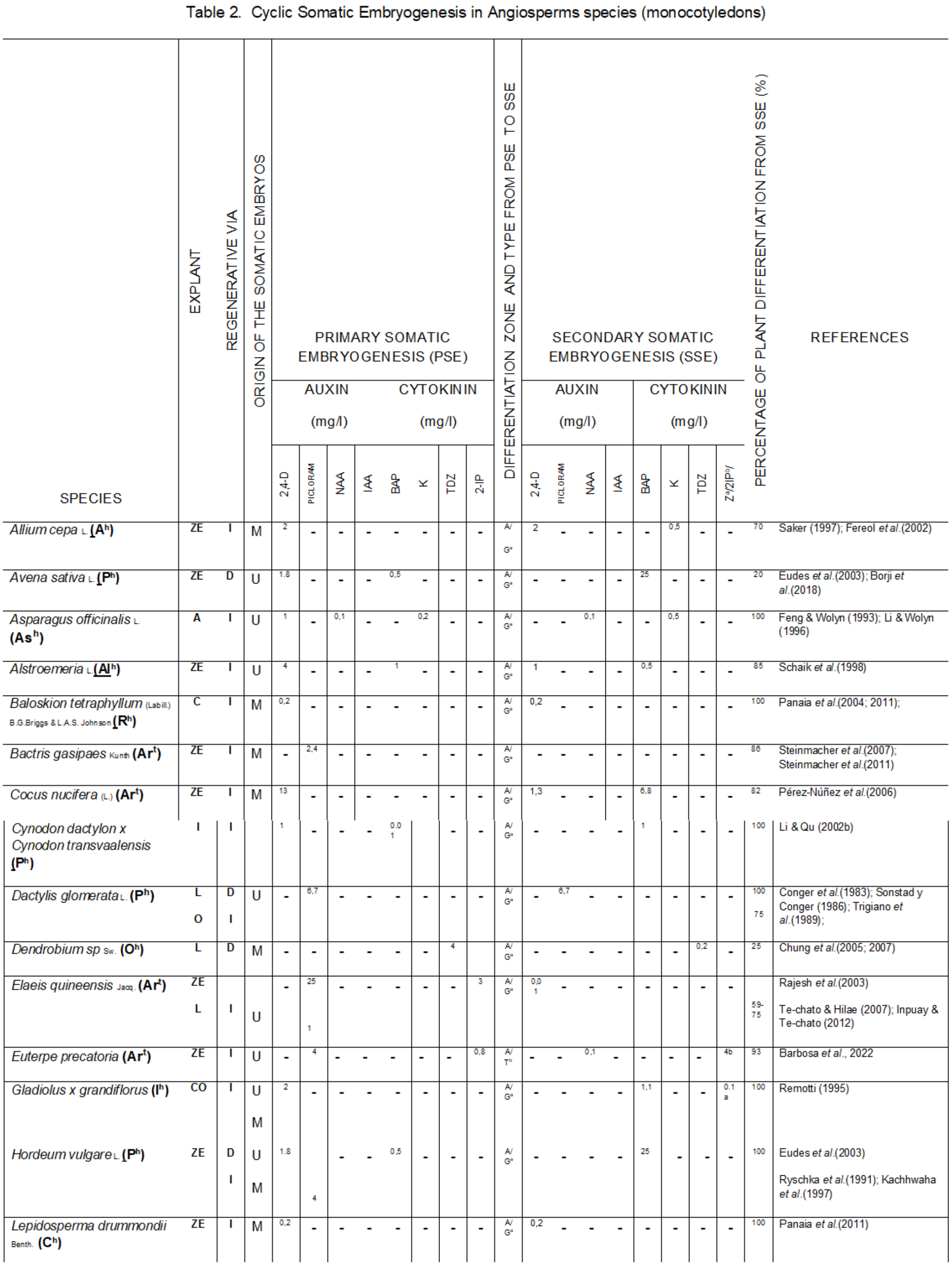

Table 2. Cyclic Somatic Embryogenesis in Angiosperms species (monocotyledons)

SPECIES	EXPLANT	REGENERATIVE VIA	ORIGIN OF THE SOMATIC EMBRYOS	PRIMARY SOMATIC EMBRYOGENESIS (PSE) AUXIN (mg/l)				PRIMARY SOMATIC EMBRYOGENESIS (PSE) CYTOKININ (mg/l)				DIFFERENTIATION ZONE AND TYPE FROM PSE TO SSE	SECONDARY SOMATIC EMBRYOGENESIS (SSE) AUXIN (mg/l)				SECONDARY SOMATIC EMBRYOGENESIS (SSE) CYTOKININ (mg/l)				PERCENTAGE OF PLANT DIFFERENTIATION FROM SSE (%)	REFERENCES
				2,4-D	PICLORAM	NAA	IAA	BAP	K	TDZ	2-IP		2,4-D	PICLORAM	NAA	IAA	BAP	K	TDZ	Z^{a}/2IP^{b}/		
Allium cepa L. **(A^{h})**	ZE	I	M	2	-	-	-	-	-	-	-	A/ G*	2	-	-	-	-	0,5	-	-	70	Saker (1997); Fereol *et al.*(2002)
Avena sativa L. **(P^{h})**	ZE	D	U	1.8	-	-	-	0,5	-	-	-	A/ G*	-	-	-	-	25	-	-	-	20	Eudes *et al.*(2003); Borji *et al.*(2018)
Asparagus officinalis L. **(As^{h})**	A	I	U	1	-	0,1	-	-	0,2	-	-	A/ G*	-	-	0,1	-	-	0,5	-	-	100	Feng & Wolyn (1993); Li & Wolyn (1996)
Alstroemeria L. **(Al^{h})**	ZE	I	U	4	-	-	-	1	-	-	-	A/ G*	1	-	-	-	0,5	-	-	-	85	Schaik *et al.*(1998)
Baloskion tetraphyllum (Labill.) B.G.Briggs & L.A.S. Johnson **(R^{h})**	C	I	M	0,2	-	-	-	-	-	-	-	A/ G*	0,2	-	-	-	-	-	-	-	100	Panaia *et al.*(2004; 2011);
Bactris gasipaes Kunth **(Ar^{t})**	ZE	I	M	-	2,4	-	-	-	-	-	-	A/ G*	-	-	-	-	-	-	-	-	86	Steinmacher *et al.*(2007); Steinmacher *et al.*(2011)
Cocus nucifera (L.) **(Ar^{t})**	ZE	I	M	13	-	-	-	-	-	-	-	A/ G*	1,3	-	-	-	6,8	-	-	-	82	Pérez-Núñez *et al.*(2006)
Cynodon dactylon x Cynodon transvaalensis **(P^{h})**	I	I		1	-	-	-	0.01		-	-	A/ G*	-	-	-	-	1	-	-	-	100	Li & Qu (2002b)
Dactylis glomerata L. **(P^{h})**	L O	D I	U	-	6,7	-	-	-	-	-	-	A/ G*	-	6,7	-	-	-	-	-	-	100 75	Conger *et al.*(1983); Sonstad y Conger (1986); Trigiano *et al.*(1989);
Dendrobium sp Sw. **(O^{h})**	L	D	M	-	-	-	-	-	-	4		A/ G*	-	-	-	-	-	-	0,2	-	25	Chung *et al.*(2005; 2007)
Elaeis quineensis Jacq. **(Ar^{t})**	ZE L	I	U	-	25 1	-	-	-	-	-	3	A/ G*	0,01	-	-	-	-	-	-	-	59-75	Rajesh *et al.*(2003) Te-chato & Hilae (2007); Inpuay & Te-chato (2012)
Euterpe precatoria **(Ar^{t})**	ZE	I	U	-	4	-	-	-	-	-	0,8	A/ T*	-	-	0,1	-	-	-	-	4b	93	Barbosa *et al.*, 2022
Gladiolus x grandiflorus **(I^{h})**	CO	I	U M	2	-	-	-	-	-	-	-	A/ G*	-	-	-	-	1,1	-	-	0.1a	100	Remotti (1995)
Hordeum vulgare L. **(P^{h})**	ZE	D I	U M	1.8	4	-	-	0,5	-	-	-	A/ G*	-	-	-	-	25	-	-	-	100	Eudes *et al.*(2003) Ryschka *et al.*(1991); Kachhwaha *et al.*(1997)
Lepidosperma drummondii Benth. **(C^{h})**	ZE	I	M	0,2	-	-	-	-	-	-	-	A/ G*	0,2	-	-	-	-	-	-	-	100	Panaia *et al.*(2011)

Musa beccarii N.W.Simmonds **(M^h)**	I	I	U	-	40	0,2	0,2	-	-	-	-	A/ G^a	20	-	-	-	-	-	-	-	57	Natarajan *et al.*(2020)
Musa laterita Cheesman. **(M^h)**	I	I	U	-	40	0,2	0,2	-	-	-	-	A/ G^a	20	-	-	-	-	-	-	-	40	Natarajan *et al.*(2020)
Musa paradisiaca L. **(M^h)**	BR	I	U	-	-	-	-	-	-	1	-	A/ G^a	-	-	-	-	-	-	-	-	100	Smitha et al. (2021)
Musa velutina H. Wendl. & Drude **(M^h)**	I	I	U	-	40	0,2	0,2	-	-	-	-	A/ G^a	20	-	-	-	-	-	-	-	47	Natarajan *et al.*(2020)
Musa spp. L. **(M^h)**	I M	I D	U	4 1	-	1	1 0,2	25	-	-	-	A/ G^a	-	-	-	-	5	-	-	-	57 100 81	Khalil et al.(2002) Escalant *et al.*(1994) Smitha *et al.*(2020) Ramírez & de García (2009)
Narcissus sp L. **(A^h)**	O	I	M	28 28	-	-	-	1,1 1,1	-	-	-	A/ G^a	28	-	0,5	-	1,1 1,1	-	-	-	100	Mujib *et al.*(2013) Malik (2008) Malik & Bach (2017)
Oncidium cv. Gower *Ramsey* & cv. Sweet Sugar **(O^h)**	L	D	U	-	-	-	-	-	-	1	-	A/ G^a	-	-	-	-	-	-	1	-	50	Cheng & Hong (2012)
Oryza sativa L. **(P^h)**	A	I	U	1	-	2	-	-	-	-	-	A/ G^a	-	-	1	-	-	0,5	-	-	90	Jones & Thomas (1989); Datta *et al.*(1990)
Panicum máximum (Jacq.) **(P^h)**	ZE I	I	U	1	-	-	-	-	-	-	-	A/ G^a	-	-	-	-	-	-	-	-	100	Lu & Vasil (1981); Lu & Vasil (1985)
Paris polyphylla Sm.**(Me^h)**	ZE	D	U		-	-	-	-	-	-	-	A/ C^a	-	-	-	-	-	-	-	-	95	Raomani *et al.*(2014)
Pennisetum americanum L.R.Br. **(P^h)**	ZE	I	U	2,5	-	-	-	-	-	-	-	A/ G^a	-	-	-	-	-	-	-	-	100	Vasil & Vasil (1981); Vasil & Vasil (1982)
Paphiopedilum niveum (Rchb.f.) Stein **(O^h)**	ZE	I	M	-	-	0,1	-	-	-	0,5	-	A/ G^a	-	-	0,1	-	-	-	0,5	-	68	Soonthornkalump *et al.*(2019)
Phoenix dactylifera L. **(Ar^t)**	L	I	M U	10	-	-	-	-	-	-	-	A/ G^a	0,1	-	-	-	-	-	-	-	90	Othmani *et al.*(2018) Sané *et al.*(2006)
Secale cereale (L.) M.Bieb. .**(P^h)**	ZE	D	U	1.8	-	-	-	0,5	-	-	-	A/ G^a	-	-	-	-	25	-	-	-	10	Eudes *et al.*(2003)
Triticum aestivum L. **(P^h)**	ZE	D I	M U	1.8 1	-	-	-	0,5	- 0,5	-	-	A/ G^a G^a	- 0,5	-	-	-	25	-	-	-	100 8,3	Eudes *et al.*(2003) Ryschka *et al.*(1991) Wu *et al.*(2005)
Triticum durum L. **(P^h)**	ZE	D	U	1.8	-	-	-	0,5	-	-	-	A/ G^a	-	-	-	-	25	-	-	-	100	Eudes *et al.*(2003) Fernandez *et al.*(1999)
Triticum monococum L. **(P^h)**	ZE	D	U	1.8	-	-	-	0,5	-	-	-	A/ G^a	-	-	-	-	25	-	-	-	100	Eudes *et al.*(2003) Miroshnichenko *et al.*(2017)
Triticum urartu Thumanjan & Gandilyan **(P^h)**	ZE	D	U	1.8	-	-	-	0,5	-	-	-	A/ G^a	-	-	-	-	25	-	-	-	100	Eudes *et al.*(2003)
Zea mays L. **(P^h)**	ZE M	I D	U	2 0,5	-	-	-	2	-	-	-	A/ G^a	0,5	-	-	-	2 2	-	-	-	80	Lupotto & Lusardi (1988)
Zingiber officinale Rosc. **(Z^h)**	S	I	U	2	-	-	-	-	-	-	-	A/ G^a	-	-	-	-	2	-	-	-	100	Lincy *et al.*(2009)

FAMILY. (A): Amaryllidaceae**; (Ar):** Arecaceae; **(Al):** Alstroemeriaceae; **(As):** Asparagaceae; **(C):** Cyperaceae**; (I):** Iridaceae; **(M):** Musaceae; **(Me):** Melanthiaceae; **(O):** Orchidaceae; **(P):** Poaceae; (**R**): Restionaceae; **(Z):** Zyngiberaceae**. HABIT.** (^{t}): tree; (^{h}): herbaceus**. EXPLANT. A:** Anther; **BR**: Male flower bract; **C:** Coleoptile; **CO**: Cormo; **I**: Inflorescence; **L**: leaf; **O**: Ovary; **M**: Meristem; **S: Stem; ZC**: zygotic embryo. **VIA REGENERATIVA**. **D**: direct; **I**: Indirect. **ORIGIN OF THE SOMATIC EMBRYOS.** (**U**): unicellular; (**M**): multicellular. **SOMATIC EMBRYO**. **PSE**: primary; **SSE**: secondary. **SYNCHRONIC OF THE SSE.** (**SIN**). **S**: synchronic; **A**: asynchrony. **DIFFERENTIATION TYPE PSE TO SSE. G**; globular; **T**: torpedo; **C**: cotyledonal. **DIFFERENTIATION ZONE PSE TO SSE. b:** base; **a:** apex. **AUXINS. 2,4-D:** 2,4-dichlophenoxyacetic; **PICLORAM:** 4-amino-3,5,6-trichloropicolinic acid**; NAA:** 1-naphthaleneacetic acid; **IAA**: indole-acetic acid. **CYTOKININS: BAP**: 6-benzyl-amino purine**; K:** 6-furfuryaminopurinre or Kinetin; **TDZ**: thidiazurom; **2-IP**: 2-isopentenyl adenine; **Z**: zeatin.

In relation to the combination of growth regulators in primary and secondary somatic embryogenesis (Table 2), it was found only in zygotic embryos, the induction media for primary embryogenesis were devoid of growth promoters in 5% of the cases, being used mostly only auxin (11% with Picloram; 32% with 2,4-D) or auxin plus cytokinin (47% with 2,4-D+ BAP; 11% with Picloram + 2-IP; 5% with ANA+ TDZ) similar trend in anther (50% with 2,4-D+ ANA; 50% with 2,4-D+ ANA+K), inflorescence (17% with 2,4-D; 17% with 2,4-D+ANA+AIA; 50% with Picloram+ANA+AIA; 17% with 2,4-D+ BAP) and ovule (50% with Picloram 50% with 2,4-D+ BAP), using only auxin (2,4-D) in corm, stem and cotyledon (100%), auxin plus cytokinin (2,4-D+ BAP) in meristem (100%) and in leaf segments with auxin (33% with 2,4-D; 67% with Picloram) or cytokinin (100%: TDZ). On the other hand, in the secondary embryogenesis induction medium, the absence of growth regulators was observed from 21% in zygotic embryos, 17% in inflorescences, while the cases with only cytokinin were 36% in zygotic embryos (BAP), 20% in leaves (TDZ), 33% in inflorescences (BAP), 50% in meristem (BAP) and 100% in corm (BAP) and stem (BAP), additionally the use of only auxin was reported in coleoptile (100% with 2,4-D), and leaf (40% with 2,4-D; 20% with Picloram), decreasing the use of only auxin and auxin plus cytokinin in zygotic embryos (5% with 2,4-D+ K; 11% with ANA+TDZ; 16% with 2,4-D+ BAP) and ovules (50% with Picloram; 50% with 2,4- D+ ANA+ BAP).

Furthermore, in the secondary somatic embryogenesis phase of Asparagus officinalis, other growth regulators, such as ABA and acymidol, increase the frequency of repetitive embryos. In this order, ABA (0.5 mg/L) increases from 77 to 95%, while acymidol (0.2 mg/L) increases from 99 to 101%, being better this last substance for this process (LI; WOLYN, 1996). Similarly, the concentration and type of carbon source affect the degree of differentiation of secondary embryos, where 6% sucrose increases up to 61% and 0.2 M Mannitol 78% in Elaeis quineensis (TE-CHATO; HILAE, 2007).

The maturation of secondary embryos, before their regeneration, is achieved in the medium of differentiation of the same. However, in some cases, other growth substances are additionally used, such as 0.5 mg/L GA3 in *Paris polyphylla* (RAOMANI; KUMARIA;TANDON, 2014), NAA 0.1 mg/L and 0.75 mg/L ancimidol in *Asparagus officinalis* (LI; WOLYN, 1996) or without growth regulators in MS medium in *E. quineensis* (TE-CHATO; HILAE, 2007).

5. Cyclic somatic embryogenesis in angiosperms: dicotyledonous group

The only preceding bibliographic compilation of 64 dicotyledonous species with secondary somatic embryogenesis was done by Raemakers *et al*. (1995), while this work reports 106 species, 39 herbaceous, and 67 trees, distributed into 44 families (Table 3).

Independently of the species habits, 16 different explants were used. The intact zygotic embryo represents 42%, followed by leaves with 19%, cotyledon with 9%, anther with 6%, inflorescences with 5%, nucellus with 2%, a zygotic embryo without meristem with 2%, and the remaining ones (corm, petiole, petale, pistils, meristem, microspore, stem and root) with 1% each; these explants regenerated exclusively by the direct way with meristems and microspores, and by the indirect way only with segments of corm, inflorescences, petiole and stem, and by both ways in anthers (D: 33%; I: 67%), cotyledon (D:40%; I:50%; both: 10%), intact zygotic embryos (D: 39%, I:54%; both: 7%), zygotic embryos without meristems (D: 50%; I: 50%), root (D: 67%; I: 33%) and nucellus (D: 33.3%; I: 33.3%; both: 33.3%). Correspondingly, the differentiation of somatic embryos was asynchronous in 96% of the species, originating unicellular in 62% of the species, multicellular in 26 (25%) and 14 (13%) with both origins.

The differentiation of secondary somatic embryos was presented in primary somatic embryos torpedo type in 88% of the species, followed by the cotyledonary (10%) and globular (2%), mostly (80%) in the hypocotyl zone and to a lesser extent in the root (18%), apex (2%) and epicotyl (1%), regenerating plants in 96 out of the 106 species (Table 3).

Regarding the combination of plant growth regulators in the primary and secondary somatic embryo induction media (Table 3), it was found only with intact zygotic embryos, the use of media lacking growth substances for primary embryogenesis in 13% of herbaceous species and 4% of forestal species, using mostly only auxin (29% with 2,4-D; 11% with ANA; 3% with IBA), cytokinin alone (11%: BAP), or auxin plus cytokinin (29% with 2,4-D+BAP or K; 18% with ANA+BAP, 8% AIB+BAP, 5% AIB+ K, 3% AIA+BAP, 3% AIB+2-IP, 3% AIB+BAP+K, 3% 2,4-D +2-IP; 3% with AIA+DPU), as well as in stem sections (11% with 2,4-D; 11% with BAP, K, 2-IP or Z; 11% with 2,4-D +BAP; 22% with ANA+BAP; 11% with ANA+BAP+K), using only auxin (100%: 2,4-D) or cytokinin (100%: K) in zygotic embryos without meristem, also using only cytokinin or auxin plus cytokinin in corm (50%: BAP+Z; 50%: 2,4-D+Z), cotyledon (9% with TDZ; 9% with 2,4-D; 45% with 2,4- D+BAP; 9% with AIB+BAP; 19% with AIB+ K; 9% with AIB+ BAP+K) and meristem (50% with BAP; 50%: 2,4-D+BAP), while using auxin plus cytokinin in microspore, petale (100%: 2 ,4-D+K), petiole, pistiles (100%: 2,4-D+BAP) and finally with media with only auxin or auxin plus cytokinin in anther (11,1% with ANA; 55.6% with 2,4-D+BAP ; 22.2% with ANA+BAP; 11,1% with 2,4-D+BAP+K), inflorescence (28.6% with 2,4-D; 28.6% with 2, 4-D+BAP; 14.3% with 2,4-D+K; 14.3% with 2,4-D+DPU; 14.3% with AIB+BAP+K), nucellus (33% with 2,4-D; 67% with 2,4-D+BAP), leaf (15.4% with 2,4-D; 3.8% with IBA or Picloram, 30.8% with 2,4-D+BAP, 23.2% with 2,4-D+ K, 3.8% with 2,4-D+ TDZ or DPU, 3.8% with 2,4-D+ NAA+ K, 15.4% with ANA+BAP, 3.8% with AIB+ BAP) and root (33.3%: AIB; ANA+BAP; AIB+K).

The induction in the cyclic embryogenesis, it is detailed that increasing in the use of medium devoid of growth promoters in 23% of herbaceous species and from 19% in the tree or forestal species, using intact zygotic embryos, as well as when using zygotic embryos without meristem (100%), petal (100%), cotyledon (25%), leaf (19%) and anther (12,5%). In media with hormones, in anther (13% with ANA; 38% with ANA+BAP; 13% with 2,4-D+BAP+ K; 13% with ANA+AIB+Z), only cytokinin and auxin plus cytokinin in corm (50%: BAP+Z ; 50%: ANA+BAP), inflorescence (28% with BAP; 14% with K; 14% with Z; 14% with 2,4-D+BAP; 14% with 2,4-D+BAP +TDZ) and nucellus (67% with BAP; 33% with ANA+BAP+K), auxin alone, cytokinin alone, and auxin plus cytokinin in intact zygotic embryos (10% with 2,4-D or ANA; 4% with AIA; 2% with ANA+AIA+AIB; 15% with BAP; 4% with K; 8% with ANA+BAP; 4% with AIB+BAP; 2% with AIB+Z; 2% with AIA+BAP or K; 8% with 2,4-D+BAP; 2% with 2,4-D+Z; 2% with Picloram+BAP), leaf (4% with 2,4-D, ANA or AIB; 12% with Picloram; 4%with K, 12% with BAP, 4%with ANA+BAP, 4%with AIB+BAP or Z, 4% with 2,4-D+ANA+K; 4% with 2,4-D+DPU, SA, TDZ or SA, 8% with 2,4-D+K; 12% with 2,4-D+BAP), cotyledon (8.3% with AIA or 2,4-D; 8.3% with BAP; 8.3% with AIB+BAP; 17% with AIB+K; 8.3% with AIB+BAP+K; 8.3% with 2,4-D+BAP; 8.3% with 2,4-D+BAP+K), stem (12.5% with ANA or 2,4-D; 25% with 2-IP; 25% with ANA+BAP).

On the other hand, some species in the differentiation stage of secondary somatic embryos used another growth regulator such as ABA, which increases the rate of cyclic embryogenesis. Thus from primary cotyledonary embryos, secondary somatic embryos increase by 73% in *Aralia cordata* with 0.2 mg/L (LEE; LEE; SOH, 1998) and by 87.5% with 3 mg/L in *Calliandra tweedii* (HEIKRUJAMA *et al*., 2014), 100% with 0.03 to 0.3 mg/L in *Daucus carota* (OGATA *et al*., 2005), or improving their morphology with 0.01 mg/L in *Aesculus hippocastanum* (CÁLIĆ; DEVRNJA; MILOJEVIĆ, 2012).

Similarly, another substance is AgNO3 at 6.7 mg/L that influences the cyclic embryogenesis rate by increasing 90% in Coffea canephora (KUMAR; RAMAKRISHNA; RAVISHANKAR, 2007), as well as the action of 0.1% activated carbon in *Sorbus pohuashanensis*, where it increases by 60.5% (YANG *et al*., 2012a). Furthermore, the concentration and type of carbon source affect the degree of secondary embryo differentiation, where 6% sucrose increases by 80 and 100% respectively in *Chrysanthemum indicum* (NAING *et al*., 2013) and Morus alba (AGARWAL *et al*., 2004), as well as in *Q. suber*, which increases by 100% when using 4% of this disaccharide or 3% glucose (BENALI; LAMARTI, 2019). Similarly, it increases by 100% in *Ocotea catharinensis* when using 0.5 M Mannitol (SANTA CATARINA *et al*., 2004). Finally, in *Q. suber*, the use of amino acids increases the secondary embryogenic rate by 80% with 438.3 mg/L of L-Glutamine and 73% with 396.3 mg/L of L-Asparagine (RAHMOUNI *et al*., 2020); however, when using a lower concentration (30 mg/L) of L-Glutamine the increase was 35%, while when using 30 mg/L of Casein hydrolysate the increase was 36% (ALI; AHMAD, 2021).

Other factors of *in vitro* culture that influence the development of repetitive embryos in some species are temperature and pH. Thus, in *Hovenia dulcis*, a maximum of 66.7% is obtained at 30°C; however, 20°C is optimum for the development of cotyledonary embryos and their conversion into plants (YANG *et al*., 2013). It increases from 70 to 84% at pH 3.5-5 in *Albizia lebbeck* (SAEED; SHAHZAD, 2015) or to 100% at pH 7 in Glycine max (SANTAREM *et al*., 1997). While in the case of light, 16 h of photoperiod improved the plant regeneration by 35% in *Olea europaea* (MAZRI; NACIRI; BELKOURA, 2020).

Furthermore, related to the secondary embryo maturation prior to their regeneration, is achieved simultaneously at the differentiation stage. Regardless, in some species, other growth substances are used, such as GA_3, in *Satalum album* at 0.5 mg/L (RAI; MCCOMB, 2002), in *Carthamus tinctorius* at 0.3 mg/L

(KUMAR; KUMARI; CASTAÑO, 2008) and 1 mg/L (KUMAR; KUMARI, 2010) and 0.1 mg/L in Olea europaea (MAZRI; NACIRI; BELKOURA, 2020). Similarly, ABA is used at 1 mg/L in *Rosa hybrida* (LI *et al*., 2002) and 0.5 mg/L in *Cinnamomum camphora* (SHIN *et al*., 2010) and *Cyclamen persicum* (YOU *et al*., 2011). In addition, MS salts were at 1/2 in *Dianthus caryophyllus* (KARAMI; DELJOU; KARIMI, 2008) *Rosa hybrida* (BAO *et al*., 2012), or to 1/3 *Panax ginseng* (KIM *et al*., 2012).

On the other hand, the increase in the number of cycles of secondary somatic embryos increases the obtaining of genetically stable plants, as was found in *Hevea brasiliensis*, evaluating the number of chromosomes and the variation rate of EST-SSRs loci, showed the chromosome number of the regenerated plants was similar to the mother tree and the rate of EST-SSRs was considered low (2.61%), fundamentally due to the unicellular origin of somatic embryos, according to the study of Wang *et al*. (2017).

Finally, the culture time in the medium significantly influences the greater number of secondary somatic embryos, according to Montoya *et al*. (2022) in *Theobroma cacao*, obtaining an average of 15.2 cyclic embryos per primary somatic embryo (globular and cotyledonary stage), in a medium without hormones after 30 days of culture, decreasing at longer incubation times (40 to 80 days).

Table 3. Cyclic Somatic Embryogenesis in Angiosperms species (dicotyledonous)

SPECIES	EXPLANT	REGENERATIVE VIA	ORIGIN OF THE SOMATIC EMBRYOS	PRIMARY SOMATIC EMBRYOGENESIS (PSE)								DIFFERENTIATION ZONE AND TYPE FROM PSE TO SSE	SECONDARY SOMATIC EMBRYOGENESIS (SSE)								PERCENTAGE OF PLANT DIFFERENTIATION FROM SSE (%)	REFERENCES
				AUXIN (mg/l)				CYTOKININ (mg/l)					AUXIN (mg/l)				CYTOKININ (mg/l)					
				2,4-D	Picloram	NAA	IAA^{a}/IAB^{b}	BAP	K	TDZ	Z^{a}/IP^{b}/DPU^{c}		2,4-D	Picloram	NAA	IAA^{a}/IAB^{b}	BAP	K	TDZ	Z^{a}/2IP^{b}/AS^{c}/DPU^{d}		
Albizia lebbeck (L.) Benth **(F^{t})**	S	I	U	-	-	-	-	-	2,8	-	-	A/ T^{h}	-	-	0,6	-	-	-	-	-	42	Saeed & Shahzad (2015)
Acanthopanax senticosus (Rupr. et Maxim) Harms **(Ar^{t})**	ZE	D	M	0,5 0,5	-	-	-	-	-	-	-	A/ T^{he}	-	-	0,2	-	-	-	-	0,5^{a}	75 -	Gui *et al.*(1991) Xing *et al.*(2006)
Aesculus carnea Hayne. **(S^{t})**	A	I	M	1	-	-	-	1		-	-	A/ T^{hr}	-	-	-	-	2	-	-	-	99	Zdravković *et al.*(2008)
Aesculus hippocastanum L. **(S^{t})**	ZE A	D I	U M	-	-	1 1	-	10	-	-	-	A/ T^{h}	-	-	1	-	0,5	-	-	-	1	Kiss *et al.*(1992) Radojević *et al.*(1978); Troch *et al.*(2009)
Akebia trifoliata Dcne. **(La^{t})**	ZE	D	U	-	-	-	-	-	-	-	-	A/ T^{r}	-	-	-	-	-	-	-	-	95	Zou *et al.*(2019)
Alyssum borzaeanum Nyar. **(B^{h})**	ZE	I	M	1	-	-	-	-	0,1	-	-	A/ T^{r}	2,5	-	-	-	-	-	-	-	100	Păunescu (2008)
Apium graveolens L. **(Ap^{h})**	L I	I	U	0,5	-	-	-	0,2	-	-	-	A/ T^{h}	-	-	-	-	-	0,5	-	-	100	Nadel *et al.*(1989;1990)
Arachis hypogaea L. **(F^{h})**	L ZE	I	M	40 40 40	-	-	-	-	0,2	-	-	A/ T^{h}	5 20	-	-	-	-	0,2	-	-	14 90 45	Baker & Wetztein (1992) Durham & Parrot (1992) Baker & Wetztein (1995) Chengalrayan *et al.*(2001)
A. paraguariensis Chodat & Hassl. **(F^{h})**	ZE	I	M	0,5	-	-	-	-	0,01	-	-	A/ G^{a}	-	-	-	-	0,5	-	-	-	100	Sellars *et al.*(1990)
Aralia cordata Thunb **(Ar^{t})**	I	I	M	1,5	-	-	-	-	-	-	-	A/ T^{h}	-	-	-	-	-	-	-	-	73	Lee *et al.*(1998)
Aralia elata Seem **(Ar^{t})**	L	I	M	-	-	-	3^{b}	-	-	-	-	A/ T^{h}	-	-	-	3^{b}	-	-	-	-	100	Dai *et al.*(2011)
Azadirachta indica A. Juss **(Me^{t})**	ZE C	I D I	U M	-	-	-	0,08^{a}	0,22	-	0,02 0,02	-	A/ T^{h}	-	-	-	1^{a}	-	-	-	-	100 10 33	Chatuverdi *et al.*(2004) Singh & Chaturvedi (2009) Artigas & Fernandez (2015;2018)

Beta vulgaris L. **(A^{h})**	**ZE**	**I**	U M	-	-	1	-	-	-	-	-	A/ T^{h}	-	-	-	-	-	0,1	-	-	61	Tenning *et al.* (1992) Zhang *et al.* (2008)
Bixa Orellana L. **(Bi^{t})**	**ZE**	**I**	U	-	-	0,01	-	0,1	-	-	-	A/ T^{h}	-	-	0,01	-	0,1	-	-	-	100	Parimalan *et al.* (2010)
Brassica campestris L.	**ZE**	**D**	M	0,02	-	-	-	-	0,002	-	-	A/ T^{h}	-	-	-	-	0,05	-	-	-	100	Maheswaran &Williams (1986)
B. napus L. **(B^{h})**	**A** **ZE** **MI**	**D**	U	0,02	-	1	-	0,5	0,002	-	-	A/ T^{h}	-	-	-	-	0,05	-	-	0,2[a]	100 75	Thomas *et al.* (1976) Pretova & Williams (1986) Koh & Loh (2000)
B. juncea (L.) Vassilii Matveievitch Czernajew **(B^{h})**	**A**	**D**	U	-	-	0,1	-	-	-	-	-	A/ T^{h}	-	-	0,1	-	2	-	-		100	Prabhudesai & Bhaskaran (1993)
B. oleracea L. **(B^{h})**	**ZE** **R**	**D** **I**	M	- 1	-	-	0,05[a]	-	0,5	-	-	A/ T^{h}	-	-	-	-	-	-	-	-	100 83 60	Ćosić *et al.* (2013) Pavlović *et al.* (2013) Shamari *et al.* (2018)
Calliandra tweedii (Benth.) **(F^{t})**	**S**	**I**	U	-	-	-	-	-	-	-	0,2[b]	A/ C^{rh}	-	-	-	-	-	-	-	0,2[b]	70	Heikrujama *et al.* (2014)
Camelia japonica L. **(T^{t})**	**ZE R**	**D**	M	-	-	-	1[b]	-	-	-	-	A/ T^{h}	-	-	-	0,1[b]	0,1	-	-	-	72	Vieitez & Barciela (1990)
C. reticulata Lindl. **(T^{t})**	**ZE**	**D**	M	-	-	-	0,5[b]	0,1	-	-	-	A/ T^{h}	-	-	-	-	0,1	-	-	-	-	Plata & Vieitez (1990); Plata *et al.* (1991)
C. sinensis (L.) Kuntze **(T^{t})**	**ZE**	**D**	M	-	-	2	0,5[b]	10 2	-	-	-	A/ T^{h} S/ T^{h}	-	-	-	3[a] 0,2[b]	2 2	-	-	-	20 92	Jhaa et al. (1992) Kuntze *et al.* (2001)
Carica papaya L. **(C^{t})**	**ZE**	**I**	M	2 7	-	-	-	-	-	-	-	S/ T^{h}	-	-	-	-	-	-	-	-	-	Cipriano *et al.* (2018) Chaudhary *et al.* (2019)
Carthamus tinctorius L. **(Asa^{h})**	**ZE** **L** **S**	**I**	U	-	-	1	2,5[b]	1,5	0,5	-	6[a]	A/ T^{rh}	-	-	1	2,5[b]	1,5	-	-	6[a]	61 100	Kumar *et al.* (2008) Kumar & Kumari (2010) Mandal & Gupta (2003)
Catharanthus roseus (L.) G. Don **(As^{h})**	**ZE**	**I**	U	-	-	1	-	1,5	-	-	-	A/ T^{h}	-	-	1	-	1	-	-	-	22	Junaid *et al.* (2007)
Centaurium erythraea Rafn **(G^{h})**	**L**	**I** **D**	U M	0,1	-	-	-	-	-	-	0,3[c]	A/ T^{h}	0,2	-	-	-	-	-	-	0,5[d]	80	Bogdanović *et al.* (2021)
Chrysanthemum indicum L. **(As^{h})**	**L**	**D**	U	2	-	-	-	-	2	-	-	A/ T^{h}	2	-	-	-	-	2	-	-	100	Naing *et al.* (2013)
Cinnamomum camphora L. **(Lu^{t})**	**ZE**	**I**	U M	0,1 0,1	-	-	-	1 1	-	-	-	A/ C^{rh}	0,1	-	1	-	1	-	-	-	93 -	Shin *et al.* (2010) Jing *et al.* (2019)
Clematis sp **(Ra^{h})**	**M**	**I** **D**	U	-	-	-	-	0,5	-	-	-	A/ C^{h}	-	-	-	-	0,5	-	-	-	100	Mitrofanova *et al.* (2021)
Clitoria ternatea L. **(F^{h})**	**ZE**	**I**	M	-	-	0,5	-	0,5	-	-	-	A/ T^{rh}	-	-	-	0,5[a]	-	0,5	-	-	-	Dhanalakshni & Lakshmanan (1992)
Coffea arabica L. **(Ru^{t})**	**L**	**I**	U M	1	-	-	-	8	-	-	-	A/ T^{h}	-	-	-	-	8	-	-	-	100	Fernández *et al.* (2005)
Commiphora wightii (Arnott) Bhandari **(Bu^{t})**	**ZE**	**I**	U	1	-	-	-	-	-	-	-	A/ C^{h}	-	-	-	-	-	-	-	-	61	Kumar *et al.* (2015)

Coriandrum sativum L. **(Ap^h)**	C S	I	U	1	-	-	-	-	-	-	-	A/ T^{rh}	1	-	-	-	-	-	-	-	90	Murthy *et al.*(2008)
Crocus vernus (L.) **(I^h)**	CO	I	M	1	-	-	-	-	-	-	0,5^a	A/ T^h	-	-	0,5	-	2	-	-	-	100	Sivanesan *et al.*(2012) Blazquez *et al.*(2009)
Cucumis sativus L. **(Cu^h)**	T	I	M	-	-	-	-	-	-	-	0,2^a	A/ T^h	-	-	-	-	-	-	-	0,2^a	82	Ziv & Gadasi (1986) Cade *et al.*(1990)
Cyclamen persicum Mill **(Pr^h)**	L	I	M	2	-	-	-	0,2	-	-	-	A/ G^a	2	-	-	-	0,2	-	-	-	100	You *et al.*(2011)
Datura metel L. **(So^h)**	ZE^{-m}	D	M	-	-	-	-	-	2	-	-	A/ T^{rh}	-	-	-	-	-	-	-	-	50	Wijesekaraa & Iqbal (2013)
Daucus carota L. **(Ap^h)**	ZE^{-m} ZE	I D	U	1	-	-	-	-	-	-	-	A/ T^h	-	-	-	-	-	-	-	-	100 93	Tokuyi *et al.*(1995) Ogata *et al.*(2005)
Dianthus caryophyllus L. **(Cr^h)**	I	I	U	0,2	-	-	-	0,2	-	-	-	A/ T^h	0,2	-	-	-	0,2	-	-	-	95	Karami *et al.*(2008)
Eleutherococcus senticosus Maxim **(Ar^t)**	ZE	D	U M	1	-	-	-	-	-	-	-	A/ Th	-	-	-	-	-	-	-	-	65	Yang *et al.*(2012b); Zhou *et al.*(2014)
Eriobotrya japonica (Thunb.) Lindl. **(Ro^t)**	A	I	M	0,5	-	-	-	2	-	-	-	A/ T^{rh}	-	-	0,2	0,2^b	-	-	-	0,05^a	73	Junqianga *et al.*(2008) Yang *et al.*(2012)
Eucalyptus citriodora Hook. **(M^t)**	ZE	I	U M	-	-	3	-	-	-	-	-	A/ T^h	-	-	-	3^a	-	-	-		50	Muralidharan *et al.*(1989)
Eucalyptus globulus Labill. **(M^t)**	ZE	I	U M	-	-	3	-	-	-	-	-	A/ T^h	-	-	-	3^a	-	-	-	-	50	Pinto *et al.*(2008)
Fagus sylvatica L. **(Fa^t)**	ZE	I	M	5	-	-	-	-	-	-	-	A/ T^h	1	-	-	-	-	-	-	-	10	Vieitez *et al.*(1992)
Fraxinus americana L. **(O^t)**	ZE	I	M	1	-	-	-	1	-	-	-	A/ T^h	-	0,2	-	-	0,2	-	-	-	20	Bates *et al.*(12993)
Garcinia indica Choiss. **(Cl^t)**	ZE	D	M	-	-	-	-	5	-	-	-	A/ C^{rh}	-	-	-	-	5	-	-	-	70	Thengane *et al.*(2006)
Gladiolus x Gladiolus L. **(I^h)**	CO	I	M	-	-	-	-	0,2	-	-	0,2^a	A/ T^h	-	-	-	-	0,2	-	-	0,2^a	100	Remotti (1995)
Glycine max L. **(F^h)**	ZE	I D	U	-	-	10 40	-	-	-	-	-	A/ T^{rh}	-	-	10 40	-	-	-	-	-	100 77	Liu *et al.*(1992)
Ipomea batatas L. (Lam) **(Co^h)**	L P	I	U	2,5	-	-	-	0,3	-	-	-	S/ T^h	0,2	-	-	-	-	-	-	-	100	Zheng *et al.*(1996)
Helianthus maximiliani (Schrader) **(Ar^h)**	L	D	U	-	-	0,5	-	0,5	-	-	-	A/ T^h	-	-	0,5	-	0,5	-	-	-	100	Vasic *et al.*(2001)
Hepatica nobilis L. **(Ra^h)**	ZE	I	M	-	-	0,2	-	0.02	-	-	-	A/ T^h	-	-	0.02	-	0,2	-	-	-	52	Szewczyk & Pawłowska (2015)
Hevea brasiliensis (Willd & A. Juss) Müll. Arg. **(E^t)**	A	I	U	-	-	0.02	-	0,5	3	-	-	A/ T^h	-	-	0.02	-	0,5	3	-	-	75	Hu *et al.*(2010)
Hovenia dulcis Thunb. **(Rh^t)**	ZE	I	U	1	-	-	-	-	-	-	-	S/ T^h	-	-	-	-	0,1	-	-	-	43	Yang *et al.*(2013)
Juglans hindsii (Jeps.) Jeps. ex R.E.Sm. **(J^t)**	C	D	U	-	-	-	0.01^b	-	2	-	-	A/ T^r	-	-	-	0.01^b	-	2	-	-	100	Tulecke & Mcgranahan (1985) Polito *et al.*(1989)
J. nigra L. **(J^t)**	ZE	D	U	-	-	-	0.01^b	-	1	-	-	A/ T^h	-	-	-	-	-	-	-	-	-	Jariteh *et al.*(2011)
J. nigra x regia **(J^t)**	C	D	U	-	-	-	0.01^b	-	2	-	-	A/ T^r	-	-	-	0.01^b	-	2	-	-	100	Tulecke & Mcgranahan (1985) Polito *et al.*(1989)
J. regia L.**(J^t)**	C	D	U	-	-	-	0,01^b	1	2	-	-	A/ T^h	-	-	-	0,01^b	1	2	-	-	48	Fang *et al.* (2022)

Limnanthes alba Benth. **(L^{h})**	ZE	D	U	0,02	-	-	-	-	-	-	0,02^{a}	A/ T^{h}	0,02	-	-	-	-	-	-	0,02^{a}	-	Southworth &, Kwiatkowski (1991)
Linum usitatissimum L. **(Li^{h})**	S	I	U	-	-	0,5	-	0,5	-	-	-	A/ T^{h}	-	-	0,5	-	0,5	-	-	-	3	Tejavathi *et al.*(2000)
Liquidambar stryaciflua L. **(Al^{t})**	I	I	U	3	-	-	-	-	-	-	-	A/ T^{h}	-	-	-	-	-	-	-	0,01^{a}	100	Merkle *et al.*(1997)
Magnolia delbata Zucc. **(Ma^{t})**	ZE	I	U	1	-	-	-	-	-	-	-	A/ T^{h}	1	-	-	-	-	-	-	-	37	Chávez *et al.*(2020)
Magnolia spp. L. **(Ma^{t})**	ZE	D I	U	2	-	-	-	0.3	-	-	-	A/ T^{h}	2	-	-	-	0.3	-	-	-	25	Merkle & Wiecko (1990)
Malus domestica Borkh. **(Ro^{t})**	N	D I	U	0,4	-	-	-	0,04	-	-	-	A/ C^{h}	-	-	0,2	-	0.2	0,2	-	-	70	Daigny *et al.*(1996)
M. pumila Mill. **(Ro^{t})**	N	D	U	0,4	-	-	-	0.04	-	-	-	A/ C^{h}	1	-	-	-	0,5	-	-	-	50	James *et al.*(1984)
Mangifera indica L. **(An^{t})**	N	I	U	2	-	-	-	-	-	-	-	A/ T^{h}	-	-	-	-	0.5	-	-	-	55	Litz *et al.*(1984)
Manihot esculenta Crantz **(E^{h})**	M L L	D I	U	0,01 4 4	1	-	-	0,1	-	-	-	A/ T^{rh} C^{h}	0,01 4	12 12	-	-	0,1 0,2	-	-	10^{c}	35 43 13 80	Szabados *et al.*(1987) Groll *et al.*(2001) Wongtiem *et al.*(2011) Anuradha *et al.*(2015)
Medicago sativa L. **(F^{h})**	C L	 I	U	2 1	-	-	-	0,3	0,2	-	-	A/ T^{h}	-	-	-	-	-	-	-	-	50	Lupotto (1986) Sangra *et al.*(2019)
Medicago trunculata Gaertn. **(F^{h})**	L	I	U	1	-	-	-	-	-	-	2^{a}	A/ T^{h}	-	-	-	-	-	-	-	-	34	Das Neves *et al.*(1999)
Morus alba L. **(Mo^{t})**	ZE	I	U	2	-	-	-	0,5	-	-	-	A/ T^{h}	0,05	-	-	-	0,01	-	-	-	92	Agarwal *et al.*(2004)
Myrtus communis L. **(M^{t})**	C S	I	U	1	-	-	-	1	-	-	-	A/ T^{h}	-	-	-	-	-	-	-	-	10	Parra & Amo (1998)
Ocotea catharinensis Mez. **(Lu^{t})**	ZE	I	U	4	-	-	-	-	-	-	-	A/ C^{h}	4	-	-	-	-	-	-	-	2,5	Moura *et al.*(1993)
Olea europaea L. **(O^{t})**	L C ZE	I D	U M	-	-	-	0,05^{b} 5,6^{b} 6,2^{b}	0,1 2,8	-	-	- 0,6^{b}	A/ T^{r}	-	-	- 0,1	0,05b 0,05b	0,1 0,1	-	-	-	90 75 35	Rugini & Caricato (1995) Pires *et al.*(2020) Mazri *et al.* (2020) Benelli et al.(2001)
Panax ginseng C.A.Mey. **(Ar^{h})**	C	I	U	1	-	-	-	0.1	-	-	-	A/ T^{rh}	-	-	-	-	-	-	-	-	88	Kim *et al.*(2012) Kim *et al.*(2010)
Panax vietnamensis Ha et. Grushv. **(Ar^{h})**	L	I	U	1	-	0,5	-	-	0,2	-	-	A/ G	1	-	0,5	-	-	0,2	-	-	66	Diem *et al.* (2022)
Passiflora cincinata Mast.. **(Pa^{h})**	A	I	U M	4	-	-	-	1	-	-	-	A/ T^{h}	4	-	-	-	1	-	-	-	100	Lemes *et al.*(2021a)
Petiveria alliacea L. **(Pe^{h})**	L	D	U	5	-	-	-	-	-	5	-	A/ T^{h}	-	4	-	-	-	-	-	-	5	Cantelmo *et al.*(2013)

Pharbitis nil L. **(M^{h})**	ZE	D	M	-	-	3	-	-	-	-	-	A/ T^{h}	-	-	-	0,2^{a}	2	-	-	-	100	Jia & Chua (1992)
Piper nigrum L. **(Pi^{h})**	ZE	D	U	-	-	-	-	-	-	-	-	A/ T^{r}	-	-	-	-	-	-	-	-	75	Nair & Gupta (2006)
Polyscias filicifolia (C. Moore ex E. Fourn.) L. H. Bailey **(Ar^{t})**	L	I	M	0,5	-	-	-	1	-	-	-	A/ T^{h}	-	-	-	-	-	-	-	-	90	Śliwińska *et al.*(2008)
Populus ciliata Wall. & Royle **(Sa^{t})**	L	I	U	0,4	-	-	-	-	-	-	-	A/ T^{h}	-	-	0,2	-	0,4	-	-	-	100	Cheema (1989) Huang *et al.*(2015)
Prunus avium L. **(Ro^{t})**	ZE	I	U	-	-	-	0,05^{b}	0,1	0,1	-	-	A/ T^{h}	-	-	0,1	0,1^{a} 0,05^{b}	-	-	-	-	18	Garin *et al.*(1997)
Prunus cerasus L. **(Ro^{t})**	C	D	U	2	-	-	-	0,1	-	-	-	A/ T^{r}	2	-	-	-	0,1	-	-	-	-	Tanga *et al.*(2000)
Prunus persica (L.) Stokes. **(Ro^{t})**	C	D	U	5	-	-	-	2	2	-	-	A/ T^{h}	1	-	-	-	0,2	0,2	-	-	100	Bhansali *et al.*(1990)
P. avium x P. seudocerasus **(Ro^{t})**	R	D	U	-	-	1	-	0,1	-	-	-	A/ T^{h}	-	-	-	-	-	-	-	-	-	Pesce & Rugini (2004)
P. incisa x P. serula **(Ro^{t})**	ZE	I	U	-	-	-	-	1	-	-	-	A/ T^{h}	-	-	-	-	-	-	-	-	-	Druart (1990)
Quercus alba L. **(Fa^{t})**	ZE	D I	U	1	-	-	-	1	-	-	-	A/ T^{h}	0,1	-	-	-	0,1	-	-	-	3	Gingas & Lineberger (1989)
Q. bicolor Willd. **(Fa^{t})**	I	I	U	1	-	-	-	1	-	-	-	A/ T^{h}	-	-	-	-	1	-	-	-	20	Gingas (1991)
Q. brantii L. **(Fa^{t})**	ZE	I	U	0,8	-	-	-		-	-	-	A/	-	-	-	-	-	-	-	-	100	Faizy *et al.*(2019)
Q. ilex L. **(Fa^{t})**	S	I	U	-	-	2	-	0,5	-	-	-	A/ T^{h}	-	-	0,06	-	-	-	-	-	67	Martínez *et al.*(2017)
Q. rubra L. **(Fa^{t})**	ZE	D I	U	1	-	-	-	1	-	-	-	A/ T^{h}	0,1	-	-	-	0,1	-	-	-	3	Gingas & Lineberger (1989)
Q.robur L. **(Fa^{t})**	ZE L	I	U M	-	-	2,4 0,06	-	0,1	-	-	-	A/ T^{h}	-	-	-	-	-	-	-	-	- 48	Zegzouti *et al.*(2001) Mallón *et al.*(2012) Puiderrajols *et al.*(2001)
Q. suber L. **(Fa^{t})**	S L	I D	U M	-	-	-	-	2 0,2	-	-	-	A/ T^{h} A/ T^{r}	-	-	-	-	-	-	-	-	- 35	El Maataqui *et al.*(1990) Fernandez *et al.*(1995) Puiderrajols *et al.*(2001)
Robinia pseudoacacia L. **(F^{t})**	ZE	D	U	4	-	-	-	0,3	-	-	-	A/ T^{rh}	4	-	-	-	0,3	-	-	-	100	Merkle & Wiecko (1989)
Rosa chinensis **(Ro^{t})**	L	I	U	3	-	-	-	-	0,5	-	-	A/ T^{h}	1	-	-	-	-	-	0,1	-	40	Cai *et al.*, 2022
Rosa hybrida **(Ro^{t})**	L	I	U	10 3	-	-	-	-	-	-	-	A/ T^{h}	-	-	-	-	-	-	-	-	100 56	Li *et al.*(2002a) Bao *et al.*(2012)
Rosa rugosa Thunb. **(Ro^{t})**	L	I	U	4	-	-	-	-	0,05	-	-	A/ T^{h}	1	-	-	-	0,01	-	-	-	86	Xing *et al.*(2014)
Satalum album Linn. **(St^{t})**	ZE	D	U	-	-	-	-	-	-	0,01	-	A/ T^{h}	-	-	1	-	-	-	-	-	65	Rai & McComb (2002)
Sorbus pohuashanensis (Hance) Hedl. **(Ro^{t})**	ZE	I	U	-	-	1	-	0.1	-	-	-	A/ T^{h}	-	-	0,01	-	-	-	-	-	40	Yang *et al.*(2012a)
Sweitenia macrophyla Jacq. **(Me^{t})**	L	I	U	1	-	-	-	2	-	-	-	A/ T^{r}	-	-	-	-	1	-	-	-	19	Gatica *et al.*(2019) Quiala *et al.* (2021)

Theobroma cacao L. (**Ml**^{t})	I	I	U	2	-	-	-	0,2		-	-	A/	-	-	-	-	-		5	-	100	Maximova *et al.*(2002)
			M	2					0.1			C^{h}	2					0,5			20	Ajijaha & Hartatib (2019)
	A				-	-	-	-		-	-	A/	-	-	-	-	-	-	-	-	70	
	PE			1					0,3			G										Montoya *et al.*(2022)
												A/										
												C^{h}										
Tilia amorensis Rupr. (**Ml**^{t})	ZE	I	U	1	-	-	-	-	-	-	-	A/ C^{h}	1	-	-	-	-	0,1	-	-	72	Kim *et al.*(2006a)
Trifolium repens L. (**F**^{h})	ZE	D	U	-	-	-	-	0,05	-	-	-	A/ T^{h}	-	-	-	-	0,05	-	-	-	100	Maneswaran & Williams (1984;1985)
Vitis latifolia L. (**V**^{t})	A	I	U	4	-	-	-	2	-	-	-	A/ T^{h}	-	-	2	-	-	-	-	-	14	Salunkhe *et al.*(1999)
V. rupestris Scheele (**V**^{t})	L	I	U	1	-	-	-	1	-	-	-	A/ T^{h}	-	-	1	-	-	-	-	-	13	Martinelli *et al.*(1993; 2001)
V. vinifera L. (**V**^{t})	ZE	D		-	-	-	-	0,2	-	-	-	A/	-	-	-	-	0,2	-	-	-	21	Emershad & Ramming (1994)
	I			0,6	-	-	-	-	-	-	1c	T^{h}	-	-	-	-		-	-	-		
		I															2				5	Hao *et al.*, 2022
			U		-	-	-	2	-	-	-											
	I	I		1	-	-	-		-	-	-		0,5	-	-	-		-	-	-		Capriotii *et al.* (2022)
	A				-	-	-	1	-	-		A/		-	-	-		-	-	-	-	
	PI			1,1							-	T^{m}					1,1					
	A	I		0,5				4					0,5								80	Zhou *et al.*(2014)
																	1,1					
Zizyphus jujuba Mill. (**Rh**^{t})	C	I	U	1	-	-	0,1^{a}	-	-	-	-	A/	-	-	-	-	0,2	-	-	-	93	Kim *et al.*(2006b)
							0,1^{b}					T^{h}										

FAMILY. (A): Amaranthaceae; **(Al):** Altingiaceae; **(An):** Anacardiaceae; **(Ap):** Apiaceae**;** **(Ar):** Araliaceae; **(As):** Asteraceae; **(Bi)**: Bixaceae; **(B)**: Brassicaceae; **(BU):** Burceraceae; **(C)**: Caricaceae; **(Cr):** Caryophyllaceae; **(Co)**: Convolvulaceae; **(Cl):** Clusiaceae; **(Cu)**: Curcubitaceae; **(E)**: Euphorbiaceae; **(F)**: Fabaceae; **(Fa):** Fagaceae; **(G):** Gentianaceae; **(I):** Iridaceae; **(J):** Juglandaceae; **(L)**: Limnanthaceae; **(La):** Lardizabalaceae; **(Lu):** Lauraceae; **(Li):** Linaceae; **(Ma):** Magnoliaceae; **(Ml):** Malvaceae; **(Me):** Meliaceae; **(Mo):** Moraceae; **(M):** Myrtaceae; **(O):** Oleaceae; **(Pa):** Passifloraceae; **(Pe):** Petiveriaceae; **(Pi):** Piperaceae; **(P):** Polygonaceae; (**Pr):** Primulaceae; **(Ra):** Ranunculaceae **(Rh):** Rhamnaceae; **(Ro):** Rosaceae; **(Ru):** Rubiaceae; **(Sa):** Salicaceae; **(St):** Santalaceae; **(So)**: Solanaceae; **(T):** Theaceae; **(V):** Vitaceae. **HABIT.** (^{t}): tree; (^{h}): Herbaceus. **EXPLANT.** **A**: anther; **C**: Cotyledon; **CO**: Cormo; **ZE**: zygotic embryo; **ZE**$^{-m}$: zygotic embryo without meristem; **L**: leaf; **I**: Inflorescence or flower; **P**: petiolo; **PE**: Petal; **PI**: Pistils; **M**: meristem; **MM**: male meristem; **MI**: microspores; **N**: nucela; **R**: root; **S**: stem. **REGENERATIVE VIA**. **D**: direct; **I**: Indirect. **ORIGIN OF THE SOMATIC EMBRYOS.** (**U**): Unicellular; (**M**): Multicellular. **SOMATIC EMBRYO**. **PSE**: primary; **SSE**: secondary. **SYNCHRONIC OF THE SSE.** (**SIN**). **S**: synchronic; **A**: asynchrony. **DIFFERENTIATION TYPE PSE TO SSE.** **G**; globular; **T**: torpedo; **C**: cotyledonal. **DIFFERENTIATION ZONE PSE TO SSE.** **r**: root; **h:** hypocotyl; **e:** epicotyl; **mc**: mid-cotyledonary co. **AUXINS. 2,4-D:** 2,4-dichlophenoxyacetic; **PICLORAM:** 4-amino-3,5,6-trichloropicolinic acid**;** **NAA:** 1-naphthaleneacetic acid; **IAA:** indole-acetic acid; **IBA**: Indole-3-butyric acid. **CYTOKININS: AS**: Adenine Sulphate; **BAP**: 6-benzyl-amino purine**; K:** 6-furfuryaminopurinre or Kinetin; **TDZ**: thidiazurom; **2-IP**: 2-isopentenyl adenine; **DPU:** 1,3-Diphenylurea; **Z**: zeatin.

6. Biotechnological applicattions of repetitive somatic embryogenesis.

In general, the applications of somatic embryogenesis are ontogenetic studies, gene expression, molecular genetics, and micropropagation of species of commercial interest, genetically modified or not, with promising characteristics (LOYOLA; OCHOA, 2016). Corresponding to secondary somatic embryogenesis is the massive micropropagation of elite varieties according to the agronomically important characteristic, particularly through Temporary Immersion (TI) systems and the efficient regeneration of transgenic plants from transformed primary somatic embryos.

In relation to the massive multiplication of secondary embryos by IT and the subsequent efficient regeneration, from globular primary somatic embryos, they multiply more than 24 times in secondary embryos in cycles of 1 min of immersion and six h in dryness in *Camellia sinensis* (AKULA; BECKER; BATESON, 2000) or with primary torpedo embryos with cycles of 1 min of immersion and 8 h without medium, developing from 86 to 90% of secondary embryos in *Q. robur* (MALLÓN; COVELO; VIEITEZ, 2012). Accordingly to the system, the mass of primary embryos initiated must be considered, as indicated by Steinmacher *et al*. (2011) and Yang *et al*. (2012b) in *Eleutherococcus senticosus* and *Bactris gasipaes*, respectively, which obtain the highest yield with 100 mg.

Another interesting aspect is obtaining plants with improved characteristics, increasing their ploidy, incubating primary somatic embryos in colchicine. Thus, the 29.9% of polyploid plants without abnormalities and with beneficial agronomic characteristics were regenerated from secondary somatic embryos of *Panax vietnamensis*, incubating primary somatic embryos in the globular stage with 0.3 to 0.5% colchicine for 48 h. The tetraploid plants obtained showed better growth than the diploid plants, as they presented a larger size of the stomata and a lower stomatal density (DIEM, PHONG, TUNG, 2022).

Regarding genetic transformation, few works reported using primary somatic embryos with the subsequent regeneration of transgenic plants resulting from the differentiation of secondary embryos from these. Among the systems used, the main one is the indirect by *Agrobacterium tumefaciens*, followed by the direct ones were Biobalistics and electroporation.

In the first case, in *J. regia*, transforming globular somatic embryos with the nptII gene (pCGN200), 70% of secondary embryos are obtained from these plants with the insert then verified by Southern blot (MCGRANAHAN *et al*., 1988). With the *gus* gene (pCGN7001), only 2.5% of *gus* positive plants are obtained (MCGRANAHAN *et al*., 1993), while with the *badhx* gene (pBI21) that confers tolerance to salt stress, 80% of transformation of globular primary embryos is achieved, regenerating 5.5% transgenic plants, after the *gus* gene test (BOLAGH *et al*., 2020). In *Medicago sativa*, inserting the *nptII* and *gus* genes, 16% of GUS-positive plants are regenerated from secondary embryos differentiated from globular primary embryos transforming with pGA472 (NINKOVIĆ; MILJUŚ;

NEŚKOVIĆ, 1995), or using the plasmid pCambia2301 in primary cotyledonary embryos 90% of secondary embryos are differentiated, of which 15.2% were positive to GUS and molecularly by PCR (LIU *et al*., 2013). Similarly, in *Rosa rugosa*, inserting the *nptII* and *gus* genes (pBI121) in globular primary embryos, 74% of secondary embryos positive for *gus* are achieved, but only 11.4% of these regenerate plants (XING *et al*., 2014), while with *Eriobotrya japonica* with globular primary embryos using pEG121 with the nptII gene, 22% of transformed plants are obtained, regenerated from differentiated secondary embryos (LIN; LI; ZONG, 2021). In *Q. ilex*, the plasmid pK7TA4 carrying the genes *nptII*, *rol*, *gus*, and *cstl*1 is transferred, the latest encoding the antifungal protein "thaumatin", which confers tolerance to the pathogen *Phytophthora cinnamomi*; in primary globular somatic embryos, obtaining from 2.8 to 66.7% of transgenic plants, after the colorimetric evaluation of *gus* and the molecular evaluation by PCR (CANO *et al*., 2020). In *Brassica oleracea*, the hpk1 and bar (pSHX004) genes that confer tolerance to salt stress and herbicide, respectively, were inserted in primary somatic embryos, obtaining 7.33 of transgenic plants, after molecular evaluation by PCR of the presence of both genes, as well as the evaluation in the field where the transformed lines had greater resistance to high concentrations of NaCl and herbicide (PAVLOVIĆ *et al*., 2020). In *Vitis vinifera*, empleando primary torpedo embryos in mid-cotyledonary stage, the pCAMBIA2301 plasmid is transferred with the *nptII,* achieving 80% of regenerated plants molecularly positive by PCR (ZHOU; DAI; CHENG, 2014), while in *Hevea brasiliensis* with the same plasmid and gene*,* achieving 4,06 % of regenerated plants GUS positive using cotyledonary primary somatic embryos (HUANG; LI; LI *et al*. 2015), improving its expression by cocultivation the same type of primary embryos with the bacteria for 84 hours, also verifying molecularly by PCR, according to Udayabhanu *et al*. (2022). In *Q. suber*, in globular and primary torpedo embryos, the pK7TA4 plasmid is transferred with the *nptII*, *gfp*, *rol* and *cstl1* genes, it is the last encoding for an antifungal protein, observing 60% of *gfp*-positive regenerated plants, of which 100 % carried the transgenes and 83.3% over-expressed the cstl1 gene product, when molecularly evaluated by real-time PCR, showing that 38.9% of the transgenic lines obtained were tolerant to the fungus, in *in vitro* assays with the pathogen fungal (CANO; MARTÍNEZ; COUSELO, 2021). In *Passiflora cincinnata*, the plasmid pCAMBIA1304 carrying the *hptII*, gus and nos genes is transferred into segments of primary cotyledonary somatic embryos, increasing the transformation efficiency to 21.4% by applying 30 s of sonication, when evaluating the presence of the gene by PCR gus (LEMES; PAIM; BARCELOS, 2021b). In *Theobroma cacao*, the hptII and gfp genes are inserted through the plasmid pCAMBIA2300 in cotyledonary segments of secondary somatic embryos, the transgenic frequency being higher (11.6%) with the *Agrobacterium* AGL1 strain and with explants from 4 to 10 mm, by performing the colorimetric evaluation of the green fluorescent protein and molecular PCR of the *nptII* and *gfp* genes (JONES; ZHANG; TUCKER, 2021).

On the other hand, by bombardment, De Guglielmo *et al*. (2010) used torpedo type somatic embryos of *C. arabica* to efficiently transfer the *Cry*-1ac gene (pUBC) that confers resistance to Lepidoptera, at a pressure of 70 psi and 14 cm distance, regenerating by secondary somatic embryogenesis 100% of uniformly transformed plants, after the molecular evaluation of the gene by PCR, Southern blot, as well as by Reverse Transcription-PCR. Likewise, in *C. sinensis*, Furukawa *et al*. (2020) inserted the gene *nptII* and *gus* (pRI201) in primary embryos at a pressure of 80 psi and 6 cm of distance, differentiating secondary embryos positive to GUS, which is 39% became transformed plants. On the other hand, the electroporation method was only reported in leaf, embryogenic callus, and primary somatic embryo (torpedo type) of *C. arabica*, at capacitance of 900 µF and voltages of 375, 625, and 875 V/cm with pCambia3201 with *gus* and *bar* genes. Although this plasmid gives resistance to herbicides, transformation (100%) was found only in primary embryos previously enzymatically treated (1 h in 2% cellulose, 1% macerosime) and electroporated at 375 V/cm, regenerating by cyclic embryogenesis in the liquid medium, 100% *gus* positive plants, verifying molecularly by PCR that the genes were transferred (FERNÁNDEZ; MENÉNDEZ, 2003).

7. Conclusions

So far, secondary somatic embryogenesis has been reported in detail in 148 species (7 Gymnosperms and 141 Angiosperms) by using different explants. The main pathway was found indirectly and asynchronously, of unicellular origin in more than 60% of the cases, regenerating plants in more than 90% of the species. The combination of growth regulators (only auxin, only cytokinin, or auxin+ cytokinin) for the stage of primary and repetitive embryogenesis varies accordingly to the plant species and explant type. However, the use of growth-regulators free media increases, decreasing the auxins concentration and increasing cytokinins in the phase of secondary embryogenesis. Despite the potential and versatile biotechnological application of cyclic embryogenesis, there are still very few works on it, so the information in this bibliographic review will be of great help for new research in these species and others where this process has not been reported yet.

8. References

AGARWAL, Sandhya; KANWAR, Kamlesh; SHARMA, D.R. Factors affecting secondary somatic embryogenesis and embryo maturation in *Morus alba* L. **Scientia Horticulturae**, v. 102, n. 3, p. 359-368, 2004. https://doi.org/10.1016/j.scienta.2004.04.002

AJIJAHA; Nur; HARTATI, Sri Rr. Primary and secondary somatic embryogenesis of cacao: the effect of explant types and plant growth regulators. **Indonesian Journal of Agricultural Science**, v. 20, n. 2, p. 69-76, 2019. http://dx.doi.org/10.21082/ijas.v20n2.2019.p69-76

AKULA, Anisha; BECKER; D; BATESON, Marion. High-yielding repetitive somatic embryogenesis and plant recovery in a selected tea clone, 'TRI-2025', by temporary immersion. **Plant Cell Report**, v. 19, n. 12, p. 1140-1145, 2000;. https://doi.org/10.1007/s002990000239

ALI, Naouar; AHMAD, Lamarti. Influence of amino acids on the secondary somatic embryogenesis proliferation process of Moroccan Cork Oak (*Quercus suber* L.). **American Journal of Plant Sciences,** v. 12, n. 4, p. 603-613, 2021. https://doi.org/10.4236/ajps.2021.124040.

ANURADHA, T; KUMAR, K; BALASUBRAMANIAN, Ponnuswami. Cyclic somatic embryogenesis of elite Indian cassava variety H-226. **Indian Journal of Biotechology**, v.14, n. 4, p. 559-565, 2015. http://nopr.niscpr.res.in/handle/123456789/34008.

ARTIGAS, María; FERNÁNDEZ, Rafael. Establecimiento del sistema de regeneración por embriogénesis somática de *Azadirachta indica* A. Juss. **Acta Biológica Colombiana**, v. 20, n. 2, p. 73-83, 2015. http://dx.doi.org/10.15446/abc.v20n2.44200

ARTIGAS, María; FERNÁNDEZ, Rafael. Morpho-anatomical characterization of secondary somatic embryogenesis in *Azadirachta indica* (Meliaceae). **Acta Botánica Mexicana**, v.122, p. 7-20, 2018. http://dx.doi.org/10.21829/abm122.2018.1242

BAKER, Charleen; WETZSTEIN, Hazel. Somatic embryogenesis and plant regeneration from leaflets of peanut, *Arachis hypogaea*. **Plant Cell Reports**, v. 11, n. 2, p. 71-75, 1992. https://doi.org/10.1007/bf00235256

BAKER, Charleen; WETZSTEIN, Hazel. Repetitive somatic embryogenesis in peanut cotyledon cultures by continual exposure to 2,4-D. **Plant Cell Tissue Organ Culture (PCTO)**, v. 40, p. 249-254, 1995. https://doi.org/10.1007/BF00048131

BAO, Ying; LIU, Guofeng; SHI, Xueping *et al*. Primary and repetitive secondary somatic embryogenesis in *Rosa hybrida* 'Samantha'. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 109, p. 411-418, 2012. https://doi.org/10.1007/s11240-011-0105-6

BARBOSA, Jéssica; DE ARAÚJO, Inaé; DE OLIVEIRA, Rennan *et al*. Somatic embryogenesis and plant regeneration from zygotic embryos of the palm tree *Euterpe precatoria* Mart. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 148, p. 667–686, 2022. https://doi.org/10.1007/s11240-022-02227-2

BATES, S; PREECE, J; YOPP, J. Secondary somatic embryogenesis and plantlet conversion of white ash. **HortScience**, v. 28, p. 405, 1993.

BENALI, Naouar; LAMARTI, Ahmed. Secondary Somatic Embryogenesis for Cork Oak (*Quercus Suber* L.): Influence of Sugars. **Intenational Journal Research in Agricultural Sciencce**, v. 6, n. 1, p.18-26, 2019.

BHANSALI, Raj; DRIVER, John; DURZAN, Don. Rapid multiplication of adventitious somatic embryos in peach and nectarine by secondary embryogenesis. **Plant Cell Reports**, v. 9, p. 280-284, 1990. https://doi.org/10.1007/bf00232302

BENELLI, Carla; FABBRI, A; GRASSI, S. *et at*. Histology of somatic embryogenesis in mature tissues of olive (*Olea europaea* L.). **Journal of Horticultural Science Biotechnology**, v. 76, n. 1, p. 112-119, 2001. https://doi.org/10.1080/14620316.2001.11511336

BLAZQUEZ, Silvia; OLMOS, Enrique; HERNÁNDEZ, José *et al*. Somatic embryogenesis in saffron (*Crocus sativus* L.). Histological differentiation and implication of some components of the antioxidant enzymatic system. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 97, p. 49-57, 2009. https://doi.org/10.1007/s11240-009-9497-y

BOGDANOVIĆ, Milica; CUKOVIĆ, Katarina; SUBOTIĆ, Angelina *et al*. Secondary somatic embryogenesis in *Centaurium erythraea* Rafn. **Plants**, v. 10, n. 2, p. 199-219, 2021. http://dx.doi.org/10.3390/plants10020199

BOLAGH, Fatemeh; SOLOUKI, Alireza; TOHIDFAR, Masoud *et al*. *Agrobacterium*-mediated transformation of Persian walnut using BADH gene for salt and drought tolerance. **Journal of Horticultural Science Biotechnology**, v. 96, n. 2, p. 1-11, 2020; http://dx.doi.org/10.1080/14620316.2020.1812446

BORJI, Manel; BOUAMAMA, Badra; CHIBANI, Farhat *et al*. Micromorphology, structural and ultrastructural changes during somatic embryogenesis of a Tunisian oat variety (*Avena sativa* L. var "Meliane"). **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 132, n. 4. p. 329-342, 2018. https://link.springer.com/article/10.1007/s11240-017-1333-1

CADE, Rebecca; WEHNER, Todd; BAZICH, Frank. Somatic Embryos Derived from Cotyledons of Cucumber. **Journal of the American Society for Horticultural Sciences**, v. 115, n. 4, p.691-696, 1990. http://dx.doi.org/10.21273/JASHS.115.4.691

CAI, Yanfang; TANG, Lintao; CHEN, Haixia *et al*. Somatic embryogenesis in Rosa chinensis cv. "Parson`s pink China". **Research Square**, 2022. PPR: PPR440286. https://doi.org/10.21203/rs.3.rs-1226862/v1

CÁLIĆ, Duśica; DEVRNJA, Nina; MILOJEVIĆ, Jelena. Abscisic Acid Effect on Improving Horse Chestnut Secondary Somatic Embryogenesis. **Hortscience**, v. 47, n. 12, p. 1741–1744, 2012. https://doi.org/10.21273/HORTSCI.47.12.1741

CANO, Vanesa; MARTÍNEZ, Teresa, COUSELO, José *et al*. Regeneration of transgenic plants by *Agrobacterium*-mediated transformation of *Quercus ilex* L. somatic embryos with the gene CsTL1. **New Forests**, v. 51, p. 1003-1021. 2020. https://doi.org/10.1007/s11056-020-09771-9

CANO, Vanesa; MARTÍNEZ, Teresa, COUSELO, José *et al*. Efficient transformation of somatic embryos and regeneration of cork oak plantlets with a gene (CsTL1) encoding a Chestnut thaumatin-like protein. **Intenational Journal of Molecular Sciences.** 2021; v. 22, n. 4, p. 1757-1780, 2021. https://doi.org/10.3390/ijms22041757

CANTELMO, L; SOARES, B; ROCHA, L. *et al.* Repetitive somatic embryogenesis from leaves of the medicinal plant *Petiveria alliacea* L. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 115, p. 385-393, 2013. https://doi.org/10.1007/s11240-013-0370-7

CAPRIOTTI, Luca; LIMERA, Cecilia; MEZZETTI, Bruno *et al*. From induction to embryo proliferation: improved somatic embryogenesis protocol in grapevine for Italian cultivars and hybrid *Vitis* rootstocks. **Plant Cell, Tissue and Organ Culture (PCTOC),** 2022. https://doi.org/10.1007/s11240-022-02346-w

CHATURVEDI, Rakhi; RAZDAN, M; BHOJWANI, S. *In vitro* morphogenesis in zygotic embryo cultures of neem (*Azadirachta indica* A. Juss.). **Plant Cell Reports**, 2004; v. 22, p. 801-809, 2004. https://doi.org/10.1007/s00299-004-0768-0

CHAUDHARY, Kulbhushan; PRAKASH, Jai. Effect of 2, 4-D and Picloram on Somatic Embryogenesis in *Carica papaya* var. P-7-9. Plant Tissue Cult Biotechnology, v. 29, n. 1, p. 25-32, 2019. http://dx.doi.org/10.3329/ptcb.v29i1.41976

CHÁVEZ, A; MATA, Martín; OYAMA, Ken *et al*. Induction of somatic embryogenesis and evaluation of genetic stability in regenerated plants of

Magnolia dealbata. **Biologia Plantarum**, v. 64, n. 48, p. 224-233, 2020. http://dx.doi.org/10.32615/bp.2020.006

CHEEMA, GURVINDER. Somatic embryogenesis and plant regeneration from cell suspension and tissue cultures of mature himalayan poplar (*Populus ciliata*). **Plant Cell Reports**, v. 8, p. 124-127, 1989. https://doi.org/10.1007/BF00716855

CHEN; J; HONG, P. Cellular origin and development of secondary somatic embryos in *Oncidium* leaf cultures. **Biologia Plantarum**, v. 56, n. 2, p. 215-220, 2002. http://dx.doi.org/10.1007/s10535-012-0079-1

CHENGALRAYAN, K; HAZRA, S; GALLO, M. Histological analysis of somatic embryogenesis and organogenesis induced from mature zygotic embryo-derived leaflets of peanut (*Arachis hypogaea* L.). **Plant Science**, v. 161, n. 3, p. 415-421, 2001. https://doi.org/10.1016/S0168-9452(01)00439-3

CHUNG, Hsiao-Hang; CHEN, Jen-Tsung; CHANG, Wei. Cytokinins induce direct somatic embryogenesis of *Dendrobium* Chiengmai pink and subsequent plant regeneration. **In Vitro Cellular & Developmental Biology-Plant**, v. 41, n. 6, p. 765–769, 2005. http://dx.doi.org/10.1079/IVP2005702

CHUNG, Hsiao-Hang; CHEN, Jen-Tsung; CHANG, Wei. Plant regeneration through direct somatic embryogenesis from leaf explants of *Dendrobium.* **Biologia Plantarum**, v. 51, n. 2, p. 346-350, 2007. http://dx.doi.org/10.1007/s10535-007-0069-x

CIPRIANO, Jamile; CRUZ, Ana; MANCINI, Karina *et al*. Somatic embryogenesis in *Carica papaya* as affected by auxins and explants, and morphoanatomical-related aspects. **Anais da Academia Brasileira de Ciências,** v. 90, n. 1, p. 385-400, 2018. http://dx.doi.org/10.1590/0001-3765201820160252

CONGER, B; HANNING, G; GRAY, D. *et al*. Direct Embryogenesis from Mesophyll Cells of Orchardgrass. **Sciense**, v. 221, n. 463, p. 850-851, 1983. https://doi.org/10.1126/science.221.4613.850

ĆOSIĆ, Tatjana; VINTERHALTER, Branca; VINTERHALTER, Dragan *et al*. *In vitro* plant regeneration from immature zygotic embryos and repetitive somatic embryogenesis in kohlrabi (*Brassica oleracea* var. gongylodes). **In Vitro Cellular & Developmental Biology-Plant**, v. 49, p. 294-303, 2013. https://doi.org/10.1007/s11627-013-9517-9

DAI, Jin-Ling; TAN, Xiao; ZHAN, Ya-Guang *et al.* Rapid and repetitive plant regeneration of *Aralia elata* Seem. via somatic embryogenesis. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 104, n. 1, p. 125-130, 2011. http://dx.doi.org/10.1007/s11240-010-9801-x

DAIGNY, G; PAUL, H; SANGWAN, R., *et al*. Factors influencing secondary somatic embryogenesis in *Malus* × *domestica* Borkh. (cv 'Gloster 69'). **Plant Cell Reports**, v. 16, p. 153-157, 1996. https://doi.org/10.1007/BF01890857

DAS NEVES, Lucinda; DUQUE Sofia; ALMEIDA Simone *et al*. Repetitive somatic embryogenesis in *Medicago truncatula* ssp. Narbonensis and *M. truncatula*

Gaertn cv. Jemalong. **Plant Cell Reports**, v. 18, n. 5, p. 398-405, 1999. http://dx.doi.org/10.1007/s002990050593

DATTA, Swapan; DATTA, Karibi; POTRYKUS, Ingo. Embryogenesis and plant regeneration from microspores of both "Indica" and "Japonica" rice (*Oryza sativa*). **Plant Science**, v. 67, n. 1, p. 83-88, 1990. https://doi.org/10.1016/0168-9452(90)90053-Q

DE GUGLIELMO, Zoraya; ALTOSAAR, Ilimar; ZAIDI, Mohsin *et al*. Transformation of coffee (*Coffea arabica* L. cv. Catimor) with the cry1ac gene by biolistic, without the use of markers. **Brazilian Journal of Biology**, 2010; v. 70, n. 2, p. 387-393, 2010. http://dx.doi.org/10.1590/S1519-69842010000200022

DHANALAKSHNI, S; LAKSHMANAN, K. *In Vitro* Somatic Embryogenesis and Plant Regeneration in *Clitoria ternatea*. **Journal Experimental of Botany**, v. 43, n. 247, p. 213-219, 1992. https://doi.org/10.1093/jxb/43.2.213

DIEM, Le Thi; PHONG, Truong Hoai; TUNG Hoang Thanh *et al*. Tetraploid induction through somatic embryogenesis in *Panax vietnamensis* Ha et Grushv. by colchicine treatment. **Scientia Horticulturae**, v. 303, p. 111254. 2022 https://doi.org/10.1016/j.scienta.2022.111254

DRUART, Ph. Improvement of somatic embryogenesis of the cherry dwarf rootstock Inmil/GM9 by the use of different carbon sources. **Acta Horticulturae**, v. 280, p. 125-129, 1990. https://doi.org/10.17660/ActaHortic.1990.280.19

DURHAM, Richard; PARROTT, Wayne. Repetitive somatic embryogenesis from peanut cultures in liquid medium. **Plant Cell Reports**, v. 11, n. 3, p. 122-125, 1992. http://dx.doi.org/10.1007/BF00232163

EASTMAN, Ann; WEBSTER, Fiona; PITEL, Jack *et al*. Evaluation of somaclonal variation during somatic embryogenesis of interior spruce (*Picea glauca* x engelmannii complex) using culture morphology and isozyme analysis. **Plant Cell Reports**, v. 10, p. 425-430, 1991. https://doi.org/10.1007/BF00232617

EL MAATAQUI, M; ESPAGNAC, H; MICHAUX, N. Histology of Callogenesis and Somatic Embryogenesis Induced in Stem Fragments of Cork Oak (*Quercus suber*) Cultured *in vitro*. **Annales of Botany**, v. 66, n. 2, p. 183-190, 1990. https://doi.org/10.1093/oxfordjournals.aob.a088014

EMERSHAD, R; RAMMING, D. Somatic embryogenesis and plant development from immature zygotic embryos of seedless grapes (*Vitis vinifera* L.). **Plant Cell Reports**, v. 14, n. 1, p. 6-12, 1994. https://doi.org/10.1007/bf00233289

ESCALANT, Jean; TEISSON, Claude; COTE, Francois. Amplified somatic embryogenesis from male flowers of triploid banana and plantain cultivars (*Musa* spp.). **In Vitro Cellular & Developmental Biology-Plant**, v. 30P, n. 4, p. 181-186, 1994. https://doi.org/10.1007/BF02823029

EUDES, Francois; ACHARYA, Sourya; LAROCHE, André *et al*. A novel method to induce direct somatic embryogenesis, secondary embryogenesis and regeneration of fertile green cereal plants. **Plant Cell, Tissue and Organ Culture**

(PCTO), v. 73, n. 2, p. 147-157, 2003. http://dx.doi.org/10.1023/A:1022800512708

FAIZY, E; MORADI, A; ASL, A. Controlling Secondary Somatic Embryogenesis in Persian Oak (*Quercus brantii* L.) Using Hormonal Compounds and Media. **Journal of Agricultural Science Technology**, v. 21, n. 3, p. 615-626, 2019. http://dorl.net/dor/20.1001.1.16807073.2019.21.3.12.5

FANG, Hongcheng; DONG, Yuhui; RUI, Zhou *et al*. Optimization of the induction, germination, plant regeneration and system for somatic embryos in apomictic walnut (*Juglans regia* L.), **Plant Cell, Tissue and Organ Culture (PCTOC)**, v. 150, p. 289-297, 2022. https://doi.org/10.1007/s11240-022-02266-9

FEHÉR, Attila; BERNULA, Dóra; GÉMES, Katalin. The Many Ways of Somatic Embryo Initiation. In: Loyola V, Ochoa N (eds.), Somatic Embryogenesis: Fundamental Aspects and Applications. Switzerland: Springer International, p. 23-37, 2016. https://doi.org/10.1007/978-3-319-33705-0_3

FENG, X; WOLYN, D. Development of haploid asparagus embryos from liquid cultures of anther-derived calli is enhanced by ancymidol. **Plant Cell Reports**, v. 12, n. 5, p. 281-285, 1993. https://doi.org/10.1007/bf00237136

FEREOL, Leonidas; CHOVELON, V; CAUSSE, Sandrine *et al*. Evidence of a somatic embryogenesis process for plant regeneration in garlic (*Allium sativum* L.). **Plant Cell Reports**, v. 21, n. 3, p. 197-203, 2002. https://doi.org/10.1007/s00299-002-0498-0

FERNÁNDEZ, Barbara; CELESTINO, Cristina; TORIBIO, Mariano. Influence of external factors on secondary embryogenesis and germination in somatic embryos from leaves of *Quercus suber.* **Plant Cell, Tissue and Organ Culture (PCTOC)**,v. 41, n. 2, p. 99-106,1995. https://doi.org/10.1007/BF00051578

FERNÁNDEZ, Sophie; MICHAUX-FERRIERE, Nicole; COUMANS, Marc. The embryogenic response of immature embryo cultures of durum wheat (*Triticum durum* Desf.): histology and improvement by AgNO3. **Plant Growth Regulation**, v. 28, p. 147-155, 1999. https://doi.org/10.1023/A:1006142504577

FERNÁNDEZ, Rafael; HERMOSO, Luis; MENÉNDEZ, Andrea. Primary and secondary somatic embryogenesis in leaf sections and cell suspensions *Coffea arabica* cv Catimor. **Interciencia**, v. 30, n. 11, p. 694-698, 2005.

FERNÁNDEZ Rafael; MENÉNDEZ, Andrea. Transient gene expression in secondary somatic embryos from coffee tissues electroporated with the genes gus and bar. **Electronic Journal of Biotechnology**, v. 6, n. 1, p. 29-38, 2003.

FURUKAWA, Kazumi; KOIZUMI, Mai; HAYASHI, Wakana *et al*. Pretreatment and posttreatment in the biolistic transformation of tea plant (*Camellia sinensis*) somatic embryos. **Plant Biotechnology**, V. 37, n. 2, p. 195-203, 2020. http://dx.doi.org/10.5511/plantbiotechnology.20.0404a

GARIN, Elizabeth; GRENIER, Emmanuel; DE MARCH, Gehislaine. Somatic embryogenesis in wild cherry (*Prunus avium*). **Plant Cell, Tissue and Organ Culture (PCTOC)**, v. 48, p. 83-91, 1997. https://doi.org/10.1023/A:1005729621557

GATICA, Andrés; VARGAS, Kaliana; BENAVIDES, Miguel; *et al*. Cambios morfológicos y bioquímicos durante la embriogénesis somática en caoba, *Sweitenia macrophya* (Meliaceae). **Revista de Biología Tropical**, v. 67, n. 3, p. 406-418, 2019. http://dx.doi.org/10.15517/rbt.v67i3.34172.

GINGAS, V. Asexual Embryogenesis and Plant Regeneration from Male Catkins of Quercus. **HortScience,** v. 26, n. 9, p. 1217-1218, 1991.

GINGAS, V; Lineberger, R. Asexual embryogenesis and plant regeneration in *Quercus.* **Plant Cell, Tissue and Organ Culture (PCTOC)**, v. 17, p. 191-203, 1989. https://doi.org/10.1007/BF00046867

GROLL, J; MYCOCK, David; GRAY, Vincent *et al*. Secondary somatic embryogenesis of cassava on picloram supplemented media. **Plant Cell, Tissue and Organ Culture (PCTOC)**, v. 65, p. 201-210, 2001. https://doi.org/10.1023/A:1010622424627

GUI, Y; GUO, Z; KE, S., *et al*. Somatic embryogenesis and plant regeneration in *Acanthopanax senticosus*. **Plant Cell Reports**, v. 9, n. 9, p. 514-516, 1991. https://doi.org/10.1007/BF00232108

HACCIUS, B; BHANDARI, N. Delayed histogen differentiation as a common primitive character in all types of non-zygotic embryos. **Phytomorphology,** v. 25, p. 91-94.1975.

HAO, Xinyi; YA, Rong, ZHANG, Tianyue *et al*. Establishment of a rapid and highly effective recycling system for production embryos in "Chardonnay". **Research Square,** 2022; https://doi.org/10.21203/rs.3.rs-1285031/v1

HEIKRUJAMA, Monika; KUMAR, Dinesh; KUMAR, Shashi *et al*. High efficiency cyclic production of secondary somatic embryos and ISSR based assessment of genetic fidelity among the emblings in *Calliandra tweedii* (Benth.). **Scientia Horticulturae**, v. 177, p. 63-70, 2014. http://dx.doi.org/10.1016/j.scienta.2014.07.036

HUA, Y; HUANG, T; HUANG, H. Micropropagation of self-rooting juvenile clones by secondary somatic embryogenesis in *Hevea brasiliensis*. **Plant Breeding**, v. 129, n. 2, p. 202-207, 2010. http://dx.doi.org/10.1111/j.1439-0523.2009.01663.x

HUANG, Zhen; XU, Congping; LI, Yun *et al*. Induction of somatic embryogenesis by anther-derived callus culture and plantlet ploidy determination in poplar (*Populus x beijingensis*). **Plant Cell, Tissue and Organ Culture (PCTOC)**, v. 120, n. 3, p. 949-959, 2015. http://dx.doi.org/10.1007/s11240-014-0649-3

HUANG, T.D.; LI, Y.T.; LI, H.S., *et al*. Somatic Embryo, an Alternative target tissue for *Agrobacterium*-mediated Transformation in *Hevea brasiliensis*. **Journal of Rubber Research**, v. 18, n. 3, p. 171–188, 2015.

INPUAY, Komgrit; TE-CHATO, Sompong. Primary and secondary somatic embryos as tool for the propagation and artificial seed production of oil palm. **Journal of Agricultural Technology**, v. 8, n. 2, p. 597-609, 2012.

JAMES, D; PASSEY, A; DEEMING, C. Adventitious Embryogenesis and the *in vitro* culture of culture of Apple Seed Parts. **Journal of Plant Physiology**, v. 115, n. 3, p. 217-229, 1984. https://doi.org/10.1016/s0176-1617(84)80124-8

JARITEH, M; EBRAHIMZADEH, H; NIKNAM, V., *et al*. Antioxidant enzymes activities during secondary somatic embryogenesis in Persian walnut (*Juglans regia* L.). **African Journal of Biotechnology**, v.10, n. 20, p. 4093-4099, 2011.

JHAA, Timir; JHAB, Sumita; SEN, S. Somatic embryogenesis from immature cotyledons of an elite Darjeeling tea clone. **Plant Science**, v. 84, n. 2, p. 209-213, 1992. https://doi.org/10.1016/0168-9452(92)90136-A

JIA, Shi; CHUA, Nam. Somatic embryogenesis and plant regeneration from immature embryo culture of *Pharbitis nil*. **Plant Sciences**, v. 87, n. 2, p. 215-223, 1992. https://doi.org/10.1016/0168-9452(92)90153-D

JING, Ruyue; WANG, Peilan; HUANG, Zhen *et al.* Histocytological Study of Somatic Embryogenesis in the Tree *Cinnamomum camphora* L. (Lauraceae). **Notulae Botanicae Horti Agrobotanici Cluc-Napoca**, v. 47, n. 4, p. 1348-1358, 2019. http://dx.doi.org/10.15835/nbha47411655

JONES, Todd; ROST, Thomas. Rost the developmental anatomy and ultrastructure of somatic embryos from rice (*Oryza sativa* L.) scutellum epithelial cells. **Botanical Gazette**, v. 150, n. 1, p. 41-49, 1989. http://dx.doi.org/10.1086/337746

JONES, Jesse, ZHANG, Elaine, TUCKER, Dominicke *et al*. Screening of cultivars for tissue culture response and stablishment of genetic transformation in a high-yielding and disease-resistant cultivar of *Theobroma cacao*. **In Vitro Cellular & Developmental Biology – Plant**, v. 58, n. 4, pp. 153-145, 2021. https://doi.org/10.1007/s11627-021-10205-0

JUNAID, Aslam; MUJIB, Abdul; SHARMA, Maheshwar *et al*. Growth regulators affect primary and secondary somatic embryogenesis in Madagaskar periwinkle (*Catharanthus roseus* (L.) G. Don) at morphological and biochemical levels. **Plant Growth Regulation**, v. 51, n. 3, p. 271-281, 2007. http://dx.doi.org/10.1007/s10725-007-9171-5

JUNQIANGA, Li; YONGQINGA, Wang; LIHUAB, Lin *et al*. Embryogenesis and plant regeneration from anther culture in loquat (*Eriobotrya japonica* L.). **Scientia Horticulturae**, v. 115, n. 4, p. 329-336, 2008. http://dx.doi.org/10.1016/j.scienta.2007.10.007

KACHHWAHA, Sumita; VARSHNEY, Alok; KOTHARI, Shanker. Somatic embryogenesis and long term high plant regeneration from barley (*Hordeum vulgare* L.) using Picloram. **Cereal Research Communications**, v. 25, n. 2, p. 117-126, 1997. http://dx.doi.org/10.1007/BF03543446

KARAMI, Omid; DELJOU, A; KARIMI, Gona. Secondary somatic embryogenesis of carnation (*Dianthus caryophyllus* L.). **Plant Cell, Tissue and Organ Culture (PCTOC)**,v. 92, n. 3, p. 273-280, 2008. http://dx.doi.org/10.1007/s11240-007-9332-2

KHALIL, S; CHEAH, Kheng; PEREZ, Eden *et al*. Regeneration of banana (*Musa* spp. AAB cv. Dwarf Brazilian) via secondary somatic embryogenesis. **Plant Cell Reports**, v. 20, n. 12, p. 1128-1134, 2002. http://dx.doi.org/10.1007/s00299-002-0461-0

KIM, Tae; CHOI, Yong; LEE, Byoung *et al*. Micropropagation of *Tilia amurensis* via repetitive somatic embryogenesis. **Journal of Plant Biotechnology**, v. 33, n. 4, p. 243-248, 2006a. http://dx.doi.org/10.5010/JPB.2006.33.4.243

KIM, Y; KIM, M; SHIMA, J., *et al*. Somatic Embryogenesis of Two New Panax ginseng Cultivars, YunPoong and ChunPoong. **Russian Journal of Plant Physiology**, v. 57, n. 2, p. 283-289, 2010. https://doi.org/10.1134/S1021443710020172

KIM, Yu-Jin; LEE, Ok-Ran; KIM, Kjung-Tack *et al*. High Frequency of Plant Regeneration through Cyclic Secondary Somatic Embryogenesis in *Panax ginseng.* **Journal of Ginseng Research**, v. 36, n. 4, p. 442-448, 2012. https://doi.org/10.5142/jgr.2012.36.4.442

KIM, Y; MOON, H; SON, S. Repetitive somatic embryogenesis and plant regeneration in *Zizyphus jujuba* Mill. **In Vitro Cellular & Developmental Biology-Plant**, v. 42, n. 3, p. 247-251, 2006b. https://doi.org/10.1079/IVP2006754

KISS, J; HESZKY, L; KISS, E., *et al*. High efficiency adventive embryogenesis on somatic embryos of anther, filament and immature proembryo origin in horse-chestnut (*Aesculus hippocastanum* L.) tissue culture. **Plant Cell, Tissue and Organ Culture (PCTOC)**, v. 30, p. 59-64, 1992. https://doi.org/10.1007/BF00040001

KLIMASZEWSKA, K; NOCEDA, C; PELLETIER, G., *et al*. Biological characterization of young and aged embryogenic cultures of *Pinus pin*aster (Ait.). **In Vitro Cellular & Developmental Biology-Plant**, v. 45, p. 20–33, 2009. https://doi.org/10.1007/s11627-008-9158-6

KOH, W; LOH, C. Direct somatic embryogenesis, plant regeneration and *in vitro* flowering in rapid-cycling *Brassica napus*. **Plant Cell Reports**, v. 19, p. 1177-1183, 2000. https://doi.org/10.1007/s002990000268

KONG, Lisheng; YEUNG, Edward. Development of white Spruce somatic embryos; II. Continual Shoot meristem development during germination. **In Vitro Cellular & Developmental Biology-Plant**, v. 28P, p. 125-131,1992. https://doi.org/10.1007/BF02823060

KRIKORIAN, A; KANN, R. Plantlet Production from Morphogenetically Competent Cell Suspensions of Daylily. **Annals of Botany**, v. 47, n. 5, p. 679-686,1981. https://doi.org/10.1093/oxfordjournals.aob.a086065

KUMAR, Pradeep; KUMARI, Ranjitha. Effect of Primary and Secondary Somatic Embryogenesis in Safflower (*Carthamus tinctorius* L) at Morphological and Biochemical Levels. **American Eurasian Journal Agricultural Environment Science**, v. 8, n. 6, p. 784-792, 2010.

KUMAR, Vijaya; KUMARI, Ranjitha; CASTAÑO, Enrique. Cyclic somatic embryogenesis and efficient plant regeneration from callus of safflower. **Biologia Plantarum**, v. 52, n. 3, p. 429-436, 2008. http://dx.doi.org/10.1007/s10535-008-0087-3

KUMAR, Santosh; NADGAUDA, Rajani. Control of Morphological Aberrations in Somatic Embryogenesis of *Commiphora wightii* (Arnott) Bhandari (Family: Bursaraceae) Through Secondary Somatic Embryogenesis. **Proceedings of the National Academy of Sciences, India Section B; Biological Sciences**, v. 85, p. 281-290, 2015. https://doi.org/10.1007/s40011-014-0347-2

KUMAR, Vinod; RAMAKRISHNA, A; RAVISHANKAR, G. Influence of different ethylene inhibitors on somatic embryogenesis and secondary embryogenesis from *Coffea canephora* P ex Fr. **In Vitro Cellular & Developmental Biology-Plant**, v. 43, p. 602-607, 2007. https://doi.org/10.1007/s11627-007-9067-0

LEE, Kang; LEE, Jong; SOH, Woong. Effects of ABA on Secondary Embryogenesis from Somatic Embryos Induced from Inflorescence Culture of *Aralia cordata* Thunb. **Journal of Plant Biology**, v. 41, n. 3, p. 187-192, 1998. https://doi.org/10.1007/BF03030252

LELU, Marie; GAUTIER, Florian; ELIÁŠOVÁ, Katerina *et al*. High gellan gum concentration and secondary somatic embryogenesis: two key factors to improve somatic embryo development in *Pseudotsuga menziesii* [Mirb.]. **Plant Cell, Tissue and Organ Culture (PCTOC)**, v. 132, n. 1, p. 137-155, 2018. https://doi.org/10.1007/s11240-017-1318-0

LEMES, Maurecilne; PAIM, Daniela; SALABERT José *et al*. Repetitive somatic embryogenesis from wild passion fruit (*Passiflora cincinata* Mast.) anthers. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 146, n. 3, p. 635-641, 2021a. https://doi.org/10.1007/s11240-021-02083-6

LEMES, Maurecilne; PAIM, Daniela; BARCELOS, Andreia *et al*. Novel and efficient transformation of wild passion fruit (*Passiflora cincinnata* Mast) using sonication-assisted *Agrobacterium*-mediated transformation. **In Vitro Cellular & Developmental Biology – Plant**, v. 57, n. 3, p. 380–386, 2021b. https://doi.org/10.1007/s11627-020-10134-4

LI, Xiangqian; KRASNYANSKI, Sergei; KORBAN, Schuyler. Somatic embryogenesis, secondary somatic embryogenesis, and shoot organogenesis in Rosa. **Journal of Plant Physiology,** 2002a; v. 159, p. 313-319. http://dx.doi.org/10.1078/0176-1617-00688

LI, L; QU, R. *In vitro* somatic embryogenesis in turf-type bermudagrass: roles of abscisic acid and gibberellic acid, and occurrence of secondary somatic embryogenesis. **Plant Breeding**, v. 121, p. 155-158, 2002b. https://doi.org/10.1046/j.1439-0523.2002.00684.x

LI, Baochun; WOLYN, David. Abscisic acid and ancymidol promote conversion of somatic embryos to plantles and secondary embryogenesis in *Asparagus officinalis* L. **In Vitro Cellular & Develomental Biology-Plant**, v. 32, p. n. 4, 223-226, 1996. https://doi.org/10.1007/BF02822691

LIN, Lihua; LI, Junqiang; ZONG, Hua *et al*. Effect of antibiotics on *Agrobacterium*-mediated transformation from anther derived embryos of *Eriobotrya japonica* (Thunb.) Lindl. cv. 'Dawuxing. **Journal of Horticultural Science Biotechnology**, v. 96, n. 2, p. 172-182, 2021. https://doi.org/10.1080/14620316.2020.1814876

LINCY, Adinkudik; REMASHREE, Azhimala; BHASKARAN, Sasikumar. Indirect and direct somatic embryogenesis from aerial stem explants of ginger (*Zingiber officinale* Rosc.). **Acta Botanica Croatica**, v. 68, n. 1, p. 93-103, 2009.

LITZ, Richard; KNIGHT, Robert; GAZIT, Shmuel. *In vitro* somatic embryogenesis from *Mangifera indica* L. callus. **Scientia Horticulturae**, v. 22, n. 3, p. 233-240, 1984. https://doi.org/10.1016/0304-4238(84)90056-6

LIU, Wennuan; MOORE, Patricia; COLLINS, Glenn. Somatic embryogenesis in soybean via somatic embryo cycling. **In Vitro Cellular & Developmental Biology-Plant**, v. 28P, p. 153-160, 1992. https://doi.org/10.1007/BF02823065

LIU, Wenting; LIANG, Zongsuo; SHAN, Changjuan *et al*. Genetic transformation and full recovery of alfalfa plants via secondary somatic embryogenesis. **In Vitro Cellular & Developmental Biology-Plant**, v. 49, p. 17-23, 2013. https://doi.org/10.1007/s11627-012-9463-y

LOYOLA, Victor. The History of Somatic Embryogenesis. An Overview. In: Loyola V, Ochoa N (eds.), Somatic Embryogenesis: Fundamental Aspects and Applications. Switzerland: Springer International, p. 9-22, 2016. https://doi.org/10.1007/978-3-319-33705-0_2

LOYOLA, Victor; OCHOA, Neftalí. Somatic Embryogenesis. An Overview enesis. An Overview. In: Loyola V, Ochoa N (eds.), Somatic Embryogenesis: Fundamental Aspects and Applications. Switzerland: Springer International, p. 1-8, 2016. https://doi.org/10.1007/978-3-319-33705-0_1

LU, Chin; VASIL, Indra. Somatic Embryogenesis and Plant Regeneration from Freely-suspended Cells and Cell Groups of *Panicum maximum* Jacq. **Annals of Botany**, v. 48, n. 4, p. 543-548, 1981. https://doi.org/10.1093/oxfordjournals.aob.a086159

LU, Chin; VASIL, Indra. Histology of somatic embryogenesis in *Panicum maximum* (Guinea Grass). **American Journal of Botany**, v. 72, n. 12, p. 1908-1913, 1985.

LUPOTTO, E. The Use of Single Somatic Embryo Culture in Propagating and Regenerating Lucerne (*Medicago sativa* L.). **Annals of Botany**, v. 57, n. 1, p. 19-24, 1986. https://doi.org/10.1093/oxfordjournals.aob.a087089

LUPOTTO, E; LUSARDI, M. Secondary somatic embryogenesis regenerating plantlets of the inbred line B79 of maize (*Zea mayz*) switch from type 1 to type 2 callus effect on the regenerative potential. **Maydica**, v. 33, n. 3, p. 163-177, 1988.

MALIK, Malgorzata. Comparison of different liquid/solid culture systems in the production of somatic embryos from *Narcissus* L. ovary explants. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 94, p. 337-345, 2008. https://doi.org/10.1007/s11240-008-9415-8

MALIK, Malgorzata; BACH, A. High-yielding repetitive somatic embryogenesis in cultures of *Narcissus* L. "Carlton". **Acta Scientiarum Polonorum-Hortorum Cultus**, v. 16, n. 2, p. 107-112, 2017.

MAHESWARAN, G; WILLIAMS, E. Primary and Secondary Direct Somatic Embryogenesis from Immature Zygotic Embryos of *Brassica campestris*. **Journal of Plant Physiology**, v. 124, n. 5, p. 455-463, 1986. https://doi.org/10.1016/S0176-1617(86)80203-6

MALLÓN, Rubén; COVELO, Purificación; VIEITEZ, Ana. Improving secondary embryogenesis in *Quercus robur*: application of temporary immersion for mass propagation. **Trees**, v. 26, n. 3, p. 731-741, 2012. https://doi.org/10.1007/s00468-011-0639-6

MANDAL, Abdul; GUPTA, Snehasish. Somatic embryogenesis of safflower: influence of auxin and ontogeny of somatic embryos. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 72, n. 1, p. 27-31, 2003. https://doi.org/10.1023/A:1021264403398

MANESWARAN, G; WILLIAMS, E. Direct Somatic Embryoid Formation on Immature Embryos of *Trifolium repens*. *T. pratense* and *Medicago sativa*, and Rapid Clonal Propagation of *T. repens.* Annals of Botany, v. 54, n. 2, p. 201-211, 1984. https://doi.org/10.1093/oxfordjournals.aob.a086784

MANESWARAN, G; WILLIAMS, E. Origin and Development of Somatic Embryoids Formed Directly on Immature Embryos of *Trifolium repens in vitro.* **Annals of Botany**, v. 56, n. 5, p. 619-630, 1985. https://doi.org/10.1093/oxfordjournals.aob.a087052

MARTINELLI, Lucia; BRAGAGNA, Paola; POLETTI, Valentino *et al*. Somatic embryogenesis from leaf- and petiole-derived callus of *Vitis rupestris*. **Plant Cell Reports**, v. 12, n. 3, p. 207-210, 1993. https://doi.org/10.1007/BF00237055

MARTINELLI, Lucia; CANDIOLI, E; COSTA, D., *et al*. Morphogenic competence of *Vitis rupestris* S. secondary somatic embryos with a long culture history. **Plant Cell Reports**, v. 20, n. 4, p. 279-284, 2001. http://dx.doi.org/10.1007/s002990100339

MARTÍNEZ, María; SAN JOSÉ, M; VIEITEZ, A., *et al*. Propagation of mature *Quercus ilex* L. (holm oak) trees by somatic embryogenesis. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 131, p. 321-333, 2017. https://link.springer.com/article/10.1007/s11240-017-1286-4

MAXIMOVA, Siela; ALEMANNO, Larence; YOUNG, Ann *et al*. Eficiency, genotypic variability, and cellular origin of primary and secondary somatic embryogenesis of *Theobroma cacao* L. **In Vitro Cellular & Developmental Biology-Plant**, v. 38, n. 3, p. 252-259, 2002. http://dx.doi.org/10.1079/IVP2001257

MAZRI, Mouaad; NACIRI, Rachida; BELKOURA, Ilham. Maturation and Conversion of Somatic Embryos Derived from Seeds of Olive (*Olea europaea* L.) cv. Dahbia: Occurrence of Secondary Embryogenesis and Adventitious Bud Formation. **Plants**, v. 9, n. 11, p. 1489-1502, 2020. https://doi.org/10.3390/plants9111489

MCGRANAHAN, Gale; LESLIE, Charles; URATSU, Sandra *et al*. *Agrobacterium*-mediated transformation of walnut somatic embryos and regeneration of transgenic plants. **Bio/technology,** v. 6, p. 800-804, 1988. https://doi.org/10.1038/nbt0788-800

MCGRANAHAN, Gale; LESLIE, Charles; DANDEKAR, Abhaya *et al*. Transformation of pecan and regeneration of transgenic plants Gale. **Plant Cell Reports**, v. 12, p. 634-638, 1993. https://doi.org/10.1007/BF00232814

MERKLE, Scott; WIECKO, A. Regeneration of *Robinia pseudoacacia* via somatic embryogenesis. **Canadian Journal of Forest Research**, v. 19, n. 2, p. 285-288, 1989. http://dx.doi.org/10.1139/x89-043

MERKLE, Scott; WIECKO, A. Somatic Embryogenesis in Three Magnolia Species. **Journal of American Society for Horticultural Science**, v. 115, n. 5, p. 858-860,1990. http://dx.doi.org/10.21273/JASHS.115.5.858

MERKLE, Scott; BAILEY, R; PAULEY, B., *et al*. Somatic embryogenesis from tissues of mature sweetgum trees. **Canadian Journal of Forest Research**, v. 27, n. 6, p. 959-964, 1997. http://dx.doi.org/10.1139/x96-216

MIROSHNICHENKO, Dmitry; CHABAN, Inna; CHERNOBROVKINA, Mariya *et al*. Protocol for efficient regulation of *in vitro* morphogenesis in einkorn (*Triticum monococcum* L.), a recalcitrant diploid wheat species. **PloS One**, v. 12, n. 3, p. e0173533, 2017. https://doi.org/10.1371/journal.pone.0173533

MITROFANOVA, Irina; IVANOVA, Natalia; KUZMINA, Tatyana *et al*. *In Vitro* regeneration of Clematis plants in the Nikita Botanical Garden via somatic embryogenesis and organogenesis. **Frontiers Plants Sciences**, v. 12, p. 541171, 2021. https://doi.org/10.3389/fpls.2021.541171

MO, Lars; VON ARNOLD, Sara. Origin and Development of Embryogenic Cultures from Seedlings of Norway Spruce (*Picea abies*). **Journal of Plant Physiology**, v. 138, n. 2, p. 223-230, 1991. https://doi.org/10.1016/S0176-1617(11)80275-0

MO, Lars; VON ARNOLD, Sara; LAGERCRANTZ, U. Morphogenic and genetic stability in longterm embryogenic cultures and somatic embryos of Norway spruce (*Picea abies* {L.} Karst). **Plant Cell Reports**, v. 8, n. 3, p. 375-378, 1989. https://doi.org/10.1007/bf00270072

MONDAL, Tapan; BHATTACHARYA, Amita; SINGH, Paramir. Induction of synchronous secondary somatic embryogenesis in *Camellia sinensis* (L.). **Journal of Plant Physiology**, v. 158, n. 7, p. 945-951, 2001. https://doi.org/10.1078/0176-1617-00179

MONTOYA, Tatiana; HENAO, Ana; DE LA HOZ, Tatiana *et al*. Propagation of IMC67 plants, universal cacao (*Theobroma cacao* L.) rootstock via somatic embryogenesis, **International Journal of fruit science,** v. 22, n. 1, p. 78-94, 2022. https://doi.org/10.1080/15538362.2021.2023067

MOURA, P; VIANA, A; MANTELL, S. *In vitro* plantlet regeneration of *Ocotea catharinensis*, an endangered Brazilian hardwood forest tree. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 35, n. 3, p. 279-286, 1993. https://doi.org/10.1007/BF00037282

MUJIB, Abdul; BANERJEE, Saumitra; MAQSOOD, Mehpara *et al*. Somatic Embryogenesis of Some Member Ornamental Genera of Amaryllidaceae and Allied Families: the Similarities and Differences. The **Open Horticulture Journal**, v. 6, p. 9-18, 2013. http://dx.doi.org/10.2174/1874840620130807001

MURALIDHARAN, E; GUPTA, P; Mascarenhas, A. Plantlet production through high frequency somatic embryogenesis in long term cultures of *Eucalyptus citriodora*. **Plant Cell Reports**, v. 8, n. 1, p. 41-43, 1989. https://doi.org/10.1007/bf00735775

MURTHY, Niranjana; HAHN, E; PAEK, Kee. Recurrent somatic embryogenesis and plant regeneration in *Coriandrum sativum* L.. **Scientia Horticulturae**, v. 118, n. 2, p. 168-171, 2008. http://dx.doi.org/10.1016/j.scienta.2008.05.037

NADEL, Barry; ALTMAN, Arie; ZIV, Meira. Regulation of somatic embryogenesis in celery cell suspensions. Promoting effects of mannitol on somatic embryo development. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 18, p. 181-189, 1989. https://doi.org/10.1007/BF00047743

NADEL, Barry; ALTMAN, Arie; ZIV, Meira. Regulation of somatic embryogenesis in celery cell suspensions. Early detection of embryogenic potential and the induction of synchronized cell cultures. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 20, p. 119-124, 1990. https://doi.org/10.1007/BF00114709

NAGMANI, R; BECWAR, M; WANN, S. Single-cell origin and development of somatic embryos in *Picea abies* (L.) Karst. (Norway spruce) and *P. glauca* (Moench) Voss (white spruce). **Plant Cell Reports**, v. 6, n. 2, p. 157-159, 1987. https://doi.org/10.1007/bf00276677

NAING, Aung; KIM, Chang; YUN, Baek *et al*. Primary and secondary somatic embryogenesis in *Chrysanthemum* cv. Euro. **Plant Cell, Tissue and Organ**

Culture (PCTO), v. 112, n. 3, p. 361-368, 2013. http://dx.doi.org/10.1007/s11240-012-0243-5

NAIR, Ramakrishnan; GUPTA, Dutta. High-frequency plant regeneration through cyclic secondary somatic embryogenesis in black pepper (*Piper nigrum* L.). **Plant Cell Reports**, v. 24, n. 12, p. 699-707, 2006. https://doi.org/10.1007/s00299-005-0016-2

NATARAJAN, Nandhakumar; SUNDARARAJAN, Sathish; RAMALINGAM, Sathishkumar *et al*. Efficient and rapid *in vitro* plantlet regeneration via somatic embryogenesis in ornamental bananas (*Musa* spp.). **Biologia**, v. 75, n. 2, p. 317-326, 2020. http://dx.doi.org/10.2478/s11756-019-00358-0

NEUMANN, Karl; KUMAR, Ashwani; IMANI, Jafargholi. Plant Cell and Tissue Culture – A Tool in Biotechnology Basics and Application. Switzerland: Springer Nature AG 2009, p. 107-183, 2020. https://doi.org/10.1007/978-3-030-49098-0_7

NINKOVIĆ, Slavica; MILJUŚ, Jovanka; NEŚKOVIĆ, Mirjana. Genetic transformation of alfalfa somatic embryos and their clonal propagation through repetitive somatic embryogenesis. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 42, p. 255-260, 1995. https://doi.org/10.1007/BF00029996

OGATA, Yumiko; IIZUKA, Misato; NAKAYAMA, Daisuke *et al*. Possible involvement of abscisic acid in the induction of secondary somatic embryogenesis on seed-coat-derived carrot somatic embryos. **Planta**, v. 221, p. 417-423, 2005. https://doi.org/10.1007/s00425-004-1449-5

OTHMANI, Ahmed; BAYOUDH, Chokri; AL-KHAYRI, Jameel *et al*. Cyclic somatic embryogenesis in date palm (*Phoenix dactylifera* L.). cv Deglet bey (Mnakher) A. **Journal of New Sciences, Agriculture and Biotechnology**, v. 51, n. 9, p. 3204-3213, 2018.

PANAIA, Maggie; BUNN, Eric; MCCOMB, J. Primary and repetitive secondary somatic embryogenesis of *Lepidosperma drummondii* (Cyperaceae) and *Baloskion tetraphyllum* (Restionaceae) for land restoration and horticulture. **In Vitro Cellular & Developmental Biology-Plant**, v. 47, n. 3, p. 379-386, 2011. http://dx.doi.org/10.1007/s11627-010-9335-2

PANAIA, Maggie; SENARATNA, T; DIXON, K., *et al*. High-frequency somatic embryogenesis of koala fern (*Baloskion tetraphyllum*, Restionaceae). **In Vitro Cellular & Developmental Biology-Plant**, v. 40, n. 3, p. 303-310, 2004. http://dx.doi.org/10.1079/IVP2004534

PARIMALAN, Rangan; VENUGOPALAN, Akshatha; GIRIDHAR, Parvatam *et al*. Somatic embryogenesis and *Agrobacterium*-mediated transformation in *Bixa orellana* L. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 105, n. 3, p. 317-328, 2010. http://dx.doi.org/10.1007/s11240-010-9870-x

PARRA, R; AMO, J. Secondary somatic embryogenesis and plant regeneration in myrtle (*Myrtus communis* L.). **Plant Cell Reports**, v. 18, n. 3-4, p. 325-330, 1998. https://doi.org/10.1007/s002990050580

PĂUNESCU, Anca. Histological investigation of the secondary somatic embryogenesis of *Alyssum borzaeanum* (Brassicaceae). **Phytologia Balcanica**, v. 14, n. 1, p. 111-117, 2008.

PAVLOVIĆ, Suzana; VINTERHALTER, Branca; ZDRAVKOVIĆ, Snežana *et al*. Recurrent somatic embryogenesis and plant regeneration from immature zygotic embryos of cabbage (*Brassica oleracea* var. capitata) and cauliflower (*Brassica oleracea* var. botrytis). **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 113, n. 3, p. 397-406, 2013. http://dx.doi.org/10.1007/s11240-012-0279-6

PAVLOVIĆ, Suzana; SAVIĆ, Jelena; MILOJEVIĆ, jelena *et al*. Introduction of the Nicotiana protein kinase (NPK1) gene by combining *Agrobacterium*-mediated transformation and recurrent somatic embryogenesis to enhance salt tolerance in cauliflower. **Plant Cell, Tissue and Organ Culture (PCTO)**, v.143, n. 3, p. 635-651, 2020. https://doi.org/10.1007/s11240-020-01948-6

PÉREZ-NÚÑEZ, M; CHAN, J; SÁENZ, L., *et al*. Improved somatic embryogenesis from *Cocos nucifera* (L.) plumule explants. **In Vitro Cellular & Developmental Biology-Plant**, v. 42, p. 37-43, 2006. https://doi.org/10.1079/IVP2005722

PESCE, Patricia; RUGINI, Eddo. Influence of plant growth regulators, carbon sources and iron on the cyclic secondary somatic embryogenesis and plant regeneration of transgenic cherry rootstock 'Colt' (*Prunus avium* · *P. pseudocerasus*). **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 79, n. 2, p. 223-232, 2004. https://doi.org/10.1007/s11240-004-0663-y

PINTO, Gloria; PARK, Yill; SILVA, Sónia *et al*. Factors affecting maintenance, proliferation, and germination of secondary somatic embryos of *Eucalyptus globulus* Labill. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 95, n. 1, p. 69-78, 2008. https://doi.org/10.1007/s11240-008-9417-6

PIRES, Rita; CARDOSO, Helia; RIBEIRO, Augusto *et al*. Somatic Embryogenesis from Mature Embryos of *Olea europaea* L. cv. 'Galega Vulgar' and Long-Term Management of Calli Morphogenic Capacity. **Plants**, v. 9, n. 6, p. 758-772, 2020. http://dx.doi.org/10.3390/plants9060758

PLATA, E; BALLESTER, A; VIEITEZ, A. An anatomical study of secondary embryogenesis in *Camelia reticulata*. **In Vitro Cellular & Developmental Biology-Plant**, v. 27, p. 183-189, 1991. https://doi.org/10.1007/BF02632214

PLATA, E; VIEITEZ, Ana. *In vitro* regeneration of *Camellia reticulata* by somatic embryogenesis. **Journal of Horticultural Science**, v. 65, n. 6, p. 707-714,1990. https://doi.org/10.1080/00221589.1990.11516112

POLITO, Vito; MEGRANAHAN, Gale; PINNEY, Katherine *et al*. Origin of somatic embryos from repetitively embryogenic cultures of walnut (*Juglans regia* L.): implications for *Agrobacterium*-mediated transformation. **Plant Cell Reports**, v. 8, n. 4, p. 219-221, 1989. https://doi.org/10.1007/BF00778537

PRABHUDESAI, Vaishali; BHASKARAN, S. A continuous culture system of direct somatic embryogenesis in microspore-derived embryos of *Brassica juncea*. **Plant Cell Reports**, v. 12, n. 5, p. 289-292, 1993. https://doi.org/10.1007/bf00237138

PRETOVA, A; WILLIAMS, E. Zygotic embryos cloning in oilseed (*Brassica napus* L.). **Plant Science**, v. 47, n. 3, p. 195-198, 1986. https://doi.org/10.1016/0168-9452(86)90178-0

PUIDERRAJOLS, Pere; MIR, Gisela; MOLINAS, Marisa. Ultrastructure of Early Secondary Embryogenesis by Multicellular and Unicellular Pathways in Cork Oak (*Quercus suber* L.). **Annals of Botany**, v. 87, n. 2, p. 179-189, 2001. https://doi.org/10.1006/anbo.2000.1317

QUIALA, Elisa; BARBÓN, Raúl; Mestanza Saúl *et al*. Somatic embryogenesis and plant regeneration from leaf of the interspecific hybrid of mahogany (*Swietenia macrophylla King x S.* mahagoni (L.) Jacq.). **Trees,** v. 36, p. 167-178, 2021. https://doi.org/10.1007/s00468-021-02192-x

QUIROZ, Francisco; ROJAS, Rafael; GALAZ, Rosa *et al*. Embryo production through somatic embryogenesis can be used to study cell differentiation in plants. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 86, n. 3, p. 285-301, 2006. https://doi.org/10.1007/s11240-006-9139-6

RADOJEVIĆ, Ljiljana. *In Vitro* Induction of Androgenic Plantlets in *Aesculus hippocastanum.* Protoplasma, v. 96, p. 369-374, 1978. https://doi.org/10.1007/BF01287696

RAEMAKERS, C; JACOBSEN, E; VISSER, R. Secondary somatic embryogenesis and applications in plant breeding. Euphytica, v. 81, p. 93-107, 1995. https://doi.org/10.1007/BF00022463

RAHMOUNI, Safaâ; EL ANSARI, Zineb; BADOC, Alain *et al*. Effect of Amino Acids on Secondary Somatic Embryogenesis of Moroccan Cork Oak (*Quercus suber* L.) Tree. **American Journal of Plant Science**, v. 11, n. 5, p. 626-641, 2020. https://doi.org/10.4236/ajps.2020.115047

RAI, Ravishankar; MCCOMB, J. Direct somatic embryogenesis from mature embryos of sandalwood. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 69, n. 1, p. 65-70, 2002. http://dx.doi.org/10.1023/A:1015037920529

RAMÍREZ, Maribel; DE GARCÍA, Eva. Secondary Somatic Embryogenesis in Banana CIEN-BTA-03 (*Musa* sp. AAAA) and Regeneration of Plants. **Acta Horticulturae**, v. 829, p. 45-50, 2009. https://doi.org/10.17660/ActaHortic.2009.829.4

RAOMANI, Shiveirou; KUMARIA, Suman; TANDON, Pramod. Plant regeneration through direct somatic embryogenesis from immature zygotic embryos of the medicinal plant, *Paris polyphylla* Sm. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 118, n. 3, p. 445-455, 2014. http://dx.doi.org/10.1007/s11240-014-0496-2

RASHID, L; STREET, E. The development of haploid embryoids from anther cultures of *Atropa belladonna* L. **Planta**, v. 113, n. 3, p. 263-270. https://doi.org/10.1007/BF00390513

RASHID, L; STREET, E. Growth, embryogenic potential and stability of a haploid cell culture of *Atropa belladonna*. **Plant Science Letters**, v. 2, n. 2, p. 89-94,1974. https://doi.org/10.1016/0304-4211(74)90063-7

REMOTTI, Patrizio. Primary and secondary embryogenesis from cell suspension cultures of Gladiolus. **Plant Science**, v. 107, n. 2, p. 205-214, 1995. https://doi.org/10.1016/0168-9452(95)04106-5

RUGINI, E; CARICATO, G. Somatic embryogenesis and plant recovery from mature tissues of olive cultivars (*Olea europaea* L.) "Canino" and "Moraiolo". **Plant Cell Reports**, v. 14, p. 257-260, 1995. https://doi.org/10.1007/bf00233645

RYSCHKA, Sieglinge; RYSCHKA, Ulrich; SCHULZE, Jutta. Anatomical Studies on the Development of Somatic Emhryoids in Wheat and Barley Explants. **Biochemie und Physiologie der Pflanzen**, v. 187, n. 1, p. 31-41, 1991. https://doi.org/10.1016/S0015-3796(11)80183-6

SAEED, Taiba; SHAHZAD, Anwar. High frequency plant regeneration in Indian Siris via cyclic somatic embryogenesis with biochemical, histological and SEM investigations. **Industrial Crops and Products**, v. 76, p. 623-637, 2015. https://doi.org/10.1016/j.indcrop.2015.07.060

SAKER, M. *In vitro* regeneration of onion through repetitive somatic embryogenesis. **Biologia Plantarum**, v. 40, n. 4, p. 499-506, 1997. https://doi.org/10.1023/A:1001788700469

SALUNKHE, C; RAO, P; MHATRE, M. Plantlet regeneration via somatic embryogenesis in anther callus of *Vitis latifolia* L. **Plant Cell Reports**, v.18, n 7-8, p. 670-673, 1999. https://doi.org/10.1007/s002990050640

SALY, Sabine; JOSEPH, Claude; CORBINEAU; Françoise. Induction of secondary somatic embryogenesis in hybrid larch (*Larix* x *leptoeuropaea*) as related to ethylene. **Plant Growth Regulation**, v. 37, n. 3, p. 287–294, 2002. https://doi.org/10.1023/A:1020856112765

SANÉ, Djibril; ABERLENC, Frederique; GASSAMA, Y., *et al*. Histocytological Analysis of Callogenesis and Somatic Embryogenesis from Cell Suspensions of Date Palm (*Phoenix dactylifera*). Annals of Botany, v. 98, n. 2, p. 301-308, 2006. http://dx.doi.org/10.1093/aob/mcl104

SANGRA, Ankush; SHAHIN, Lubana; DHIR, Sarwan. Long-Term Maintainable Somatic Embryogenesis System in Alfalfa (*Medicago sativa*) Using Leaf Explants: Embryogenic Sustainability Approach. **Plants**, v. 8, n. 8, p. 278-293, 2019. https://doi.org/10.3390/plants8080278

SANTA CATARINA, Claudete; DOS SANTOS, Alessandra; DE ANDRADE, Geraldine *et al*. Repetitive somatic embryogenesis of *Ocotea catharinensis* Mez. (Lauraceae): effect of somatic embryo developmental stage and dehydration.

Plant Cell, Tissue and Organ Culture (PCTO), v. 78, p. 55-62, 2004. https://doi.org/10.1023/B:TICU.0000020395.40974.8a

SANTAREM, Eliane; PELISSIER, Bernard; FINER, John. Efect of explant orientation, pH, solidifying agent and wounding on initiation of soybean somatic embryos. **In Vitro Cellular & Developmental Biology-Plant,** v. 33, n. 1, p. 13-19,1997. http://dx.doi.org/10.1007/s11627-997-0034-6

SELLARS, Rebecca; SOUTHWARD, G; PHILLIPS, Gregory. Adventitious Somatic Embryogenesis from Cultured Immature Zygotic Embryos of Peanut and Soybean. **Crop Science**, v. 30, n. 2, p. 408-414, 1990. https://doi.org/10.2135/cropsci1990.0011183X003000020035x

SHAMARI, Magda; RIHAN, Hail; FULLER, Michael. An Effective Protocol for the Production of Primary and Secondary Somatic Embryos in Cauliflower (*Brassica Oleraceae* Var. Botrytis). **Agricultural Research & Technology: Open Access Journal**, v. 14, n. 1, p. 38-46, 2018. http://dx.doi.org/10.19080/ARTOAJ.2018.14.555908

SHI, Xueping; DAI, Xigang; LIU, Guofeng *et al*. Cyclic secondary somatic embryogenesis and efficient plant regeneration in camphor tree (*Cinnamomum camphora* L.). **In Vitro Cellular & Developmental Biology-Plant**, v. 46, p. 117-125, 2010. https://doi.org/10.1007/s11627-009-9272-0

SHUAIYU, Zou; YAO, Xiaohong; ZHONG, Caihong *et al*. Recurrent somatic embryogenesis and development of somatic embryos in *Akebia trifoliata* (Thunb.) Koidz (Lardizabalaceae). **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 139, n. 3, p. 493-504, 2019. https://link.springer.com/article/10.1007/s11240-019-01686-4

SINGH, Mithilesh; CHATURVEDI, Rakhi. An Efficient Protocol for Cyclic Somatic Embryogenesis in Neem (*Azadirachta indica* A Juss.). **Proceedings of Internatiotal Conference on Energy and Environment**, v. 1, n. 1, p. 656-658, 2009.

SIVANESAN, Iyyakkannu; SON, Moon; JANA, Sonali *et al*. Secondary somatic embryogenesis in *Croccus vernus* (L.) Hill. **Propagation Ornamental Plants**, v. 12, n. 3, p. 163-170,2012.

ŚLIWIŃSKA, Anita; OLSZOWSKA, O; FURMANOWA, M., *et al*. Rapid multiplication of *Polyscias filicifolia* by secondary somatic embryogenesis. **In Vitro Cellular & Developmental Biology-Plant**, v. 44, n. 2, p. 69-77, 2008. http://dx.doi.org/10.1007/s11627-008-9132-3

SMITHA, P; BINOY, K; NAIR, Ashalatha. Enhanced Secondary Somatic Embryogenesis in Suspension Culture of Four Diploid Banana Cultivars from Kerala. International Journal of Fruit Sciences, v. 2, p. 617-626, 2020. https://doi.org/10.1080/15538362.2020.1753138

SONSTAD, D; CONGER, B. Direct embryogenesis from cultured anthers and pistils of *Dactylis glomerata*. **American Journal of Botany**, v. 73, n. 7, p. 989-992, 1986. https://doi.org/10.1002/j.1537-2197.1986.tb08542.x

SOONTHORNKALUMP, Sutthinut; NAKKANONG, Korakot; MEESAWAT, Upatham. *In vitro* cloning via direct somatic embryogenesis and genetic stability assessment of *Paphiopedilum niveum* (Rchb.f.) Stein: the endangered Venus's slipper orchid. **In Vitro Cellular & Developmental Biology-Plant**, v. 55, p. 265-276, 2019. https://doi.org/10.1007/s11627-019-09981-7

SOUTHWORTH, Darlene; KWIATKOWSKI, Stephen. Somatic embryogenesis from immature embryos in meadowfoam (*Limnanthes alba*). **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 24, p. 193-198,1991. https://doi.org/10.1007/BF00033476

STEINMACHER, Douglas; GUERRA, Miguel; SAARE, K., *et al*. A temporary immersion system improves *in vitro* regeneration of peach palm through secondary somatic embryogenesis. **Annals of Botany**, v. 108, n. 8, p. 1463-1475, 2011. http://dx.doi.org/10.1093/aob/mcr033

STEINMACHER, Douglas; KROHN, Nadia; DANTAS, Adriana *et al*. Somatic Embryogenesis in Peach Palm Using the Thin Cell Layer Technique: Induction, Morpho-histological Aspects and AFLP Analysis of Somaclonal Variation. **Annals of Botany**, v. 100, n. 4, p. 699–709, 2007. http://dx.doi.org/10.1093/aob/mcm153

SZABADOS, László; HOYOS, Rodrigo; ROCA, William. *In vitro* somatic embryogenesis and plant regeneration of cassava. **Plant Cell Reports**, v. 6, n. 3, p. 248-251, 1987. http://dx.doi.org/10.1007/BF00268492

SZEWCZYK, Bożena; PAWŁOWSKA, Bożena. Recurrent somatic embryogenesis and plant regeneration from seedlings of *Hepatica nobilis* Schreb. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 120, n. 3, p. 1203-1207, 2015. http://dx.doi.org/10.1007/s11240-014-0661-7

TANG, Hauru; REN, Zhenglong; KRCZAL, Gabi. Somatic embryogenesis and organogenesis from immature embryo cotyledons of three sour cherry cultivars (*Prunus cerasus* L.). **Scientia Horticulturae**, v. 83, n. 2, p. 109-126, 2000. http://dx.doi.org/10.1016/S0304-4238(99)00073-4

TE-CHATO, Sompong; HILAE, A. High-frequency plant regeneration through secondary somatic embryogenesis in oil palm (*Elaeis guineensis* Jacq. var. tenera). **Journal of Agricultural Technology**, v. 3, n. 2, p. 345-357, 2007.

TEJAVATHI, D; SITA, G; SUNITA, A. Somatic embryogenesis in Flax. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 63, n. 2, p. 155-159, 2000. https://doi.org/10.1023/A:1006469900025

TENNING, Paul; WREMERTH, E; KJARSGAARD, Ulla *et al*. Somatic embryogenesis from zygotic embryos of sugar beet (*Beta vulgaris* L.). Plant Science, v. 81, n. 1, p. 103-109, 1992. http://dx.doi.org/10.1016/0168-9452(92)90029-L

THENGANE, S; DEODHAR, S; BHOSLE, S., *et al*. Repetitive somatic embryogenesis and plant regeneration in *Garcinia indica* Choiss. **In Vitro Cellular & Developmental Biology-Plant**, v. 42, n. 3, p. 256-261, 2006. https://doi.org/10.1079/IVP2006763

THOMAS, Emry; HOFFMANN, Franz; POTRYKUS, Ingo *et al*. Protoplast Regeneration and Stem Embryogenesis of Haploid Androgenetic Rape. **Molecular and General Genetics**, v. 145, p. 245-247, 1976. https://doi.org/10.1007/BF00325819

TOKUYI, Yoshihiko; MIZUE, Yuka; MASUDA, Hiroshi. Effects of methyljasmonate and concanavalin A on embryogenesis and the induction of secondary somatic embryos of carrot. **Bioscience, Biotechnology, and Biochemistry**, v. 59, n. 9, p. 1675-1678, 1995. https://doi.org/10.1271/bbb.59.1675

TRIGIANO, R; GRAY, D; CONGER, B., *et al*. Origin of direct somatic embryos from cultured leaf segments of *Dactylis glomerata*. **Botanica Gazette**, v. 150, n. 1, p. 72-77, 1989.

TROCH, Veronique; WERBROUCK, Stefaan; GEELEN, Danny *et al*. Optimization of horse chestnut (*Aesculus hippocastanum* L.) somatic embryo conversion. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 98, n. 1, p. 115-123, 2009. http://dx.doi.org/10.1007/s11240-009-9544-8

TULECKE, Walt; MCGRANAHAN, Gale. Somatic embryogenesis and plant regeneration from cotyledons of walnut, *Juglans regia* L. **Plant Science**, v. 40, n. 1, p. 57-63, 1985. https://doi.org/10.1016/0168-9452(85)90163-3

UDAYABHANU, Jinu; HUANG, Tiandai; XIN, Shichao *et al*. Optimization of the Transformation protocol for increased efficiency of genetic Transformation in *Hevea brasiliensis*, **Plants,** v. 11, n. 8. p. 1067-1080, 2022. https://doi.org/10.3390/plants11081067

VASIC, Dragana; ALIBERT, G; SKORIC, D. Protocols for efficient repetitive and secondary somatic embryogenesis in *Helianthus maximiliani* (Schrader). **Plant Cell Reports**, v. 20, n. 2, p. 121-125, 2001. https://doi.org/10.1007/s002990000291

VASIL, Vimla; VASIL, Indra. Somatic Embryogenesis and Plant Regeneration from Suspension Cultures of Pearl Millet (*Pennisetum americanum*). **Annals of Botany**, v. 47, n. 5, p. 669-678, 1981. https://doi.org/10.1093/oxfordjournals.aob.a086064

VASIL, Vimla; VASIL, Indra. The ontogeny of somatic embryos of *Penisetum americanum* (L.) K. Schum. I. in cultured inmature embryos. Botanica Gazette, v. 143, n. 4, p. 454-465, 1982.

VIEITEZ, Ana; BARCIELA, Jesus. Somatic embryogenesis and plant regeneration from embryonic tissues of *Camellia japonica* L. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 21, p. 267-274, 1990. https://doi.org/10.1007/BF00047620

VIEITEZ, Javier; BALLESTER, Antonio; VIEITEZ, Ana. Somatic embryogenesis and plantlet regeneration from cell suspension cultures of *Fagus sylvatica*. **Plant Cell Reports**, v. 11, n. 12, p. 609-613, 1992. https://doi.org/10.1007/BF00236383

VON ARNOLD, Sara. Improved Efficiency of Somatic Embryogenesis in Mature Embryos of *Picea abies* (L.) Karst. **Journal of Plant Physiology**, v. 128, n. 3, p. 233-244, 1987. https://doi.org/10.1016/S0176-1617(87)80237-7

VOOKOVÁ, B; MATUSOVÁ, R; KORMUTÁK, A. Secondary somatic Embryogenesis in *Abies mumidica*. **Biologia Plantarum**, v. 46, n. 4, p. 513-517, 2003. https://doi.org/10.1023/A:1024899124774

VOOKOVÁ, B; KORMUTÁK, A. Comparison of induction frequency, maturation capacity and germination of *Abies numidica* during secondary somatic embryogenesis. **Biologia Plantarum**, v. 50, n. 4, p. 785-788, 2006. http://dx.doi.org/10.1007/s10535-006-0132-z

WALTHER, Madlen; WAGNER, Isabel; RASCHKE, Juliane *et al*. Abscisic acid induces somatic embryogenesis and enables the capture of high-value genotypes in Douglas fir (*Pseudotsuga menziesii* [MIRB] Franco). **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 148, p. 45-59, 2022. https://doi.org/10.1007/s11240-021-02159-3

WANG, T.D.; HUANG, T.D.; HUANG, H.S *et al*. Origin of Secondary Somatic Embryos and stability genetic of the Regenerated Plants in *Hevea brasiliensis*, **Journal of Rubber Research**, v. 20, n. 2, p. 101-116, 2017. https://doi.org/10.1007/BF03449145

WIJESEKARAA, K; IQBAL, M. Absence of meristems in androgenic embryos of *Datura metel* (L.) induces secondary embryogenesis *in vitro*. **Scientia Horticulturae**, v. 164, p. 287-294, 2013. http://dx.doi.org/10.1016/j.scienta.2013.07.007

WILLIAMS, E; MAHESWARAN, G. Somatic Embryogenesis: Factors Influencing Coordinated Behaviour of Cells as an Embryogenic Group**. Annals of Botany**, v. 57, n. 4, p. 443-462, 1986. https://doi.org/10.1093/oxfordjournals.aob.a087127

WÓJCIKOWSKA, Barbara; GAJ, Malgorzata. Somatic Embryogenesis in Arabidopsis. In: Loyola V, Ochoa N (eds.), Somatic Embryogenesis: Fundamental Aspects and Applications. Switzerland: Springer International, p. 185-199, 2016. https://doi.org/10.1007/978-3-319-33705-0_11

WONGTIEM, P; COURTOIS, D; FLORIN, B., *et al*. Effects of cytokinins on secondary somatic embryogenesis of selected clone Rayong 9 of *Manihot esculenta* Crantz for ethanol production. **African Journal of Biotechnology**, v. 10, n. 9, p. 1600-1608, 2011.

WU, Bihua; ZHENG, Youliang; LUO, Jianming. Secondary somatic embryo production from somatic embryo *in vitro* of bread wheat (*Triticum aestivum*). **Southwest China Journal Agricultural Science**, v. 18, n. 4, p. 373-377, 2005.

XING, Wen; BAO, Yin; LUO, Ping *et al*. An efficient system to produce transgenic plants via cyclic leave-originated secondary somatic embryogenesis in *Rosa rugosa.* **Acta Physiologiae Plantarum**, v. 36, n. 8, p. 2013-2023, 2014. http://dx.doi.org/10.1007/s11738-014-1578-9

XING, Z; SHEN, H; ZHAO, L., *et al*. Somatic cell embryogenesis *Acanthopanax senticosus*. **China Trad Herb Drugs**, v. 37, n. 5, p. 769-772, 2006. (ABSTRACT)

YAN, Juan; WANG, Yongqing; LI, Junqiang *et al*. Morphological and histological observations on the induction of anther calluses and embryos in loquat (*Eriobotrya japonica* Lindl.). **African Journal Agricultural Research**, v. 7, n.1, p. 123-127, 2012.

YANG, Ling; WANG, Jianan; BIAN, Lei *et al*. Cyclic secondary somatic embryogenesis and efficient plant regeneration in mountain ash (*Sorbus pohuashanensis*). **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 111, n. 2, p. 173-182, 2012a. http://dx.doi.org/10.1007/s11240-012-0181-2

YANG, Jingli; WU, Songquan; LI, Chenghao. High Efficiency Secondary Somatic Embryogenesis in *Hovenia dulcis* Thunb. through Solid and Liquid Cultures. **Scient World Journal**, v. 2013, n. 2, p. 1-6, 2013. http://dx.doi.org/10.1155/2013/718754

YANG, Jingli; ZHOU, Chenguang; LIU, Lihui *et al*. High conversion frequency of germinated somatic embryos of Siberian ginseng (*Eleutherococcus senticosus* Maxim) using a bubble column bioreactor. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 110, p. 289-298, 2012b. https://doi.org/10.1007/s11240-012-0150-9

YOU, Cui; FAN, Ting; GONG, Xue *et al*. high-frequency cyclic secondary somatic embryogenesis system for *Cyclamen persicum* Mill. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 107, n. 2, p. 233-242, 2011. https://doi.org/10.1007/s11240-011-9974-y

ZDRAVKOVIĆ, Snežana; CALIĆ, Dusica; UZELAC, Branca *et al*. Secondary somatic embryogenesis versus caulogenesis from somatic embryos of *Aesculus carnea* Hayne.: developmental stage impact. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 94, n. 2, p. 225-231, 2008. http://dx.doi.org/10.1007/s11240-008-9399-4

ZEGZOUTI, Redouane; ARNOULD, Marie; FAVRE, Jean. Histological investigation of the multiplication step in secondary somatic embryogenesis of *Quercus robur* L. **Annals of forest Science**, v. 58, n. 6, p. 681-690, 2001.

ZHANG, Cl; CHEN, Dong; KUBALAKOVA, Marie *et al*. Efficient somatic embryogenesis in sugar beet (*Beta vulgaris* L.) breeding lines. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 93, n. 2, p. 209-221, 2008. http://dx.doi.org/10.1007/s11240-008-9364-2

ZHENG, Qi; DESSAI, Ananta; PRAKASH, Channapatna. Rapid and repetitive plant regeneration in sweetpotato via somatic embryogenesis. **Plant Cell Reports**, v. 15, n. 6, p. 381-385, 1996. https://doi.org/10.1007/bf00232059

ZHOU, Chenguang; LIU, Likun; LI, Chenghao. Microarray Analysis of Siberian Ginseng Cyclic Somatic Embryogenesis Culture Systems Provides Insight into Molecular Mechanisms of Embryogenic Cell Cluster Generation. **PLoS ONE**, v. 9, n. 4, p 1-13, 2014. https://doi.org/10.1371/journal.pone.0094959

ZHOU, Qi; DAI, Lingmin; CHENG, Siyan *et al*. A circulatory system useful both for long-term somatic embryogenesis and genetic transformation in *Vitis vinifera* L. cv. Thompson Seedless. **Plant Cell, Tissue and Organ Culture (PCTO)**, v. 118, n. 1, p. 157-168, 2014. https://doi.org/10.1007/s11240-014-0471-y

ZIV, Meira; GADASI, Geula. Enhanced embryogenesis and plant regeneration from cucumber (*Cucumis sativus* L.) callus by active charcoal in solid/liquid double-layer cultures. **Plant Science**, v. 47, n. 2, p. 115-122, 1986. https://doi.org/10.1016/0168-9452(86)90058-0

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