

Review Article

Advances in Breeding *Oncidium* Orchids: Strategies, Challenges, and Future Prospects

Abstract

Oncidium orchids, commonly known as “dancing lady orchids,” represent a diverse genus with significant horticultural and commercial value. Breeding programs aimed at improving *Oncidium* species and hybrids have developed over the past few decades, driven by their ornamental characteristics such as flower color, form, fragrance, and disease resistance. This review explores the traditional and modern approaches used in *Oncidium* orchid breeding, including classical hybridisation, mutagenesis, polyploidy and some biotechnological advancements such as tissue culture and molecular markers. Furthermore, the challenges and potential future directions in breeding *Oncidium* orchids, including the development of novel traits and conservation strategies, are discussed.

Keywords: *Oncidium*, improvement, breeding, hybridisation and embryo culture

Introduction

Orchids are the indicators of the health of the ecosystem and their presence signifies that the ecosystem is vibrant and live. Orchidaceae constitute one of the largest families of angiosperms. They are one of the most ecological and evolutionary significant plants and have successfully colonised almost every habitat on earth. The genus *Oncidium* is very popular in gardens of Kerala because of the unique feature of flower resembling a ‘dancing lady or girl’. They bear numerous numbers of attractive blossoms in various size and forms and are commonly called as ‘Golden Showers’ and ‘Dancing Ladies’ (De, 2022).

Oncidium orchids are commercially flourished in National and International markets for its quality cut flower. *Oncidium* species are known variously as ‘bee orchids’, ‘tiger orchids’ and ‘dancing ladies’ because of their appearance. Hybrids within the genus *Oncidium* are some of the top-traded cut flowers and differ from other commercial genera by their predominant yellow coloration commonly accented with reds (Hsiao *et al.*, 2011). According to Rianawati *et al.* (2021), *Oncidium* have been preferred as the second genus after *Dendrobium* by most of the people. This genus has been favoured as a collection of

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ornamental plants and the most important filler used in flower arrangement. The most famous type of *Oncidium* as cut flowers are *Oncidium* Golden Shower, *Oncidium* Goldiana, *Oncidium* Sweet Sugar and *Oncidium* Gower Ramsey (Bolanos-Villegas, 2022).

Comment [JO10]: after name a genus *Oncidium* please abbreviate like *O.*

1. Description and botany of *Oncidium* orchids

Botanical Name: *Oncidium* sp. (pronunciation: on-SID-dee-um)

Abbreviation: *Onc.*

Popular names: Dancing lady/girl orchids, tiger orchids

Tribe: Oncidieae

Subtribe: Oncidiinae

Origin: Central and South America

Colours: Mostly yellow, brown, white but also available in red, pink, and purple

Growing classification: Mostly epiphytes with some lithophytes and terrestrial.

The name *Oncidium* was derived from a Greek word “onkos”, which means “swelling” and it refers to the small callus at the base of the lip. *Oncidium* genus consists of more than 300 species of tropical and subtropical American orchids (family Orchidaceae). *Oncidium* flowers are complete, zygomorphic, bisexual, epigynous, trimerous, ebracteate, sessile or pedicellate. The leaves are elliptic in nature. Usually, *Oncidium* orchids flower twice per year from March to May and from September to November.

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Oncidium spp. are generally characterised by the presence of column wings, a complicated callus on the lip, pseudobulbs with one to three leaves, several basal bracts at the base of the pseudobulbs. The petals are often ruffled on the edges, as is the lip. The lip is enormous, partially blocking the small petals and sepals. Flowers usually bloom in multiple long spikes. These are distinguished from others by a wart-like formation on its lip (from which they are named) having pseudobulbs with 1-3 leaves, flowers whose petals have wavy edges, and flowers that bloom in shades of yellow, white and pink. In general, all three sepals are alike in size, shape and colour, in some cases, these vary. The two lateral petals are similar in size and shape while dorsal sepals are larger. They are often referred to as ‘spray orchids’ because of the raceme’s colourful bursts of flowers. Through modern breeding approaches red, magenta and green colour flowers can be achieved. Some orchid species from this genus are also blessed with a pleasant scent.

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2. Origin, distribution and cytogenetics of *Oncidium* orchids

Oncidium orchids were first officially described by Olaf Swartz, a Swedish botanist, in the year 1800. The name was taken from the Greek word “onkos” which means “swelling or mass” referring to the uniquely shaped bump on the lips of its flowers. *Oncidium* orchids are native to the lush, wild jungles of Central and South America. In their natural habitat, they can be seen thrive on trees and on top of rocks both on coastal areas and high up the mountains, up to 8,000 feet in the Andes mountains (De, 2022). *Oncidium* adjust well to indoor environments and with a little loving care can bring a beautiful addition to any home or home gardens. They prefer temperatures around 55-60 °F at night and 80-85 °F during the day. *Oncidium* orchid is a member of the *Oncidium* Alliance.

An alliance is a group of different orchid genera that possess a lot of similarities and that can be crossbred. The *Oncidium* Alliance, in particular, is comprised of over 1,200 orchid species from as many as 70 orchid genera. The biggest number of delegates are orchid species from the *Oncidium* and *Odontoglossum* genera. Other well-known orchid genera that belong to the *Oncidium* Alliance include *Brassia*, *Miltonia*, *Miltoniopsis*, *Psychopsis*, *Trichopilia* and *Tolumnia* (Figure 1). According to the American Orchid Society (AOS), there are at least, 300 accepted names of *Oncidium* orchid species. Some of the most popular ones are listed in Table 1.

3. Pollination behaviour

Orchids are highly cross-pollinated in nature. Herkogamy mechanism is attributed to the physical barriers between the anthers and stigmas of a flower. This mechanism enhances the rate of cross-pollination. The preferred time for hand cross-pollination after emasculation is between 8 am to 10 am as suggested by Cardoso (2017).

4. Self-incompatibility (SI)

Oncidiinae has 65 genera and more than 1600 species. Approximately 69.4% of *Oncidiinae* species are self-incompatible, 22.2% are self-compatible and 8.3% have both self-incompatible and self-compatible populations. SI is the incapability of viable pollen grains to fertilise the same flower. It may be due to the failure of pollen germination, pollen tube growth and degeneration of embryo after fertilization.

The identification of SI in *Oncidiinae* is determined by fruit set and seed

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This is redundant, it was already said in the description of the genus

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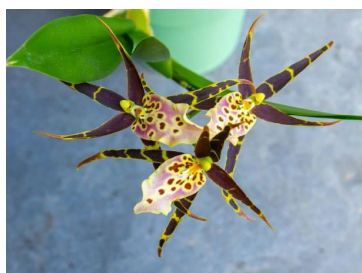


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production after self-pollination. In *Oncidiinae*, the growth of pollen tubes after self-pollination has only been reported in *Oncidium flexosum*. The pollen tubes either did not germinate or stop growing at the stigmatic surface and the flowers withers in four days after pollination. This subtribe requires more pollen tube observation experiments to study the extend of incompatibility (Rianawati *et al.*, 2021).



Miltonia

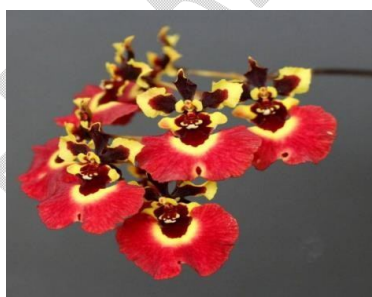


Brassia

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Trichopilia



Tolumnia

Figure1. Related genera of *Oncidium* or some members of the *Oncidium* Alliance

Table1. Some of the most popular *Oncidium* species

S.No.	Botanical name	S.No.	Botanicalname
1	<i>Oncidium gutfreundianum</i> 'Gigi'	17	<i>O.concolour</i> 'Mother Teresa'
2	<i>Oncidium tigrinum</i>	18	<i>Oncidium reductum</i>
3	<i>Oncidium sarcodes</i>	19	<i>Oncidium remotiflorum</i>
4	<i>Oncidium varicosum</i>	20	<i>Oncidium retusum</i>

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5	<i>Oncidiumleucochilum</i>	21	<i>Oncidiumrodrigo</i>
6	<i>Oncidiumcarthagenense</i>	22	<i>Oncidiumluridum</i>
7	<i>Oncidiumsplendidum</i>	23	<i>Oncidiumornithorhynchum</i>
8	<i>Oncidiumcrispum</i>	24	<i>Oncidiumabortivum</i>
9	<i>Oncidiumcheirophorum</i>	25	<i>Oncidiummacrochordonia</i>
10	<i>Oncidiumsphacelatum</i>	26	<i>Oncidiumacinaceum</i>
11	<i>Oncidiumaberrans</i>	27	<i>Oncidiumraniferum</i>
12	<i>Oncidiumabruptum</i>	28	<i>Oncidiumadelaidae</i>
13	<i>Oncidiumampliatum</i>	29	<i>Oncidiumrhinoceros</i>
14	<i>Oncidiumreflexum</i>	30	<i>Oncidiumriograndense</i>
15	<i>Oncidiumreichenbachii</i>	31	<i>Oncidiumriopalenqueanum</i>
16	<i>Oncidiumriviereanum</i>	32	<i>Oncidiumrobustissimum</i>

5. Cytogenetics

Felix and Guerra (2000) performed mitotic studies on various *Oncidium* species in root tips using Feulgen technique and revealed the ploidy information as mentioned in Table 2.

<i>Oncidium</i> sp.	Somatic Chromosome number
<i>Oncidiumbifolium</i> Sims	2n=108
<i>O.divaricatum</i> Lindl.	2n=42,56
<i>O.edwallii</i> Cogn.	2n=42
<i>O. fimbriatum</i> Lindl.	2n=56
<i>O. longicornu</i> Mutel.	2n=42
<i>O. longipes</i> Lindl.	2n=56
<i>O.pubes</i> Lindl.	2n=84
<i>O.riograndense</i> Cogn.	2n=56
<i>Miltoniaflavescens</i> Lindl.	2n=60

Oncidium genus showed $2n = 28, 42, 56$ as the most common chromosome numbers. All the *Oncidium* species studied showed small chromosome size (0.5 to 3 micrometer) and $2n = 42, 56$ as the most common numbers, with the exception of *O. bifolium* ($2n=108$) and *O. pubes* ($2n=84$). Cytotype $2n=84$ is present in at least six species (Felix and Guerra, 2018) that can be considered 12-ploid, whereas cytotype $2n = 108$ (derived from $2n = 112$) can be considered 16-ploid based on $x = 7$. Hence, ploidy is not stable from species to species since the crop is highly cross pollinated in nature.

6. Breeding objectives

Breeding in *Oncidium* orchids focuses to produce fragrant varieties prioritises developing fragrant *Oncidium* varieties, enhancing their ornamental value, varieties with better root proliferation thus enable to absorb nutrients more efficiently. Moreover, development of high-yielding with more flowers per inflorescence, early-flowering varieties with longer inflorescences with vibrant colours, while also improving adaptability, extending the blooming period and introducing fragrance can improve quality and quantity of flowers in the inflorescence. This may add value in floriculture industry both in terms of trade and aesthetic sense.

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7. Breeding methods in *Oncidium* improvement

The majority of the success in orchid breeding was brought out by the art of patient breeding, intuition and perseverance of the orchid breeders and on several occasions merely by luck (Arditti, 1992). It is not possible to make crosses between any two genera, though free breeding is common in orchids. It requires several years to raise progeny from seeds to flowering stage. Unlike other crops, orchid seeds cannot be germinated without special facilities. It takes a long time for the seeds to mature. Moreover, the number of seeds produced in a capsule is so high that to get a representative sample of the progeny that will be required to draw any valid genetic inferences will be very large and may be impossible on most occasions. Hence, information on combining ability and inheritance of characteristics in orchids is scanty. Till date, traditional breeding is the main approach to any orchid breeding. In recent years, transgenic molecular breeding has been extensively used employed by introducing the desired target genes into orchids using *Agrobacterium* mediated transformation and particle bombardment methods. The development of DNA based molecular marker technology provides plant breeders with new opportunities to employ molecular marker

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assisted selection in **breeding**.

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7.1. Hybridisation: It is defined as the crossing of two or more plants which are genetically different from each other to produce a new crop. Hybridisation is effective to combine all the good characters in a single variety to create genetical variation and to exploit the hybrid vigour. Hybrids of orchids produced by crossing orchid species from the same genus or closely related orchid genera. Meanwhile, based on Julia Stewart's book, *Orchid Care for Beginners* (2013), the first *Oncidium* orchid hybrid was first registered in 1909. The hybrid was named *Oncidium Illustre*, which was a cross between *Oncidium laucochilum* and *Oncidium maculatum*.

Classical breeding in *Oncidium* orchids primarily relies on cross-pollination between different species and hybrids to generate new cultivars with desirable traits. Hybridization between species within the *Oncidium* alliance, which includes genera like *Cochlioda* and *Odontoglossum*, has been successful in producing robust hybrids with diverse flower colorations, shapes, and extended blooming periods (Cai *et al.*, 2019). Significant hybrids, such as *Oncidesa* Gower Ramsey, have revolutionized the cut flower market due to their vibrant yellow flowers and high yield (Manning *et al.*, 2017). However, achieving fertility in these hybrids can be challenging, and extensive backcrossing is often necessary to stabilize desirable traits.

Today, there are perhaps over a thousand *Oncidium* orchid hybrids available. Some of the famous hybrids available worldwide are *Oncidium* Gower, a prolific bloomer and a cross between *Oncidium* Goldiana and *Oncidium* Guinea Gold, *Oncidium* Sherry Baby—an excellent indoor orchid, which is a cross between *Oncidium* Jamie Sutton and *Oncidium* Honolulu and *Oncidium* Twinkle, created by a Hawaiian pioneer in orchid hybridisation, this petite orchid beauty was conceived using *Oncidium cheiroporum* and *Oncidium ornithorhynchum*.

7.2. Orchid Hybridisation Programme at Singapore Botanical Gardens

The orchid hybridisation programme in the Singapore Botanic Gardens was initiated over 80 years ago by Dr. R. E. Holttum. *Oncidium* Goldiana (*Gomesa flexuosa* × *Oncidium sphacelatum*) commonly known as 'Golden Shower' or 'Dancing Lady', was produced by this Gardens. It flowered first in 1939. To date, the Gardens has registered more than 630 hybrids including various *Oncidium* hybrids. Their breeding programme mainly focuses on *Dendrobium*, *Vanda* species and *Oncidium* orchids.

7.3. *Oncidium* intergeneric hybrids

The *Oncidium* family is very large and includes many flower varieties, the most common being referred to as the "dancing lady". Intergeneric hybrids consist of several different genera that can be crossed together to create new 'manmade' intergeneric orchids. Common genera that are used for intergeneric hybrids include *Cochlidium*, *Miltonia*, *Odontoglossum*, *Oncidium* etc. The result of these hybrids leads to new genera names are pretty confusing. Some common intergeneric names are *Beallara* (Blra.), *Brassosteale* (Bst.), *Bratonia* (Brat.), *Colmanara* (Colm.), *Odontocidium* (Odcdm.), *Odontonia* (Odn.), *Oncosteale* (Onc.) and *Vuylstekeara* (Vuyl.).

Intergeneric hybrids are created by crossing orchids from different unrelated genera. An excellent example of this is 'Oncosteale Wildcat', formerly known as *Colmanara* Wildcat. It is an intricate intergeneric orchid hybrid made of *Oncidium*, *Miltonia*, and *Odontoglossum*. 'Burrageara Nelly Isler' and 'Odontocidium Mitsuishi' are other recognized intergeneric hybrids (De, 2022).

Table 3. Types and Hybrids of *Oncidium* orchids (De, 2022)

Types	Species & Hybrids
Yellow Flowered	<i>Oncidium splendidum</i> , <i>O. lanceanum</i> , <i>O. spaceatum</i>
Golden Showertype	Aloha Iwanga Dogasima, Goldiana, Gower Ramsey, Golden Shower, Jungle Queen, Sharry Baby Sweet Fragrance
White coloured	<i>Oncidium variegatum</i> White
Red coloured	Popki Red, Irine Gleason Red, Vision Brownish Red, Catherine, Wilson x New Calidonia Brownish Red
Pink coloured	Robson Orchid Glad
Cream coloured	<i>O. lowianum</i> hybrids

1.1.1. Interspecific hybrids:

'Dark Tower', 'Ruby Frost', 'Sanddrinho', 'Barbara Ann', 'Flamingo', 'Flower Fairy', 'Nutmeg Dancer', 'Midnight Moon', 'Lemon Ice', 'Caribbean Stars', 'Ruby Jewell', 'Debonoir', 'Fragrance Fantasy', 'Red fantasy' (De,

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very redundant

Comment [JO31]: *Oncidium* Aloha Iwanga, *O. Goldiana*...

Comment [JO32]: Include the genus and its abbreviation depending on the case.

Comment [JO33]: The correct name is: [Tolumnia variegata](#)

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2022).

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1.1.2. Inter-varietal hybrids:

'Volcano Gold', 'Dark Sun', 'Coral Gold', 'Golden Sun', 'Sundown', 'Sweet Sunset', 'Golden Bonanza', 'Dear Friend', 'Music Shower', 'SummerGlow', 'IslandGold', 'Space Baby', 'Golden Prince', 'GoldenRiver', 'Sun Shade', 'Fragrant Red Barry', 'Golden Sunray', 'Sungold', 'Sharry Baby Dancing Doll', 'Sharry Baby Pink Lip', 'Sharry Baby 'Tricolor' (De, 2022).

Comment [JO37]: names incorrectly described

1.1.3. Bigeneric hybrids:

Aspasium = *Oncidium X Aspasia*; Brassidium = *Oncidium X Brassia*; Miltonidium = *Oncidium X Miltonia*; Odontocidium = *Oncidium X Odontoglossum*; Trichocidium = *Oncidium X Trichocentrum*; Oncidipilia = *Oncidium X Trichopilia* (De, 2022).

1.1.4. Trigeneric hybrids

Aliceara = *Oncidium X Brassia X Miltonia*; Wilsonara = *Oncidium X Cochlioda X Odontoglossum*; Colmanara = *Oncidium x Miltonia X Odontoglossum* (De, 2022).

Comment [JO38]: numerals 1.1.2 to 1.1.4 could be organized in a unified table



Medicinal *Oncidium*: *Oncidium cebolleta* is reported to contain phenanthrene derivatives

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8. Mutation breeding

Mutation breeding can be used to obtain wide variations in flower colour, morphology and size by overcoming incompatibility and sterility. Accordingly, combining hybridisation and mutation breeding would represent an effective strategy for realising the full potential of hybridisation in orchid breeding.

Comment [JO40]: references

9. Polyploidy breeding

Polyploidy occurs naturally in plants through cell division errors or can artificially be induced by antimetabolic agents and has ecological effects on species adaptation, evolution, and development. In agriculture, polyploidy provides economically improved cultivars. Furthermore, the artificial induction of polyploids increases the frequency thus, it accelerates obtaining polyploid plants used in breeding programs. This is the reason for its use in developing many crops of economic interest, as is the case of orchids in the flower market.

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Ployploidy in ornamental plants is mainly associated with flowers of larger size, fragrance, and more intense colouring when compared to naturally diploid plants. Currently, orchids represent the largest flower market worldwide. Thus, breeding programs aim to obtain flowers with the larger size, durability, intense colours, and resistance to pathogens. Furthermore, orchid hybridisation with ployploidy induction has been used to produce improved hybrid cultivars.

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The correlation between ployploidy and genetic improvement is remarkable. In some genera, like *Phalaenopsis*, ployploid commercial hybrids are predominately used in floriculture. In case of *Oncidium*, still more cytogenic studies are required for ployploidy induction experiments.

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10. Achievements and constraints in *Oncidium* breeding

Breeding of *Oncidium* is rare because the genetic information is not much available. The main factors that affect the success of *Oncidium* breeding through sexual hybridisation are the seed germination and seedling development. Orchid seed germination success is heavily influenced by a lot of factors viz., seed maturity media composition and plant growth regulators. The researchers aimed to develop efficient *in vitro* seed germination and seedling development methods for *Oncidium* orchids by exploring different plant growth regulators (PGRs) and basal nutrient media. The study spanned from 2013 to 2019 and involved hybridizing *Oncidium* orchids, with pollination occurring within the first week of blooming. Seed maturation took 3 to 9 months. Three basal germination media viz., Murashige and Skoog (MS), Vacin and Went (VW) and Tsuchiya were tested out of 556 hybridization attempts made, only 85 capsules were obtained successfully, with a 15.29% success rate. 165 to 273 days were required for capsule ripening, with 19 crosses forming protocorms in under 41 days. However, reproductive barriers limited success, with only 31 capsules successfully germinating. Tsuchiya medium proved most effective for seed germination, followed by ½ MS and VW media (Rianawati *et al.*, 2021).

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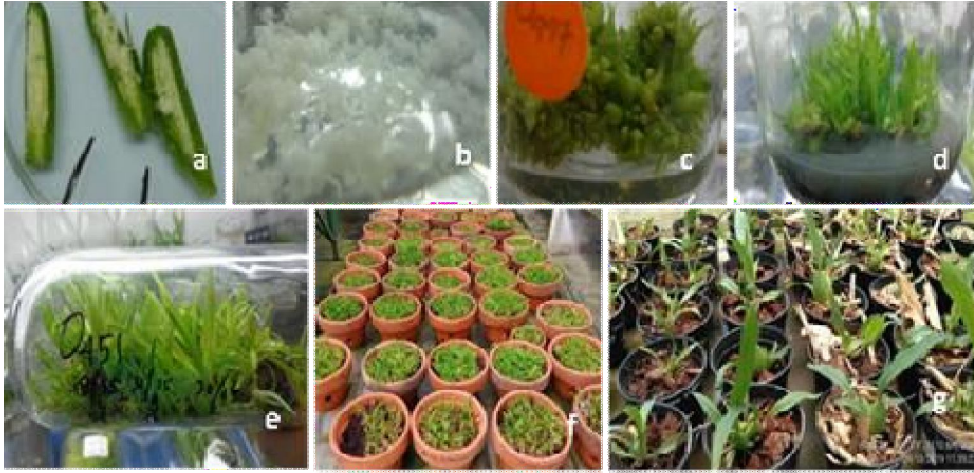


Figure 2. Development of seed to individual resulted by hybridisation (a) capsule contain seed, (b) seed spreading in media, (c) protocorm like bodies, (d) & (e) plantlet/seedling on media. (f) compost (g) individual plants using bamboo litter. **Source:** (Rianawati *et al.*, 2021)

**11. A successful *Oncidium* inter-hybridisation attempt by Faria *et al.* (2015):
Oncidium sarcodes x *Oncidium Aloha 'Iwanaga'*: new option of *Oncidium*
 hybrid**

Breeding of native species with ornamental potential is an important strategy to ensure a better adaptability of cultivars to Brazilian conditions. Among them, the Brazilian species *Oncidium sarcodes* stands out for long stems with large yellow flowers with brown stains. The aim of this work was to characterise the progenies resulting from the *Oncidium* hybridisation in order to select a potential cultivar. Selected *O. sarcodes* plants were used as the female parental and *O. Aloha 'Iwanaga'* as the male parent. Pollination was manually controlled and the obtained seeds were germinated *in vitro*. For the morphological description of the hybrids, 10 progenies were selected to evaluate the characteristics of vegetative development and inflorescences. The sepals and petals have yellow gold colour with brown spots, with well-defined limits between the colours.

Oncidium sarcodes, epiphyte plant is found in some states of the south-eastern and southern- Brazil. Features sympodial growth, dark green pseudobulbs, 1-3 foliate, presents

inflorescence arising from the base of the pseudobulbs, formed by more than 150 flowers, descending, panicle, approximately 200 cm long. Flowers with curved dorsal sepal forward, reddish-brown, yellowish side sepals and reddish-brown side petals, trilobed and yellow label. *Oncidium Aloha 'Iwanaga'* is a hybrid obtained from the crossing of *Oncidium Goldiana* x *Oncidium Star Wars*.



Figure 3. *Oncidium sarcodes* (female parent, image top left), *Oncidium Aloha 'Iwanaga'*(male parent, upper right image) and hybrid (central bottom image) obtained from the artificial crossing.

Improvement method

Sound and vigorous plants, grown in the orchid of the State University of Londrina, with a high number of flowers were used as matrices for the intersections between *Oncidium sarcodes* and *Oncidium Aloha Iwanaga*. The hybridisation process occurred using controlled manual pollination; polineas of the donor plant (*O. Aloha 'Iwanaga'*) were collected from flowers (48 hours after anthesis) and transferred to the stigma of flowers (24 to 48 hours after anthesis) of the receiving plant (*O. sarcodes*). Nine months after crossing, the capsules (fruits) were obtained with seeds and were germinated *in vitro* in MS media.

For the morphological description of the hybrids, 10 plants were selected in and evaluated. Length and diameter of the pseudobulb, length and width of leaves; and the phytometric characteristics of the reproductive parts *viz.*, length of the stem, length and width of the flowers, number of flowers per stem were observed. The dimensions of the

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floral verticils were determined from the measurement of four flowers from the basal region of the inflorescence, four flowers from middle and four flowers of the apical region, total of 12 flowers per stem. It was noticed that the obtained hybrid was vigorous in terms of pseudobulbs, floral axis etc.

***Ionocidium* 'Cerrado101'**: Intergeneric orchid hybrid with high quality of blooming was created by Cardoso (2017). This study was to determine the capacity of crossing between these two species by hand crossing pollination, followed by the cultivation, evaluation and selection of superior progenies for breeding and use in floriculture as a new cultivar. Two *Oncidium* Hybrid Groups (OHGs) famous in the Brazilian flower market were 'Golden Rain Orchids' (including *Oncidium* Aloha 'Ywanaga', *O.* 'Sweet Sugar') with large inflorescences with yellow canary flower colour and the 'Chocolate Orchid' (*O.* 'Sharry Baby') with red-brown flowers distributed in inflorescences and with a sweet smell that resembles chocolate. *Ionopsis* is another genus from subtribe *Oncidiinae* with occurrence in Cerrado vegetation areas and riparian forests and their ornamental potential and its use for OHGs breeding was reported. For all stages of *in vitro* growth there was used the Murashige and Skoog (1962) culture medium with half concentration MS media. The selection of progenies as a new cultivar was based on visual good and vigorous vegetative development with absence of pests and diseases, rapid growth. Reproductive development was observed mainly by the early blooming and high quality of flowers and inflorescences, based on architecture, length of inflorescence, flower size and colour.

The viability of the intergeneric crossing was possible only when *Oncidium* was used as female and *Ionopsis* as male parent resulted in fruits and seeds. Using *Oncidium* 'Sweet Sugar' as female parent, the fruit set was 70% (7/10), instead of no fruit production when *Ionopsis utricularioides* was used as female. Characteristics of inflorescences from male and female parent and the intergeneric progenies obtained as a new cultivar *Ionocidium* 'Cerrado 101' is mentioned in Table 4. Among the main superior characteristics of the progeny selected *Ionocidium* 'Cerrado 101' is the high quantity of ramifications and number of flowers, more than three times the number of flowers of *Oncidium* 'Sweet Sugar' used as female parent.

Traits	Parents		
	<i>Oncidium</i> 'Sweet Sugar'	<i>I. utricularioides</i>	<i>Ionocidium</i> 'Cerrado 101'
Pseudobulb length/diameter (cm)	9.4/2.9	1.5/0.3	9.1/3.8
Leaf length/diameter (cm)	24.3/3.2	9.5/1.1	26.8/3.8
Number of flowers	36	158	115
Number of inflorescences	1	3-4	1
Number of ramifications	5	13	8
Inflorescence length (cm)	51.0	46.5	83.0
Flower Diameter (cm)	4.1	1.2	4.0

In *Oncidium* most of the species have yellow with brown spots or yellow or brown flower colours, including its hybrids (Faria *et al.*, 2015). Only the crossings among other correlated general like *Miltonia* (Miltonidium), *Odontoglossum* and others were capable to produce new cultivars with more diverse flower colours for the floriculture market. The tentative of self-pollination of *Ionocidium* 'Cerrado 101' not resulted in fruits until the moment.

Biotechnology and Transformation technology in *Oncidium* improvement

Many researchers had devoted efforts to the study of gene transformation of *Oncidium* to improve various traits or to create new variants from the past two decades. Several factors are considered essential for the gene transformation method of orchids *viz.*, how to choose, what kinds of explants and regeneration capacity is important to increase the efficiency of transgenic *Oncidium* plants. Using unsuitable explants such as callus cultures as target materials for transformation may cause chimeric transgenic plants and often confuse the analysis because of difficulty in maintaining single-cell embryogenesis or a high incidence of somaclonal variation (Ko *et al.*, 2019). In general, protocorm-like bodies (PLBs) have been generally used as target tissues because of their higher regeneration capacity for gene transformation of orchids, especially in *Oncidium*. So far, PLBs have been used as target tissues for orchid transformation in *Oncidium* orchid 'Sherry Baby cultivar 'OM 8'.

Three major methods for gene transformation in *Oncidium* orchids include *Agrobacterium tumefaciens*-mediated transformation, microprojectile bombardment and direct gene transformation. *Agrobacterium tumefaciens*-mediated transformation is 1

commonly used in dicots, whereas microprojectile bombardment and direct gene transformation are mainly used in monocots. But, recently, several *A. tumefaciens*-mediated transformation events for monocotyledonous ornamental plant, *Oncidium*, have been reported (Chin *et al.*, 2021).

Castro *et al.* (2019) developed a highly efficient protocol for efficiently producing transgenic plants of *O.* ‘Sherry Baby cultivar OM8’. PLBs pre-treated and were transformed by particle bombardment with the *pflp* gene. The treated PLBs showed 3 to 4 fold increased single-cell embryogenesis and 14.8-fold increased *GUS* expression compared with untreated PLBs. Hence, sucrose-pre-treated *Oncidium* PLBs can increase single-cell embryogenesis and efficiency of transformation (Chin *et al.*, 2021).

Disease resistance

A novel selection marker system was developed successfully by Thiruvengadam *et al.* (2011), the sweet pepper (*Capsicum annuum* L.) ferredoxin-like protein (*pflp*) gene, for *O.* ‘Sherry Baby cultivar OM8’ transformation by *A. tumefaciens* and particle bombardment. The *pflp* gene is a disease resistance gene, which encodes a ferredoxin-like protein to decrease infection by *E. carotovora* pathogen for soft rot disease.

Species	Genes	Explant	Method
<i>Oncidium</i> GowerRamsey	<i>gusA, hptII.</i>	PLBs	<i>A.t</i>
<i>Oncidium</i> GowerRamsey	<i>gusA, gfp, hptII, pflp</i>	PLBs	PB and <i>Agrobacterium</i>
<i>Oncidium</i> GowerRamsey	<i>gusA, OgCHI, OgDFR, OgMYB1</i>	Petals (lip)	PB
<i>Oncidium</i> GowerRamsey	<i>hptII, gfp, antisenseCHS</i>	PLBs	Particle Bombardment
<i>Oncidium</i> GowerRamsey	<i>nptII, etr1-1</i>	PLBs	<i>A.t</i>
<i>Oncidium</i> GowerRamsey	<i>hptII, pmi, gfp</i>	PLBs	<i>A.t</i>

Abbreviations: *etr1-1*: mutated ethylene receptor from *Arabidopsis thaliana*,
gfp: green fluorescence protein gene, *GST*: Glutathione S-Transferase, *gusA*: β -

glucuronidase (also known as *uidA*), *hptII*: hygromycin phosphotransferase II, *LTP*: Lipid Transfer Protein gene, *luc*: luciferase, *MSO*: L-Methionine Sulfoximine, *nptII*: neomycin phosphotransferase II, *OgCHI*, *OgDFR*, *OgMYB1*: anthocyanin biosynthetic pathway genes for *Oncidium* Gower Ramsey.

In practice, *Oncidium* is propagated by simple division of pseudobulbs, but is time-consuming and expensive; propagation from seeds is highly undesirable due to high heterozygosity. In recent years, advancements in molecular biology and genetic engineering techniques particularly in gene identification and isolation have powered specific alteration of single traits in already successful floriculture varieties (Tanaka *et al.*, 2005). Furthermore, these techniques allow delivery of genes of different origins (bacteria/virus) into the orchid genome by using *Agrobacterium*-mediated or microprojectile bombardment methods (Chin *et al.*, 2021).

12. Future thrusts

Red *Oncidium* flowers and perfect flower shapes with a pleasant fragrance are the most expectations of consumers. In addition, poor quality of planting materials due to somaclonal variations generated by micropropagation constrains the full expansion of the orchid industry (Hsiao *et al.*, 2011). Genetic engineering of novel flower colours is now a practical technology, as typified by commercialisation of a transgenic blue rose and blue carnation (Nishihara and Nakatsuka, 2021).

Red *Oncidium* cannot be bred by traditional means. Through basic research into the formation and regulation of floral colour of *Oncidium*, genetically modified orchid flowers with designed colours will be genetically engineered, propagated by micropropagation and then distributed worldwide. Understanding epigenetic regulation will have important implications in the orchid industry while increasing the consistency of floral products. Eventually, directed manipulation of epigenetic regulators will open the way to epigenetic engineering in orchids.

13. Conclusion

As research on hybridisation and *in vitro* production of *Oncidium* orchids are feeble in India, gene action, the possibility of diverse crossing and compatibility reactions are not well studied yet. National Research Centre for Orchids, Sikkim is actively involving in the *Oncidium* research but clear findings are not yet scientifically published. A regular supply of

Oncidium flowers to the market all year round has been constrained by lack of effective means for flowering modulation in flower markets. Exploring new genes which are involved in early/late flower development, subsequent functional analysis and innovation of novel flower specific promoters will certainly add benefit to *Oncidium* improvement. However, in addition to inducing early flowering or overexpression of genes is often associated with undesirable phenotypes, such as reduced vegetative development, smaller leaves and abnormal flower development. These effects will have to be overcome before commercialization can be considered. Having a well-defined regeneration and transformation process is key to successful improvement of *Oncidium* genotypes. A much more urgent issue faced by the orchid industry is the decrease in the early detection of somaclonal variations occurring during mass clonal micropropagation. More studies have to be done in breeding for new varieties through biotechnological approaches. Like other orchids, *Oncidium* can also be exploited for better commercial hybrids by utilising clear cytogenetical and physiological information in future.

14. References

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UNDER PEER REVIEW

It is an interesting review in terms of progress in orchid breeding from the Oncidium alliance. I leave some comments and some considerations that in my opinion could improve this manuscript.



UNDER PEER REVIEW