Chapter 5

Teaching of Meiosis and Mitosis in Schools of Developing Countries: How to Improve Education with a Plant Reproduction Project

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Additional information is available at the end of the chapter

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1. Introduction

Recent investigations on Biology Education in Brazil showed that most classes involve the use of textbooks and illustrations [1, 2]. Theoretical and lecture classes predominate in Sciences and Biology courses [3, 4], and there is a scarce variety of teaching materials. On the other hand, recent investigations have led to the development of several practical lessons to improve education quality. Some studies involve proposals of biological models [5]; elaboration of teaching games [6]; analysis of biological specimens [7]; laboratory lessons using microscopy [8]; ecotourism in natural ecosystems, observation of wildlife and environment [9] and visits to Natural History Museums, Zoo and Botanical Gardens [3]. Moreover, other initiatives to improve theoretical classes of Biology and Sciences include donation of small libraries to rural public schools [10] and availability of computer with internet access in rooms at schools [11].

The Brazilian Basic Education system is divided into three cycles, as follows: *Educação Infantil*; *Ensino Fundamental* and *Ensino Médio*. *Educação infantil* can be translated here into Early Child Education [21], encompassing children from 0 to 5 years old; *Ensino fundamental* corresponds to Junior High School [4], for students aged 6 to 14 years old; and *Ensino Médio* corresponds to High School of United States of America (USA). In Brazilian High School, the students are teenagers from 15 to 17 years old. Nowadays, technology courses in Brazil are offered concomitantly with High School. Students that have access to Graduation courses enter higher education institutions after High School. Until the present moment, of all governmental and non-governmental programs to improve Brazilian Basic Education, the only one that became universal is the free distribution of textbooks in public schools [12,13] followed by the availability of computer with internet access at schools. These are present in 93.4% of High Schools; 70% of Junior High Schools and 30% of Early Childhood Education Schools.

Therefore, the present study is aimed to elaborate a project with practical lessons of Mitosis and Meiosis, at very little to no costs, based on the local environment of students from two cities of the Southeastearn Region of Brazil: São Mateus, in the state of Espírito Santo and Santos Dumont, in the state of Minas Gerais.

We proposed practical lessons of Mitosis and Meiosis within the context of a project of Plant Reproduction. The project bears the following contents: biological species; varieties; cultivars; gene; mutation; chromosome; ploidy; plant cell; cell division; mitosis; plant tissues; meristems; plant growth; plant asexual reproduction; meiosis; pollen and spores; plant sexual reproduction; plant life cycle; environmental education, effects of climate changes on plant reproduction and food security. These contents are consistent with textbooks of Biology, as well as with the National Curriculum Parameters for Sciences, Biology and Environmental Education [14,15,16,17].

The Plant Reproduction project is based on the local environment of the students, e.g., the plant material is based on species used as local food and crops cultivated in rural areas of São Mateus and Santos Dumont. Some of these plants are not native [18] and their introduction in Brazil is also described. Also, the historic deforestation process occurred in Brazil following to develop the several existing crops was discussed. The cities São Mateus-ES and Santos Dumont-MG are situated in the Atlantic Tropical Forest Biome, one of the world biodiversity hotspots [19].

According to Paulo Freire: an education adapted to real-life contexts of students, their environment and culture facilitates the learning process. Education can prepare students to become responsible citizens that will be able to promote positive changes in their society and their natural space in the future [20].

2. Teaching of meiosis and mitosis in developing countries: How to improve education with a plant reproduction project

The current project concerns the elaboration of practical lessons of Mitosis and Meiosis based on the local environment of teachers and students from two cities of Southeastearn Brazil: São Mateus-ES and Santos Dumont-MG. The costs of the project range from little to no costs. Also, the project can be adopted in developing countries.

A brief Environmental Analysis of São Mateus-ES and Santos Dumont-MG was conducted [22]. A literature review of São Mateus and Santos Dumont was performed, which included historical aspects, geographical characterization and the anthropic use of space. The literature review bears historical aspects of São Mateus and Santos Dumont from the time Brazil was a colony of Portugal (16th century) to the present time. The geographical characterization comprised: location, geomorphology, climate, hydrography, natural ecosystems and flora. Field work was carried out in tourist places and rural areas of both cities and aspects of anthropic use of natural areas were investigated. Moreover, visits to historic markets, supermarkets and restaurants were conducted last year, and information on the local typical food was obtained. Pictures were taken of the major crops grown by the local population. Field work was carried out on secondary roads of both cities to record the main crops grown. Pictures of different sites were taken.

Based on data collected during the environmental analysis, vegetables that could be easily found by teachers and students were elected as material for the Project of Plant Reproduction. From May 2012 to January 2013, pictures were taken of macroscopic events related to mitosis and meiosis. Practical lessons of the microscopic events of mitosis and meiosis are also proposed, based on literature review of protocols, at little cost.

Biology textbooks published in Brasil were analyzed [14] as well as the National Curriculum Parameters for Sciences, Biology and Environmental Education [15,16,17] to understand how Mitosis, Meiosis and Plant Reproduction are being taught in Brazilian Basic Education. The Plant Reproduction project aims to raise the following question to students: How is a Plant life cycle? After understanding the main process of a plant life cycle, should the teacher motivate students to answer the following question: What is the relationship between Plant life cycle, Meiosis and Mitosis?

The present study is aimed to formulate biological pratical lessons to students from early childhood ducation to high school. However, Meiosis and Mitosis lessons are usually taught in the second half of Junior High School (for students aged 11 to 14 years old) and during High School (15 to 17 years old). In early childhood education and in the first half of Junior High School, some concepts of Plant life cycle are developed. As for the contents of the present book, macroscopic observations of plant life cycle could be used in all levels. Practical lessons of microscopy should be introduced at Junior High School and High School.

2.1. The plant reproduction project in the city of São Mateus, Espirito Santo state, Brazil

In the city of São Mateus-ES, we proposed a fieldwork at Guriri Beach (Figure 1A), one of the most popular tourist attractions in the city. Last year, students of São Mateus public schools have often visited that place, and, thus, we suggested that we could perform the proposed fieldwork during these annual tours. Teachers should encourage their students to bring zoom cameras; mobile phones with built-in digital cameras; magnifying glasses and hand lenses. Hand lenses are sold at cheap prices in Brazilian shops. Notebooks and pencils are also needed for note taking.

Guriri is an island in São Mateus. The road from downtown to the beach of Guriri bears some crops of the Dwarf coconut palm. The state of Espírito Santo, and, in particular, the city of São Mateus, are great producers of coconut water that is exported to tourist locations in Bahia, Espirito Santo and Rio de Janeiro. The dwarf variety contains sweet coconut water. Plant height facilitates harvesting. The Portuguese introduced the giant coconut palm in Brazil in 1533. The dwarf coconut palm came from Java, Malaysia, Cameroon and Ivory Coast and was introduced in Brazil from 1925 to 1978 [23].

The dwarf Coconut palm belongs to the same species of the giant coconut palm, *Cocus nucifera* L. Dwarf Coconut is a cultivar of *Cocus nucifera* named *Cocus nucifera* L. var. nana (Figure 1A-C). It is a mutation of the giant coconut palm. It has a mutant gene that prevents stem growth. This variety bears several cultivars of dwarf coconut: yellow of Brazil of Gramame (AABrG); yellow of Malaysia (AAM); green of Brazil of Jiqui (AVeBrJ); red of Brazil of Gramame (AVBrG); red of Cameroon and red of Malaysia (AVM) [23]. The dwarf coconut palm is abundant in Guriri Beach (Figure 1A-B). Students could take pictures of dwarf coconuts and listen to the teacher's explanation. In the subsequent class, at school, they should be encouraged to research about the concept of biological species; varieties; agronomical cultivars; chromosome, gene, mutation and mutant on their textbooks and educational websites. Regarding the exploration of the DNA concept, we suggest a low cost protocol of DNA extraction proposed by [7].

Besides Biology and Genetics, teachers could ask their students to search about historical and geographical aspects of São Mateus: e.g.: what kind of socioeconomic relationship existed between Portugal and Brazil in 1533? Has Brazil been an exploitation colony of Portugal from 22th April 1500 until 7th September 1822. When was the city of São Mateus founded? Was São Mateus founded during the period of coconut introduction in Brazil, in 1544 [24]. What is the geographical location of Java, Malaysia, Cameroon and Ivory Coast? Teachers of History, Geography and Portuguese should be invited to this tour and use transdisciplinary lessons.

The flowering and fruiting of coconut palm occurs throughout the year at 'the Restinga' vegetation of Guriri Beach (Figure 1A-C). The dwarf coconut can be used as material for the study of meiosis, mitosis and plant life cycle. Immature flowers can be explored to explain meiosis (Figure 1C). After pollination, flowers develop into fruits (Figure 2A-C). Coconut fruit bears several different tissues that can be seen with the naked eye (Figure 2B-C). These tissues grow during fruit development as a result of several mitotic divisions. In the field, the teacher can explore concepts of cell division and mitosis, and collect material to explore meiosis in a practical lesson in classroom.

The dwarf coconut palm is a monocot angiosperm. It belongs to the Arecaceae family, formerly known as Palmae family. The Life cycle of the coconut palm is a practical example of Angiosperm life cycle (Figure 1A-C and 2A-C), which is included in the curriculum of the Junior High School and High School. For a review of the theory of plant life cycle see [25, 26, 27, 28, 29]. Particularly about Angiosperm life cycle, there is an animation in [30].

All land plants, and some algae, have life cycles in which a multicellular haploid gametophyte generation alternates with a multicellular diploid generation [31]. In vascular plants, the dominant generation is the sporophyte [31]. This is an evolutive trend of vascular plants that include Pteridophytes, Gymnosperms and Angiosperms. If the sporophyte is the dominant generation, which visible structures of coconut palm belong to the sporophytic generation? All vegetative organs as roots stem and leaves belong to the sporophytic generation (Figure 1B). Some reproductive structures also belong to sporophyte, such as the inflorescence axis, sepals, petals, stamen, pistil and teguments of the ovule (Figure 2A).

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Figure 1. Guriri Beach at São Mateus-ES, Brazil (A) Guriri Beach. (B) The dwarf coconut palm. (C) Inflorescence of dwarf coconut palm with flowers and immature fruits.

The gametophytes comprise the pollen grains and the embryo sac. Pollen grains are produced within the anthers (Figure 2A). The embryo sac develops within the ovule. Pollen is the male gametophyte. The male gamete cells develop within the pollen grain. Male gametes are called sperm [24]. The embryo sac is the female gametophyte. The female gametes are: the egg cell and the middle of the cell. Almost all the following structures in the dwarf coconut can be viewed by the students: roots, stem, leaves, inflorescences, and flowers with sepals, petals, stamen and pistil (Figure 1B-C, Figure 2A). In classroom, with textbooks and educational websites, students should be able to recognize flower morphology in coconut palm flowers (Figure 2A). Teachers can cut anthers with a blade and observe the pollen grains. Students should observe pollen with hand lens or microscope. To prepare this lesson, the teacher collects some flowers and keeps them inside a sealed plastic pot with a spoonful of water under refrigeration at 4-8°C.

And how about learning how sporophytes give rise to gametophytes? In immature flowers or buds, the sporophyte gives rise to two types of sporangia: the microsporangium in the immature anthers and the megasporangium inside the immature ovule [24]. Microsporangium and megasporangium give rise to microspores and megaspores by meiosis. During meiosis, each diploid cell suffers a reduction division and gives rise to four haploid cells; haploid microspores will give rise to pollen grains by mitosis; also by mitotic divisions, the haploid megaspore gives rise to an embryo sac with seven cells [24]. In short, all coconut palm structures belong to the sporophytic generation, except for the pollen grains and embryo sac that are the gametophytes.

Regarding meiosis, it can also be asked: what are the differences between animal meiosis and meiosis of land plants? Meiosis in animals gives rise to gametes. In land plants it gives rise to spores within the immature flower; these spores germinate and develop into gametophytes; the pollen grain and embryo sac [24]. Animal gametes are generated by meiosis and land plant gametes are generated by mitosis. Meiosis occurs in land plants in immature anthers with liquids; after the end of meiosis, anther parietal tissues absorb liquids inside the anther. Several events take place in the cell, and meiocytes are converted into pollen grains [24].

Students can use a blade to cut small flower buds containing immature anthers from different sizes. Different size of anthers can correspond, in some cases, to different stages of another development, of microsporogenesis and microgametogenesis.

Then, students can view with a hand lens or a microscope the presence or absence of liquids inside the anthers. The presence of liquids indicates meiosis If the meiosis process is completed, students can find a dry anther with pollen grains. If school has got a microscopy laboratory with reagents, teachers can formulate a laboratory practice to see meiosis phases: Prophase I, Metaphase I, Anaphase I, Telophase I, Prophase II, Metaphase II, Anaphase II, Telophase II, as well as cytokinesis and the tetrad stage [8]. Cytokinesis occurs at the end of meiosis and gives rise to tetrads at eudicots. At monocots, cytokinesis occurs after meiosis I and after meiosis II. After meiosis I, the teacher can find dyads and after meiosis II, tetrads. For a review of the process of meiosis see [24].

Still in Guriri Beach, during the observation of coconut palm, some *Apis melifera L.* honeybees act as pollinators of coconut palm flowers (Figure 2A). It can be seen that honeybee transports an amount of pollen in the honeybee pollen basket. Honeybees are not native from Brazil and

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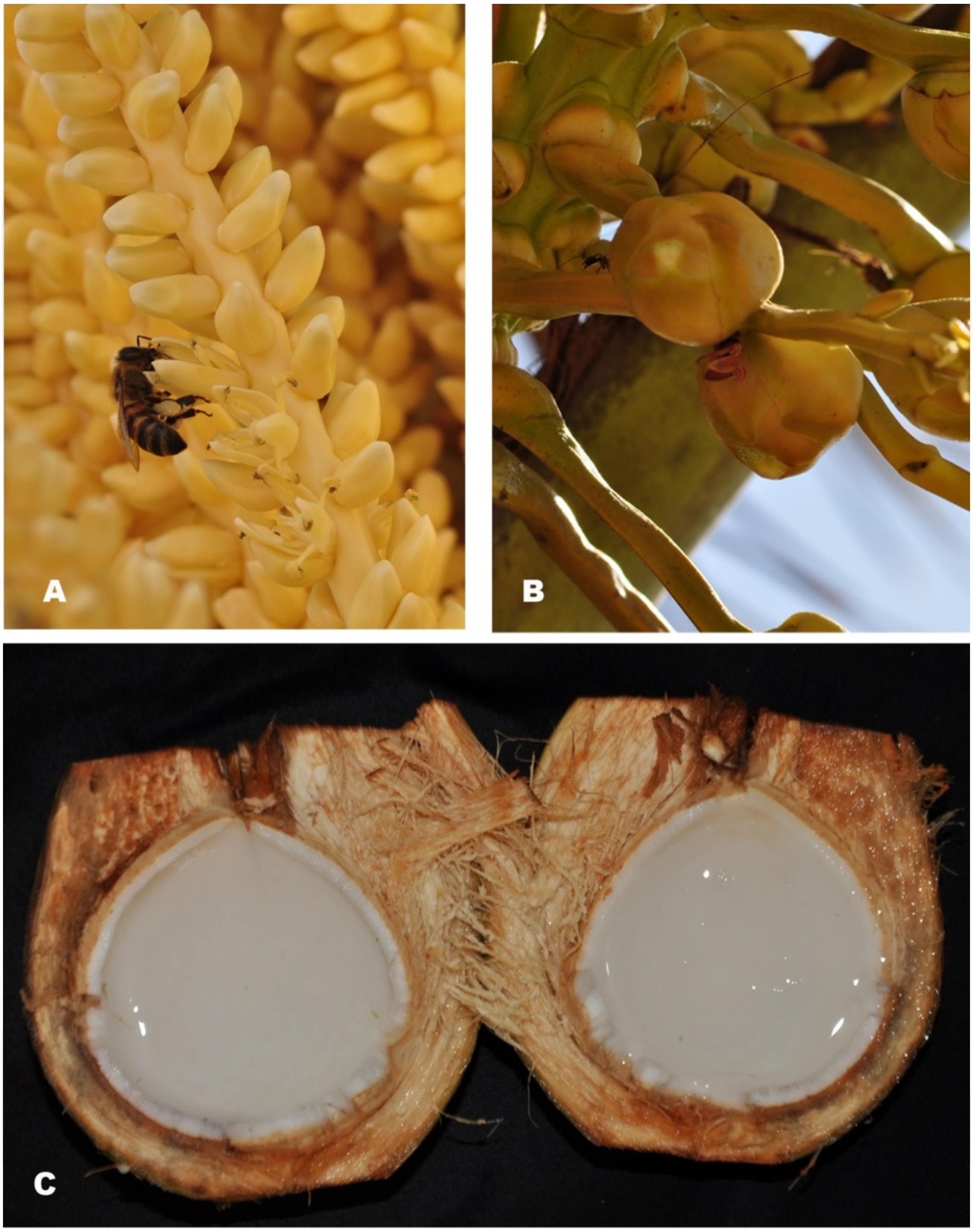

Figure 2. The dwarf coconut flower and fruit. (A) Immature buds of flowering and mature open flowers. See the pollinator on the open flower. (B) Immature coconut. (C) Mature coconut. Fruit pericarp, solid endosperm (edible part of the coconut) and liquid endosperm (coconut water).

are also known in the country as European bees. Honeybees were introduced in Brazil for honey production. Nowadays, the introduction of exotic pollinator species led to the extinction of native bees [32].

Pollinator agents transport pollen grains to stigma pistils and promote pollination. The pollination is the pollen tube growth along the pistil style carring the male gametes to the embryo sac, within the ovule. The fusion of male gametes with female gametes is called double fertilization. There are low-cost protocols for the observation of pollen tube *in vitro* growth that may be made at classroom with the presence of at least, one microscope [7, 33, 34]. Double-fertilization gives rise to embryo and endosperm (Figure 2C). The coconut water at immature fruit and the white coconut tissue at mature fruit stage compose the coconut endosperm. Figure 2C shows a fruit with coconut water and a little of solid endosperm. Animations about Double fertilization are avaible on [30]. A photomicrograph of double fertilization is disponible on [25].

At this point it is possible to formulate another question. How a small fruit containing this single seed with embryo and endosperm develops into a mature coconut (Figure 2B-C)? Embryo, endosperm, coconut seed integument as well as epicarpous, mesocarpous and endocarpous parts of the fruit suffer innumerable mitotic divisions to promote coconut growth. Protocol to observe chromosome of immature fruit somatic cells and mitotic divisions is available in [8]. Coconut water bears polythenic chromosomes [35] and can be used for the observation of chromosome morphology in schools that count on microscopy laboratory. To see how prepare material to analyse chromosomes see [8].

The native tree *Theobroma cacao*, the cocoa or cacao can also be used in the project involving meiosis and mitosis practical lessons. All the practical lessons on coconut palm which we suggested could be taught at Guriri Beach (Figure 1A-C, 2A-C) could also include cacao trees, abundant in farms of São Mateus-ES (Figure 3A-E). Chocolate is made from different proportions of cocoa nuts and milk. *Theobroma cacao* is an American native tree. In Brazil, *Theobroma cacao* occurs in Amazonia region, to the north of the states of Espírito Santo and Bahia. In farms, cacao is grown in some parts of the Atlantic Forest. *Theobroma cacao* also occurs in other tropical forests in Central and South Americas. During the Maya civilization, a territory nowadays situated at the Honduras and Mexico countries, *Theobroma cacao* was used to make a ritualistic drink. Cocoa nuts were transported to Europe after Spanish colonization came to American continent. In Europe, milk was added to this drink and the chocolate was invented.

The morphology of cacao tree is quite different from that of the coconut palm. Both species are angiosperms bearing flowers and fruits. The *Cocus nucifera* (Arecaceae family) is a monocot and *Theobroma cacao* (Malvaceae family) is a eudicot [35]. The morpholology of roots, leaves and flowers can be explored on field or at classroom. To keep lived plant material with good appearance, keep them at 4°C, in refrigerator, inside a sealed plastic bag with a spoonful of water.

According to the curriculum of botanical courses in Brazilian High School, after the study of diversity of vascular plants: Pteridophytes, Gymnosperms and Angiosperms, didactic books explore angiosperm plant anatomy [14]. A plant anatomy tissue closely related to mitosis is the meristem tissue [8].

The subsequent lesson concerns the following question: How is the development of morning glories? Where can the highest mitotic activity be found? Morning glory or *Ipomea purpurea* is an angiosperm, eudicot, from the Convolvulaceae family [36]. It Is abundant in anthropized

Figure 3. Cocoa tree. (A) Flower. (B) Small immature fruits. (C) Big immature fruit. (D) Mature fruit. (E) Seeds or cocoa nuts inside dry fruit.

environments of Restinga at Guriri Beach (Figure 4A). Morning glory occurs in the coastal regions of five continents and the colors of its petals range from white to purple [37]. Previous

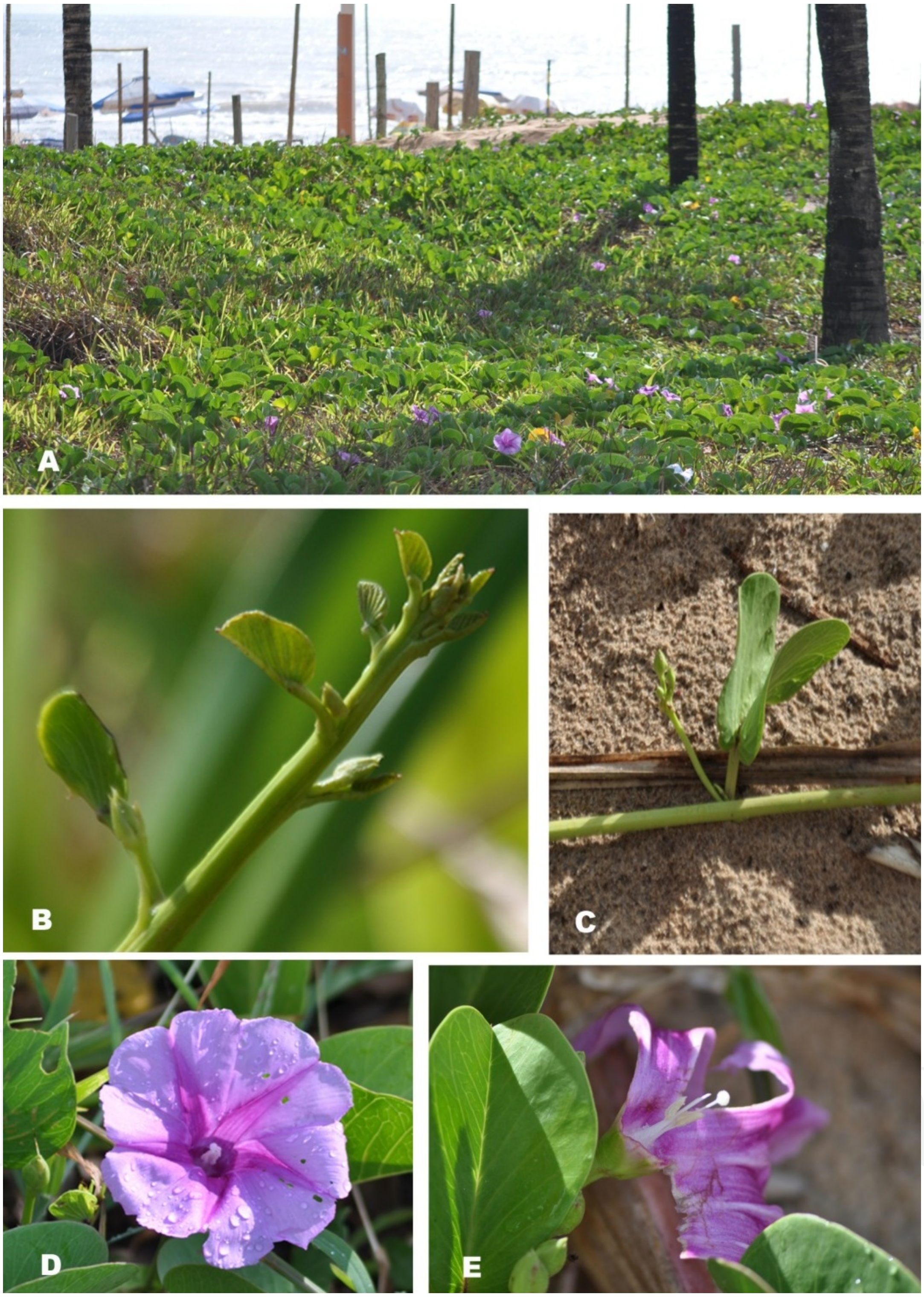

Figure 4. Morning glories. (A) Morning glory flowers at Guriri Beach, (B) Apical stem meristem. (C) Axilary flower meristem. (D) Open flower. (E) Stamen and pistil.

studies on morning glory polymorphism discussed the pollination natural selection that promotes genetic variability and, thus, different phenotypes with varied flower colours. Recent

Figure 5. Brazilian peppers. (A) Pepper fruit. (B) Open pepper fruit showing seeds, the former ovule, or seminal rudiment.

studies revealed that the mutations underlying the genetic variation in flower colours were mostly caused by transposable elements. Restinga of Guriri Beach has morning glories with purple flowers and a small population with white flowers, nearby. This provides teachers with an excellent opportunity to explain pollination events and genetic concepts, their relationship with genetic variability, karyotype, genome, genotypes and phenotypes, and transposable elements. This lesson may be split into two parts: fieldwork at Guriri Beach and one lesson in classroom with the aid of textbooks and websites on the proposed concepts. Concernign Mitosis, let´s go back to our questions: How is the development of morning glories? Where can the highest mitotic activity be found? Points of higher mitotic activity in plants are at meristems tissues. The growth of morning glories, as well as other herbaceous green plants, is a consequence of activity at the shoot apical meristem (Figure 4B) with elongation of shoots and axillary shoot meristem giving rise to leaves (Figure 4C) and flowers (Figure 4D). Flowers of morning glories can also be used for practical lessons on flower morphology, pollination and meiosis (Figure 4D-E) proposed above to *Cocus nucifera*, the coconut palm. Coconut palm and Morning Glory are interesting plant material for practical lessons in developing countries once these species have wide geographical distribution. Morning Glory is also a suggestion of plant material for explanation of Plant life cycle in Child Education. There is a DVD for small kids where morning glories are used in a germination experiment. In this experiment, children can view the lifecycle of the plant from germination to flowering [37]. Another suggestion concerns the observation of pollinator visitors in morning glories. This experience will involve the concepts of flower function, the pollination event and its consequences, the development of seed and fruits. To improve germination experiments, there is a detailed project of Sciences for Early Childhood Education at [38]. We also propose the study of plant life with germination experiments of bean, maize and pepper for all education levels Bean (*Phaseolus vulgaris*), maize (*Zea mays*) and peppers (*Capsicum* spp) are commonly found in Brazilian gastronomy (Figure 5A-B) [18]. The first event of germination is root or radicle emission. The apical zone of the root is situated in the root apical meristem. Following axial root development, axillary roots can develop by mitotic activity of the axillary region. Onions can be used in classroom to explore mitotic activity with root development. Big onions can be placed in a glass with water for a few days at room temperature. Long adventitious roots will develop inside the glass. Onion roots have large chromosomes and squash techniques can be used for their observation, as well as mitotic divisions [8]. In classroom, mitotic activity can also be demonstrated with bud growth at the stem of the potato (*Solanum tuberosum),* and leaf development in *Allium cepa*. Both biological materials show bud growth when kept in refrigerator.

2.2. The plant reproduction project in Santos Dumont city, state of Minas Gerais, Brazil

Santos Dumont (21°27′25′′S 43°33′10′′ O) is located in the state of Minas Gerais. The city was first called Palmyra until 1932 when it was named after the Brazilian aviation pioneer Alberto Santos Dumont [34], who was born in Palmyra, Brazil, in 1873 and died in 1932. The heir of a wealthy family of coffee producers, Santos Dumont dedicated himself to flying studies and experiments in Paris, France, where he spent most of his adult life [39]. Santos-Dumont designed, built and flew the first flying machine, demonstrating that controlled flight was possible [35]. This conquest of air, in particular the *Deutsch de la Meurthe* prize that he won on October 19th, 1901, in a flight around the Eiffel Tower, made him one of the most well-known figures of the world during in the early 20th Century [40]. In Brazil, he is considered the Father of Aviation and Patrone of Aeronautics. Moreover, there are several artistic monuments in his honour in Brazilian airports (Rio de Janeiro and Porto Alegre) and national parks (Iguaçu Falls). Three of the many houses where he spent his life are now historical places and museums, in Santos Dumont-MG (Brazil), Paris, Ile de France (France) and Petrópolis-RJ (Brazil).

To improve the teaching of Meiosis and Mitosis in Santos Dumont, we propose a fieldwork in the farm where Alberto Santos-Dumont was born, the Cabangu Historical Museum (Figure 6A-B) and its green area (Figure 6C). Santos Dumont is located in Serra da Mantiqueira, 850 meters above sea (Figure 6C). The climate is altitudinal tropical with dry and wet seasons [41]. The maximum annual temperature is 30°C and the minimum is 12°C [36] and heavy tropical rains are common at the end of the afternoons. The original vegetation belongs to Atlantic Forest Biome (Figure 6D) [19]. Most of the territory was deforested and replaced with coffee crops in the 19th Century. The old r crops of coffee no longer exist and the land is used for dairy cattle production (Figure 6E). *Araucaria angustifolia*, a Brazilian species of Gymnosperm is native of Santos Dumont. Despite of desforestation, *Araucaria* trees are kept in pasture (Figure 6F). They have economic importance. *Araucaria* seeds are used in local gastronomy.

The local climate favors the occurrence of Bryophytes and Pteridophytes (Figure 7A-B). Such specimens could be used to explain the diversity of land plants and the life cycle of land plants. Pteridaceae are native species (Figure 6D and Figure 7A) and can be found in local houses where they are used as ornamental plants (Figure 7B).

Finally, we select two common angiosperms of the region: the violet, one eudicot, and the banana, one monocot. Both plants cited are exotic; the first one is original from Africa, and the second one, from Asia.

Figure 6. Landscapes of Santos Dumont city, Minas Gerais state, Brazil. (A) *Cabangu* Museum. House where Alberto Santos Dumont was born. (B) Alberto Santos Dumont photograph at Cabangu Museum. (C) Cabangu Museum. View of landscape from the top of mountain. (D) Original vegetation of Santos Dumont city. Atlantic Forest. (E) Cattle for dairy production. (E) The native gymnosperm *Araucaria angustifolia*.

We propose a fieldwork at Cabangu Museum with the purpose of observing the diversity of land plants. There are many *Araucaria* specimens near the House of Alberto Santos Dumont there. There is a waterfall behind the pavilion of Aviation where many species of Pteridophytes can be found. Walking from the Aviation pavilion until the playground area there are many Bryophytes at dry season. At playground area, there is the entrance of the heliport trail. At the beginning of this trail, we can find the *samambaia-açu* (Figure 7A), an arborescent Pteridophyte, an endangered species. It is a typical element of Atlantic Forest, used in past to produce plant pots named in Portuguese language as "xaxim". Nowadays, xaxim extraction is forbidden by Brazilian law code.

After the fieldwork, the teacher may propose a practical lesson of reduction division (meiosis) and plant life cycle in the classroom. The fertile leaves of pteridophytes (Figure 7B), pollen cones of *Araucaria* (Figure 7C), violet flowers and banana flowers (or any other angiosperm flower) must be collected and transported to the classroom. Using a hand lens or a microscope, observe Pteridophyte spores, *Araucaria* pollen, and angiosperm pollen. And then ask the students the following question: how is the morphology of the three materials? In conclusion, the morphology of the three materials is similar. Why are they similar? A meiotic diploid cell gives rise to four haploid spores, as it was observed in the spores of the Pteridophyte fertile leaves. During the Pteridophyte life cycle, spores fall from fertile sporophyte leaves. The spores germinate on soil, undergo many mitosis and give rise to a gametophyte which give rise to male and female gametes by mitotic divisions. Then, another question should be asked: Gymnosperm and Angiosperm pollen grains are spores? Reviewing part explained above, at page 4, Gymnosperm and Angiosperm pollen grains are male gametophytes that developed into sporodermis, the case of ancient spore. By mitotic divisions occurred inside sporodermis, the spore germinates and gives rise to a male gametophyte, in a endosporic mode. This fact explains why spores and pollen grains are so similar. Spores gives rise to pollen grains. At sum, Reduction meiosis gives rise to spores. Spores, by mitotic divisions, develop into gametophytes.

Gametophytes generate gametes by mitotic divisions. The fusion of gametes in the female gametophyte named embryo sac gives rise to seeds. There is an embryo within the seeds that will germinate and give rise to a new sporophytic plant and the endosperm, a kind of embryonic nutrition tissue. The fusion of gametes and the seed production is sexual plant reproduction.

Violets, bananas and grass species used for cattle forage are three local examples of reproduction for vegetative propagation (Figure 8A-G). Violets form other plants by budding in their leaves. Bananas and grass are monocots with underground stems. Their stems propagate giving rise to other plants. Mitotic divisions propagate these plants. They have the same ploidy of mother plant and the same genome. They are clones. It is a kind of natural cloning.

Genetic variability is promoted by crossing-over during meiosis that generates spores, and during the fusion of gametes, in sexual reproduction. Vegetative propagation does not promote genetic variability. It is a technique used in agriculture to homogenize crop population and, thus, has some advantages. On the other hand, clone populations are susceptible to diseases. They have the genome, and, consequently, the same immune system responses. The banana propagates spread out by vegetative propagation. Most banana populations do not have seeds, or else seeds are abortive. Many studies address the genetic variability of bananas and their risk of extinction. In classroom, teachers can place violets leaves inside glasses containing water to be observed by students: root budding will occur in violet leaves. At fieldwork, in students' houses and in the farms of Santos Dumont, teachers may ind out the banana shoots from the soil and grass to show how long can be a cloning population reproduced by vegetative propagation.

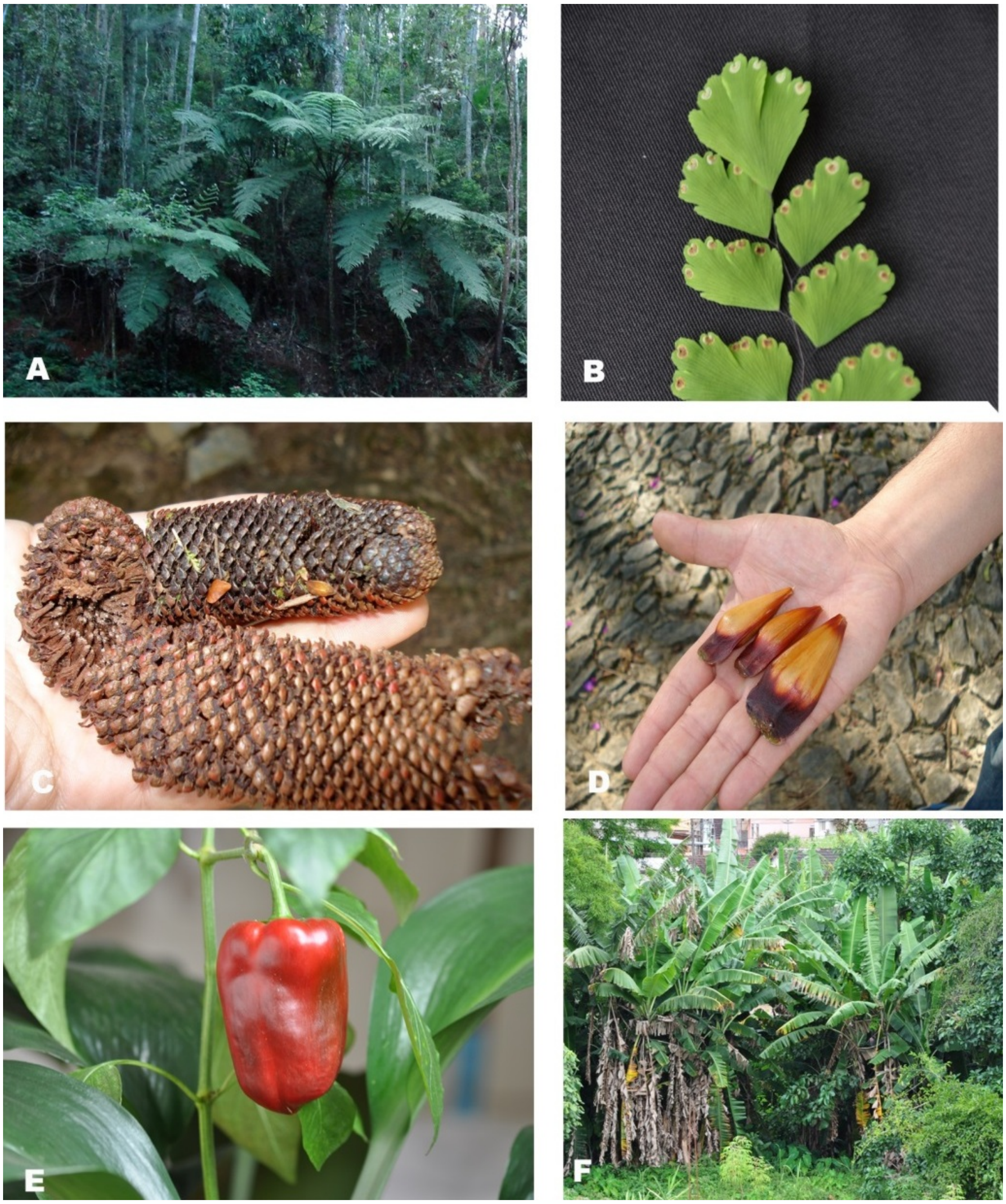

Figure 7. Diversity of vascular plants in the city of Santos Dumont, Brazil. (A) Pteridophyte. *Dicksonia* gender. called *samambaia-açu* in Brazil (B) Pteridophyte. *Adiantum* gender. called *avenca* in Brazil. (C) Gymnosperm. Pollen cones of *Araucaria angustifolia*, the *Pinheiro do Paraná*. (D) Seeds of *Araucaria angustifolia*, known as *pinhões*. (E) Angiosperm, eudicot. Pepper fruit. (F) Angiosperm monocot. Banana trees.

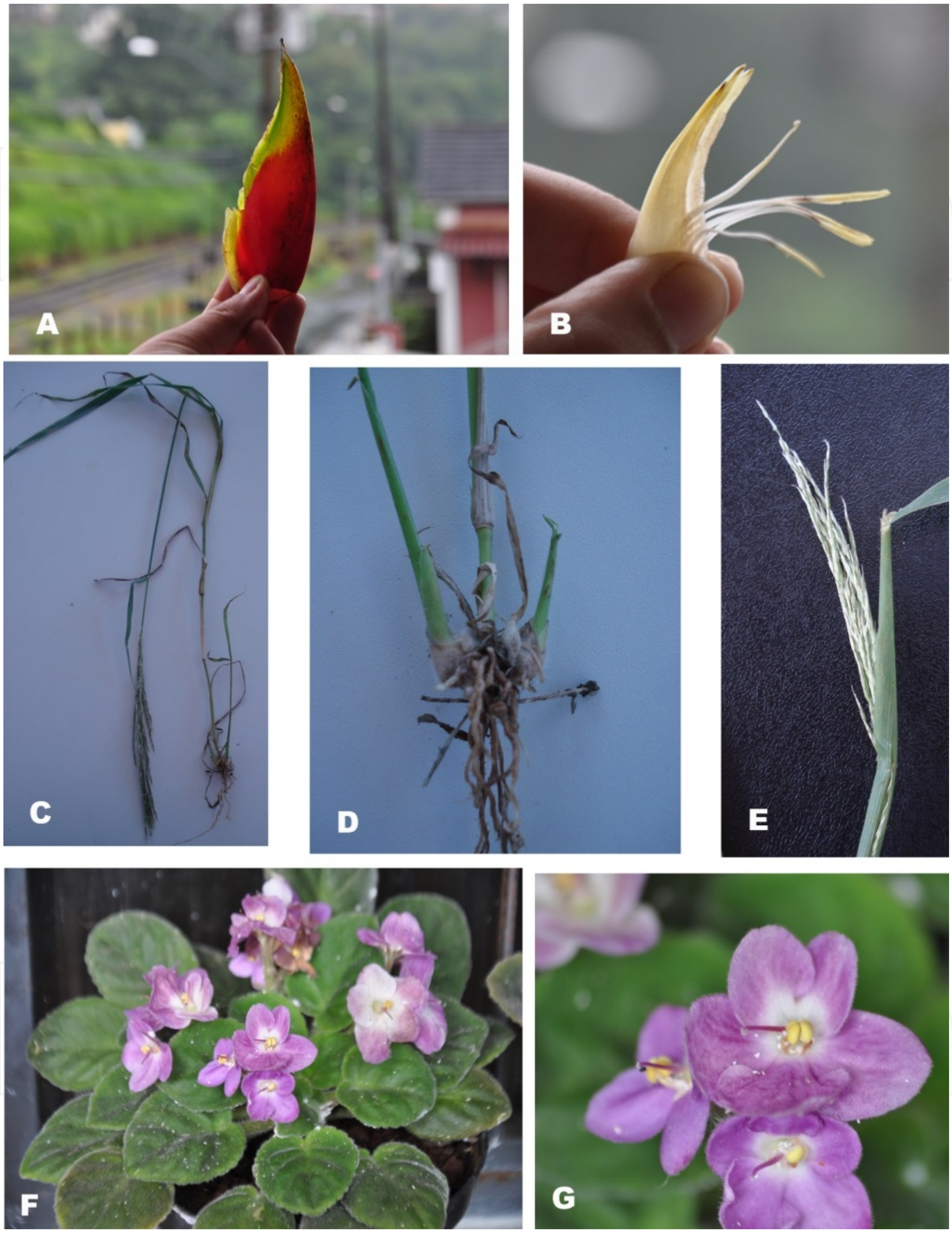

Figure 8. Eudicots and Monocots species that occur in the city of Santos Dumont, Brazil. Examples of vegetative propagation. (A) Monocot. Ornamental Banana. *Heliconia* gender. Red Bract. (B) Ornamental Banana. Flower. Stamen and pistil. (C) Monocot. Grass. Poaceae family. (D) Vegetative propagation on grass stem basis. (E) Inflorescence of grass. (F) Eudicot. Violet. Their leaves are able to do vegetative propagation. (G) Violet flower.

3. Conclusions

In the present didactic sequence of meiosis and mitosis lessons, we show different botanical materials from Brazil local environments. Dwarf coconut palm and cacao trees are two agricultural crops of São Mateus city, ES. Morning glories compound the Restinga of Guriri Beach visited by tourists throughout the year. Cocoa juice, bean, maize, peppers, potato and onion are part of the local gastronomy and are cultivated in small farms for sale and subsistence. The plants showed at the present work (coconut tree, morning glory, peppers, bananas and others) are present at beaches and crops of developing countries from Latin American, Africa, Asia and Oceania.

At the present chapter, there are many cited works at Portuguese and Spanish language, a benefic aspect to Developing Countries of Latin American, as well as the African nations of Angola, Mozambique, São Tomé and Príncipe, Equatorial Guinea, Guinea Bissau, Cape Verde islands; and the Asian areas of Macao and East Timor. On other hand, for teachers from other developing countries, we recommend the following educational references in English language [25, 52, 53, 54, 55, 56, 57, 58].

To produce coconut fruits, cocoa nts, beans and maize grains and peppers fruit plants reduction division (meiosis) is required. Meiosis generates spores that germinate and will develop into pollen grains and embryo sacs. Plants also need sexual reproduction through pollination, promoting the fusion of male and female gametes. The fusion of gametes or fecundation only occurs if the pollen tube grows through the style carrying male gametes inside.

Meiosis can be affected by temperature rise. Increase in temperature causes defective meiosis [41]. There are many consequences of defective meiosis, e.g. anomalous flowers with no pollen grains or pollen grains that fail to grow pollen tubes [41, 42]. The practical lesson of pollen tube growth [7], proposed here can show students if the plants studied bears viable pollen grains, as a result of a normal meiotic process. Based on this, plant reproduction is stressed by increase in temperature. Therefore, plants produce less seeds and fruits. Eighthy percent of the world edible plants depend on sexual reproduction for propagation [43]. That's why global warming may affect food production.

In the next 100 years, it is estimated that the global temperature will increase 1.4 to 5.8 °C [44, 45, 46]. Although the reasons behind global warming are still controversial, its adverse consequences are clear and are a matter of increasing concern worldwide [33]. Climate changes consequences include decrease in reproductive performance of plant species in natural biomes and crops [41, 44]. Studies of the effect of climate changes on plant breeding have been a trend in the international scientific scenarios of plant reproduction [45]. Studies on the effect of temperature on plant propagation were conducted with coffee, demonstrating that the global warming expected by the IPCC for our planet promotes the emergence of sterile flowers in coffee plants. The decrease in the number of flowers has reduced the number of coffee grains produced [44]. Some literature reviews cite temperature increases as one of the causes of pollen sterility [25, 41, 44, 45]. The sterile pollen grain is a structure that does not emit the pollen tube containing the male gametes, and therefore generates lower pollination and fertilization, causing a reduction in the production of fruits and seeds [25, 45]. The performance of pollen is an important factor for successful fertilization, but the high variability in pollen behavior in the same species occurs under many environmental conditions [47, 48], such as temperature, water stress, availability of nutrients, ultraviolet (UV) light quality and intensity, and CO2 concentration [47].

Likewise, seeds depend on the physiological conditions for germination, e.g. appropriate temperatures [41]. Above a certain temperature, both pollen grains and seeds are incapable of germination generating local extinctions of populations of native plants [33] or decrease in agricultural crops [42, 39].

Another type of plant reproduction is vegetative propagation, e.g., potato and cassava crops. The propagation of plants by cuttings generates clonal production [43]. Clones produced from a plant do not have the entire genetic variability from one species [49]. Sexual reproduction (natural or assisted) is needed for the preservation of the genetic variability of one species [50]. The phase of sexual reproduction in plants can be particularly vulnerable to climate changes [39].

The improvement of quality in meiosis and mitosis teaching is an opportunity to explore plant reproduction background that involves: Education for Food Security; Environmental Education and Education for Science and Biotechnology. In the last International Congress on Sexual Plant Reproduction, Food security was the central theme as the quotation below: food is required for survival; agricultural productivity expense increasing energy and water consumption; food shortages can soon be critical; a major drought; a natural disaster or war; greater climate instabilities now seem inevitable, and we know we cannot increase production by increasing energy input; global food security will demand the development and delivery of new technologies to increase food production on limited arable land, and without increasing the amount of water and fertilizers [41].

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