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# COMPARATIVE ANALYSIS OF OXYGEN EVOLUTION IN INDOOR PLANTS BASED ON ANTHRONE METHOD

A Dissertation work submitted to

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MASTER OF SCIENCE IN BOTANY

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## ABSTRACT

Houseplants are popular Indoor decorations. Light provides the energy plants need to make the food required for them to grow and flower. Lack of adequate light is the most common factor limiting the growth of plants in many areas of the home. Supplementary electric lighting is usually the easiest and least expensive way to provide enough light for plants that do not receive adequate natural light. Fluorescent tubes provide one of the best artificial light sources available for plants in the home. Photosynthesis helps the plant to get carbon from the air and adding it to its body-leaves, stems and roots. The rate of photosynthesis increases, when artificial light is used. Each molecule of carbon dioxide absorbed, adds one atom of carbon to the weight of the plant and produces one molecule of oxygen. We can therefore get an estimate of the amount of oxygen produced by weighing the plant.

## 1. INTRODUCTION

Indoor plant is a plant that is grown Indoors in places such as residences and offices. They are an ideal way to create attractive and restful settings while enhancing our sense of well-being. Much of the scenic beauty of nature has been replaced by densely populated areas that sprawl for miles from urban centres. We spend about 80% of our time indoors so that, house plants can be a satisfying hobby and can help purify the air in our homes. Indoor plants not only convert carbon dioxide to oxygen, but they also trap and absorb many pollutants many of these chemical compounds, which are released into our air through a process called "off grassing" come from everyday items present in our homes and offices.

People want to spend more time indoors, therefore the health risks due to indoor air pollution may be greater than outdoor air pollution. From past studies, it is clear that Indoor environmental quality (IEQ) can play an important role in work performance productivity and the health of building users. Using plants as design elements in working environments bring nature inside to create inviting spaces that may reduce stress and may increase the overall wellbeing, resulting in healthier work and living areas. Interaction with plants can change human attitudes, behaviours and physiological responses. Furthermore it may decrease absenteeism, increase productivity and overall satisfaction and happiness in people's lives. Even though studies with potted plants and vegetation system such as biowalls, have shown potential for absorbing potentially harmful pollutants and improve the overall comfort. At present, the use of Indoor greenery offers several benefits such as producing oxygen through photosynthesis, generating humidity and providing an aesthetical pleasure environment to work and leave as well as visual performance to Indoor environment. In active vegetation systems, air –cleaning rates have proven to be significantly higher than in passive vegetation

systems because of the use of active fan – assisted hydroponics technology that draws the air through the root rhizomes of the plants.

There is general agreement amongst scientists that plants improve the indoor environment and are useful in fighting the modern phenomenon of Sick Building Syndrome (SBS). No specific cause of SBC has been identified but poor air quality, excessive background noise and inadequate control of light and humidity are all thought to be important factors. Because plants have large surface areas and exchange gases and water with their surroundings, plants can help tackle some of these issues. Particular benefits of interior plants include **a**. Reducing carbon dioxide levels, **b**. Increasing humidity, **c**. Reducing levels of certain pollutants, such as benzene and nitrogen dioxide **d**. Reducing airborne dust levels, **e**. Keeping air temperatures down. As part of the photosynthetic and respiratory process, plants release moisture vapour, which increases humidity of the air around them. Plants release roughly 97% of the water they take in.

Studies at the Agricultural University of Norway document that using plants in interior spaces decreases the incidence of dry skin, colds, sore throats and dry coughs. Without plants, humans and animals would have less fresh air to breathe. Through the process of photosynthesis, plants release oxygen back into the atmosphere. Phytoplankton's provide most of the air we breathe. Green terrestrial plants make up the rest of atmospheric oxygen that's essential for the survival of living organisms.

During the time of climate uncertainty, it's important to realize the role plants can play to help mitigate the effects of climate change. One of the biggest environmental issues the world faces today is the burning of fossil fuels which has resulted in high levels of carbon dioxide in the atmosphere. Although climate change is a reality the world must face, society is still highly reliant on fossil fuels to supply energy needs. This is where plants come in to play. Terrestrial and oceanic plants are considered carbon sinks because of their ability to store carbon dioxide from the atmosphere. About 10% of the moisture in the atmosphere is released by plants through the process of transpiration. Plants uptake water through their roots and release water vapour through small pores on the underside of their leaves. Through this process of transpiration plants also help circulate water from the soil back into the atmosphere. Not only that, but plants help stabilize bodies of water such as rivers, lakes and streams. Plant roots improve soil stability, prevent landslides, and keep these ecosystems intact. Commonly grown indoor plants are *Aloe vera*, *Anthurium, Asparagus* Fern, Peace lily, *Peperomia*, Snake plant, Cast- Iron plant, Christmas cactus, *Dieffenbachia*, Chinese evergreen, *Dracaena*, English ivy, *Hoya* , Parlor palm, *Philodendron*, Spider plant, *Tradescantia*, *Plectranthus* etc.

**1.1 BENEFICIAL AND HARMFUL EFFECTS OF INDOOR PLANTS**

**Allergy Relief:-** Researchers found that rooms with plants have less dust and mould than rooms without any foliage. Leaves and other parts of the plants act as natural filters to catch allergens and other airborne particles. Common low light house plants like Chinese ever green or the peace lily can do the job. Violets and other plants with textured leaves might be even better trappers. Avoid plants with pollen or spores.

**Happy Blooms:-** Plants not only can brighten up our surroundings, but they can lift our mood. Employees who work in offices with plants tend to feel better about their jobs, worry less and take fewer sick days. Flowers in particular are a good pick-me-up. So liven up our rooms with blooms.

**Spider plants for moisture:-** Furnaces and air conditioners can sap humidity indoors, especially in the winter. That can raise the chances for catching a cold or the flu or make the skin itch. House plants add moisture to the air.

**Air Purifiers:-** Carpets, paint, cleaners, printer toners and inks and many other indoor objects give off pollutants called volatile organic compounds ( VOCs). They can build up in the air and irritate our eyes and

skin, worsen our asthma, or make it hard for us to breath. House plants can soak up VOCs. Some good air-scrubbers are English ivy, *Asparagus* fern and Dragon tree.

**Herbs for better digestion:-** Mint may help tamp down bloating, gas and other problems after eating. Common varieties that can be grown in containers include peppermint and spearmint.

**Relaxing Lavender:-** The fragrant purple plant has been an important herbal medicine for centuries.

***Aloe* for first aid:-** Gel from this plant is a popular home remedy. It can treat sun burns and other minor burns. It can soothe psoriasis and other skin conditions .

**Restful sleep:-** Plants take in carbon dioxide and give off oxygen. Its how they turn sunlight into food, a process called photosynthesis. Some, like Gerbera daisies keep giving off oxygen even after the sun goes down.

**Stress Relief:-** Several studies have measured people's levels of blood pleasure, heart rate and the stress hormone cortisol while they handled a tough task or were under mental stress. Being around plants has a calming effect on people.

**Sharper Focus:-** Plants may help to raise concentration on tasks and strengthen memory. Students in class rooms with three potted plants performed better on math, spelling, reading and science test than kids in class rooms without any greens.

**Faster Healing:-** A bouquet of flowers or potted foliage in the room may actually help a sick person to recover more quickly. Researchers found that people who had surgery got better faster if they had plants in their room or even a view of the nature from their window. They also tolerate pain better and need fewer medications when surrounded by greenery.

**Better Mental and Emotional Health:-** Some therapists use gardening to help treat depression, schizophrenia and other psychiatric conditions. Learning to nurture a living plant may help lower anxiety, improve attention lessen the severity of depression .Plants also might help people recovering from trauma as well as those with dementia or who live in long- term care facilities.

Most indoor plants need more frequent watering than they would if planted outdoors because the soil dries out quickly in containers. Despite the additional care required, growing plants indoor overcomes the risk of plant damage or death due to frost which is one of the disadvantages of outdoor plants. Houseplants may not get the optimum amount of light and moisture they need, they may develop moulds on the soil or a fungus or bacterial infection on their leaves – conditions that can kill the plant. The infections can release mould spores and pollutants into the air that we breathe. Plants like *Dieffenbachia*, *Caladium*, *Philodendron*, Pothos, Peace lily, Calla lily can cause stinging or burying of mouth and throat. It can also cause soft tissue to tear and become inflamed. Oleander may cause severe rash, nausea, vomiting, dizziness, heart problems and seizures. Indigestion of bulbs of Daffodils can cause mouth and throat irritation, nausea, vomiting and diarrhoea. Contact with Iby leaves can cause the skin to redden, itch and blister. Ingestion can cause fevers, difficulty in breathing, delirium and convulsions. Ingestion of the bulbs of Tulip can cause

symptoms similar to ingestion of hyacinth bulbs. Snake plant it is extremely toxic to pets. Symptoms are often mild in humans and include mouth and throat irritation, nausea and vomiting.

**Cultivation of indoor plants involve (a)** Purchasing an interior plant:-Select only those plants that appear to be free of pests. Check the under sides of foliage and the junction of leaf and stem for signs of insects or disease select plants that look sturdy, clean and well potted. Choose plants with healthy foliage. Avoid plants with yellow or chlorotic leaves, brown leaf margin, wilted foliage, spots or blotches or spindly growth. In addition avoid those with torn leaves. Plants that have new flower and leaf buds along with young growth are usually of superior quality. Optional light and watering requirements are usually included on the tag with the plant. Make sure interior can meet the requirement from natural sun light. If not artificial lighting may be required. **(b)**Transporting house plants:- The two seasons of the year that the prevailing out door conditions can cause damage to the plants are the hot summer and the cold winter months. In the summer, avoid placing plants in a car with the windows shut, because temperatures will rise and destroy the plant in a short period of time. Shade the plant from direst sun while it is in the car, this is especially true for shade loving plant.**(c)** Acclimatization :-Tropical plants grown in full sun have leaves that are structurally different from the leaves of plants grown in shade (Shade leaves). Sun leaves have fewer chloroplast and thus less chlorophyll. Their chloroplast are located deep inside the leaves and the leaves are thick, small and large in number. Shade laves have greater numbers of chloroplasts and thus more chlorophyll, are thin, large and few in number. The gardener should acclimatize plants when placing them out doors in summer by gradually increasing light intensities and reverse the process again before plants are brought indoors in the fall. For newly purchased plants grown in high - light conditions acclimatize them by initially locating them in a high-light area of home and gradually moving them to their permanent, darker location over a period of 4-8 weeks.

Plant growth is affected by light, temperature, humidity, water, nutrition and soil. **Light**:- Of all of the factors affecting plant growth in interiors, adequate light is by far the most important. Because light is needed for plants to produce food and survive light is measured in units called foot candle. One foot candle (ft-C) is the amount of light cast by a candle on a white surface one foot away in a completely dark room. **Temperature:-** Temperature is the second most important factor influencing plant growth in interior environments. People feel comfortable in the range of 72 ˚F – 82 ˚F, and interior plants can tolerate and grow well in the 58 ˚F -86 ˚F range because most indoor plants originate from tropical and subtropical areas of the world. Temperature and light are linked through the processes of photosynthesis and respiration. These processes can be thought of as the “yin and yang” of plant life- two parts of a circle. Photosynthesis builds sugars and starch, which are then broken down by respiration to provide energy for the development of new tissues and the maintenance of existing ones. High temperature speeds up respiration. If the plant is not producing sufficient sugars, then high temperatures may break down what little sugars are made, leaving little to none for growth. Maintenance takes precedence over growth; therefore, under insufficient light,

plants do not grow. If light is so low that sugars produced are insufficient for maintenance, the plant eventually dies.

**Relative Humidity:-** Relative humidity is the amount of moisture contained in the air. For interior plants, relative humidity below 20 percent is considered low, 40 percent to 50 percent is medium, and above 50 percent is high. Relative humidity is a very important factor, but it is easily overlooked. In a greenhouse, relative humidity is 50 percent or higher. Rapid transpiration and water loss may result when newly purchased plants are placed in the 10 percent to 20 percent relative humidity typical of most homes. Most indoor plants come from the tropics where high relative humidity is common. Therefore, take the following steps to help plants adjust to the low relative humidity in home. **Water Quantity:-** Learning to water is one of the most important skills in plant care. Applying too much water can suffocate plant roots and too little water causes growth to become erratic and stunted. Watering frequency will depend on the conditions under which the plants are growing. Not all plants are similar in their water requirements. For example, a croton, which prefers high light, will likely need more frequent watering compared with a succulent plant such as *Opuntia* cactus. Both have similar light needs but dissimilar water requirements.

Improper watering causes many problems. Containers with saucers may cause an excessive build-up of soluble salts (from the applied fertilizer). High levels of soluble salts can cause damage to plant roots and a decline in growth. Discard any water that had drained in the saucer after irrigation, and apply large quantities of water to the soil to leach the accumulated soluble salts. If the soil is still moist, no further water is needed. Water devices or water meters are also available to simplify watering. **Water Quality:-** The quality of the irrigation water is an issue with plants that are susceptible to fluorine and chlorine, such as Corn Plant (*Dracaena*),Ti Plant (*Cordyline*), Peacock Plant (*Maranta*), and Rattlesnake Plant (*Calathea*). Alleviate this problem by letting the water stand for several days — so that some chlorine and fluorine will be released from it — before applying the water to the plants. Move susceptible plants away from the edge of the pool to prevent water splashes from reaching the foliage. Do not use susceptible plants around enclosed pools. In general, plants with long linear leaves (such as the Spider Plant) are more susceptible to fluorine. Many indoor gardeners have the same problem with fertilizer that they have with water — they want to give their plants too much. Danger from over fertilization occurs because any fertilizer used, whether in liquid, powder, or tablet form, will dissolve in soil water and will form salts in the water. When overfertilized, the water in the soil becomes so salty that it “burns” the plant’s roots by removing water from them.Excess soluble salts accumulate as a whitish crust on the surface of the growing medium and/or near the rim of the container.

**Before feeding plants, consider the following:**

• Plant type: Some plants are heavy feeders (e.g., *Ficus* species), while others need little or no additional fertilizer for months (e.g., succulents).

• Volume of soil: The growing medium that is present—smaller pots require less fertilizer compared with larger pots because they contain less soil.

• **Light intensity:** The higher the light levels, the more nutrients needed for plant growth. The secret to fertilizing plants indoors is to apply small amounts of fertilizer as the plant grows. Without new growth, the plant has a limited need for more fertilizer. During the winter, when light levels are low, a plant's need for fertilizer reduces. During the summer, when light levels increase and the plant is actively growing, its need for fertilizer increases.If the overall plant colour becomes lighter green, fertilize every two weeks. If the new growth is dark green but the leaves are small and internodes seem longer than on the older growth, decrease the fertilizer rate.

The growing medium provides anchorage, water, sand and minerals. When repotting plants, make sure that the new mix is well drained and aerated, holds water and nutrients well, and is within the right pH range (5.0-6.5). A good potting mix provides ample amounts of oxygen to the root system. Most professional mixes are good to use. Some plants require special mixes, e.g., bromeliads, orchids, and African violets. Either purchase these mixes or prepare your own. Below are some formulas that can be used to prepare a homemade potting mix.

The following potting mix will grow acceptable flowering plants in most homes for most gardeners: Add 2 to 3 ounces of 20 percent superphosphate and ¾ ounce of either bone meal or dolomitic limestone (by weight) to 4 gallons of potting mix. After sterilizing the soil, add 3 tablespoons of a 6-6-6 or similarly balanced fertilizer to every 4 gallons (½ bushel) of mix. Add a minor element formulation according to the manufacturer's recommendations. Although most foliage plants will grow satisfactorily in the growing mix recommended for flowering house plants, they will grow better if the mix contains a higher percentage of organic matter. Add 2 to 3 ounces (dry weight) of dolomitic limestone to 4 gallons (½ bushel) of mix. For fluoride-sensitive plants, adjust the pH so it is no lower than pH 6.5. Superphosphate contains enough fluoride to cause foliar burn on sensitive plants. After sterilizing the soil, add 3 tablespoons of a 6-6-6 or another fertilizer such as 5-10-5 to each ½ bushel. Plastic-coated fertilizers also can be used; most of them require about 2 ounces per ½ bushel. Add a minor element formulation to the potting mix per the manufacturer's recommendation.

Bromeliads are plants from Central and South America, which are either epiphytic (they grow on tree branches or in the crotches of trees) or terrestrial (they grow in the ground). Although most of the bromeliads can be grown successfully in foliage plant mixes, most grow better in specially designed soil mixes. Any mix for bromeliads must be well aerated and drained. Add 2 ounces of dolomitic limestone to 4 gallons (½ bushel) of soil mix and a minor element mix. Dissolve 1 ounce of 10-10-10 water-soluble fertilizer in 3 gallons of water. Use this solution after repotting and again monthly when watering. Also, add enough water to fill the vase formed by the overlapping leaf bases.

Orchids have a great deal in common with bromeliads because they also grow on trees as epiphytes and on the ground as terrestrials. A mix for orchids should have excellent drainage and aeration, too. Some soil mixes that can be used are: Add 1 ounce (dry weight) of dolomitic limestone per 4 gallons (½ bushel) of soil mix. Do not add fertilizer to the mix. After the plants are potted, add ¼ ounce of liquid 10-10-10 with minor elements per gallon of water and fertilize once every 6 weeks (if the plants are growing in Osmunda fern fibres). If plants are growing in fir bark, use a liquid 30-10-10 with minor elements every 6 weeks instead of a 10-10-10 fertilizer. Cacti and other succulents grow best in a well drained and aerated soil.

Ferns grow well in most recommended mixes that have a high proportion of organic matter with good soil aeration and drainage characteristics. Use any of the suggested foliage plant mixes. However, most ferns kept indoors grow better in the following mix: Add 2 ounces (dry weight) of dolomitic limestone to each ½ bushel (4 gallons) of soil mix and ½ ounce of either bone meal or 20% superphosphate. After pasteurizing the soil mix, add minor elements to the mix. Add 1 tablespoon of a 6-6-6 or similarly balanced fertilizer to each ½ bushel of soil mix.

Sterilization reduces the number of diseased organisms and weeds present in the soil. First, mix the soil with an equal portion of vermiculite or peat moss (otherwise, the soil will become very hard). Next, moisten the mixture and place it in the oven. Allow it to “bake” at 180 ˚F - 200 ˚F for 1 hour. Once the soil cools, it is ready to use. To treat soil in the microwave, first mix the portion with an equal amount of vermiculite or peat moss and moisten. Place the mixture in a plastic bag. Next, consult the manufacturer’s manual to determine the amount of time and power level needed to heat the quantity of soil to about 180 ˚F (most portions of soil will generally require about 10 to 15 minutes). Insert a probe into the soil and make sure it has heated to 180 ˚F -200 ˚F. Allow the soil to cool before using it or storing it for future use.

The style, shape, and size of the container should complement the plants grown. Small containers are best for small slow-growing plants, while fast growing plants are better suited for large containers. Containers can be made from a wide range of materials — terra cotta, clay, plastic, or ceramic. Terra cotta pots, made of fired clay, are some of the most popular choices, with designs ranging from plain to ornate. Plants perform very well in terra cotta pots, as the porous surface allows good air exchange between the plant roots and the environment. Other clay containers (not considered terra cotta) range from gray to brown in colour, depending on the clay used. Clay pots can be glazed or unglazed. The glazed pots restrict air exchange but offer more design choices. Unglazed pots evaporate water faster and plants in them may need more frequent watering. Disadvantages of clay containers include their weight (especially large pots) and the chance they will chip or break.

Constructed of materials such as polyethylene, polyurethane, recycled plastic, and fiberglass, plastic pots have evolved from very simple to quite elaborate. They have the advantage of being lightweight as well as chip- and break-resistant. Air exchange and water evaporation rates are generally lower in plastic containers compared with clay containers. Plants in plastic pots will not dry out as quickly as plants in clay pots, increasing the danger of over-watering. In general, there are two types of containers — ones with drainage holes and ones without. Do not allow plants in containers with drainage holes to sit in saucers filled with water, unless the plant is suspended above the water level by a layer of rocks. To avoid salt build up, leach the soil once a month by applying a gallon of water to every cubic foot of potting medium; after a few hours, follow with ½ gallon of water. If the potting medium contains garden soil, apply 5 gallons of water per every cubic foot of growing medium.

There are many types of containers from which to choose. A good container should be large enough to provide room for the root ball and root growth, have sufficient room above the medium (soil) line for proper watering, provide bottom or side drainage, and be attractive. Containers may be made from ceramics, plastic, fiberglass, wood, aluminum, copper, brass, and other materials. Unglazed porous and glazed clay pots with drainage holes are widely used. Unglazed clay pots absorb and lose moisture through their walls. Although easily broken, unglazed clay pots provide excellent aeration for plant roots and are considered by some to be the ideal type of container for a plant. Ceramic pots are usually glazed on the outside, and sometimes on the inside. If a container does not have drainage holes, then one can place a conventional growing container (with plant and drainage holes) inside the one without holes. Make sure to place some stones or some other structure on the bottom of the hole-less container to keep the conventional container about an inch above the bottom of the hole-less container. This will allow irrigation water to drain from the conventional container. Unless one has a very small plant, avoid using small novelty containers, as they have little room for medium and roots, and are largely ornamental.

Plastic and fiberglass containers are usually quite light and easy to handle. They have become popular in recent years because they are relatively inexpensive and often quite attractive in shape and colour. Plastic pots are easy to clean and sterilize for reuse, and, because they are not porous, they need less frequent watering and tend to accumulate fewer salts.

There are many commercially available potting soils, also called potting media, potting mixes, or soil-less substrates. Potting soils are generally composed of organic components such as peat moss or pine bark. However, there is a great amount of variation in potting soil characteristics. A potting soil is composed of solids, air spaces (voids), and water. Potting soils not only differ in organic component composition, but also in the percentages of solids, air, and water. These differences are important to know about since some potting soils are too “heavy,” that is, they hold too much water and not enough air following irrigation. Some are too “light,” that is, they hold too much air and not enough water following irrigation. The ideal container substrate is one that provides an appropriate amount of water and air following irrigation. Most potting soil

packaging does not show water and air data, thus, you will have to experiment with different potting soils to find one the meets the needs of your plants. Of course, the type of plant will dictate the type of potting soil selected. Adding a layer of gravel or shards to the bottom of the pot allows for less potting soil in the container compared to a container without additions. Less potting soil means less water, nutrients, and space for roots. Another common recommendation is to add sand to a potting mix. This practice decreases drainage and air space. Thus, sand is not a recommended potting soil amendment.

Artificial mixtures can be prepared with a minimum of difficulty. Most mixes contain a combination of organic matter, such as sphagnum peat moss or ground pine bark, and inorganic material, like washed sand, vermiculite, or perlite. Materials commonly used for indoor plants are mixtures consisting of sphagnum peat moss, vermiculite, and perlite. Sphagnum peat moss is readily available baled or bagged. Such materials as Michigan peat, peat humus, and native peat are usually too decomposed to provide necessary structural and drainage characteristics and should be avoided. Most sphagnum peat moss is acid in reaction, with a pH ranging from 4.0 to 5.0. It usually has a high water-holding capacity and a very low fertility level.

Vermiculite is a sterile, lightweight mica product. When mica is heated to approximately 1800°F, its plate-like structure expands. Vermiculite will hold large quantities of air, water, and nutrients needed for plant growth. Its pH is usually in the 6.5 to 7.2 range. Vermiculite is available in four particle sizes. For horticultural mixes, sizes 2 or 3 are generally used. If at all possible, the larger-sized particles should be used, since they give much better soil aeration. Vermiculite is available under a variety of trade names. Vermiculite collapses with time and loses its positive characteristics. Avoid insulation grade vermiculite. Perlite is a sterile material produced by heating volcanic rock to approximately 1800°F. The result is a very lightweight, porous material that is white. Its principal value in potting soils is aeration. It does not hold water and nutrients as well as vermiculite. The pH is usually between 7.0 and 7.5. Perlite can cause fluoride burn on some foliage plants, usually on the tips of the leaves. The burn progresses from the tip up into the leaf. Fluoride burns can be prevented by adding 11/2 times the recommended amount of lime when mixing the medium. Potting mixes with garden loam (mineral soil) should be avoided, as loam is highly variable from shovelful to shovelful. Mineral soil also does not drain well in a container. Mineral soil must be pasteurized in the kitchen oven (not microwave). The process of pasteurizing your own soil can be difficult and smelly.

Most foliage and flowering plants can be successfully grown in the media mixes previously highlighted, with some modifications in certain cases. Specific nutrient needs can be readily met with soluble or slow-release fertilizers as recommended on the product packages. Plants such as African violets, cacti and succulents, orchids, etc., that are more sensitive to specific proportions of media components, can easily be grown in commercial mixes specially prepared for these plants.

Actively growing indoor plants need repotting from time to time. How often a plant needs to be repotted depends upon how fast it is growing. In general, foliage plants require repotting when their roots have filled the pot and are growing out the bottom holes. Most plants requiring repotting can be easily removed from their container if it is held upside-down while knocking the lip of the container sharply on the edge of a table. Hold the hand over the medium, straddling the main plant stem between the fore and middle fingers. If the plant has become root-bound, then tease out/unwind or cut the large roots that circle the root ball. If the old potting soil surface has accumulated salts (appears white), the top layer should be removed. To repot, select a new container that is about a third larger than the old pot. Add enough soil to the bottom of the pot so that the root ball will be slightly above the desired height (about two inches below the top of the container). Watering the soil will cause the soil to settle and the root ball will be at the desired height. Centre the root ball in the middle of the new pot. Fill soil around the sides between the root ball and pot. Add soil to just above the original level on the root ball (again, the soil will settle when irrigated). Gently firm the soil with your fingers. After watering and settling, the soil level should be sufficiently below the top of the pot (about one to two inches). This gap allows one to water to be applied without spilling over the sides of the container.

Keeping plants clean and neat through regular grooming improves the appearance of plants and reduces the incidence of insects and disease problems. Remove all spent flowers, dying leaves, and dead branches. Keep leaves dust-free by washing plants with warm water and mild true soap – avoid detergent, which can cause damage to leaves and buds. Cover the pot to prevent soap from entering the soil. If tips of leaves become brown and dry, trim them off neatly with sharp scissors. Humidity can be increased by placing plants on trays lined with pebbles and filled with water to within one half inch of the base of the pot. If heated with wood, keep a pot of water on the stove.

Training includes a number of minor care activities that distinguish the beginner from the more experienced indoor plant grower. For example, pinching is the removal of one inch or less of the stem tip and leaf growth, just above a node, to stimulate new growth below the tip and encourage lateral branching. Pinching can be a one-time or continuous activity, depending on the need and the desires of the plant owner. Frequent pinching will keep a plant compact, but well filled-out. Pruning includes removal of plant material other than terminal shoot tips. Sometimes an entire branch or section of a plant should be removed for the sake of appearance. Disbudding is the removal of certain flower buds either to obtain larger blooms from a few choice buds or to prevent flowering of a very young plant (or recently rooted cutting) that should not bear the physical drain of flowering early. Trellising is an attractive way to display vines such as Ivies and *Hoya*, as well as *Philodendron* and *Syngonium*.

Most plants should not be watered until the soil feels somewhat dry. There are commercially available water meters to determine the soil moisture content of container and garden-grown plants. However, the old tried and true method of sticking your finger into the soil is the most reliable. With

experience you can lift a container and judge its water content and thus its need for water. Apply enough water to thoroughly saturate the potting soil. In most cases, the soil is saturated when water drains from the bottom of the pot. Placing a saucer under the container eliminates water damaging the surface where the container sits. In some cases, such as a root-bound plant, water will drain from a container before the potting soil is saturated. In this case, fill the saucer with water and allow it to be absorbed into the container. Make sure to empty the saucer once water is no longer being absorbed. An indoor plant's need for fertilizer is related to its growth rate. A plant that produces a lot of leaves and stems will need more fertilizer that a slower-growing plant. There are two main methods of fertilizing a container-grown plant. One can buy a soluble fertilizer, either in liquid or dry form, and apply at the recommended rate. For slow-growing plants, reduce the recommended fertilizer amount and frequency by about one-half. For fast-growing plants, apply the recommended amount at the recommended frequency

The second method of fertilizing is the use of slow release (controlled-release) fertilizers. Slow-release fertilizers supply small amounts of nutrients over an extended period of time. In most cases, nutrients of slow-release fertilizers are in small beads (prills) that should be applied uniformly to the surface of the potting soil. Follow the manufacturer's recommendations for the amount and frequency of application. Adjustment to the recommended rate can be made for slow growing plants as previously suggested for the soluble fertilizer. The length of time a slow-release fertilizer supplies nutrients depends on the product; some products can last for 9 months. Some potting soils contain slow-release fertilizers, which satisfies a plant's nutritional requirements for several months. Most potting soils supply little trace (minor) elements such as iron, manganese, zinc, and copper; therefore, it is important to use a fertilizer that contains these trace elements.

When the weather warms in the spring, houseplants can be put outside. Don't be too anxious to move your houseplants outdoors, as even a good chill can knock the leaves off tender plants. To avoid cold temperature damage, find out the minimum temperature your particular indoor plants can tolerate. Make sure the outdoor light conditions are compatible with those of your plants. Plants can get "sunburned" if you move them from an average indoor light exposure to a full sun exposure of the outdoors. Avoid windy locations, since such exposure can tear leaves and accelerate water loss and increase watering frequency. Houseplants that have been outside all summer should be allowed to make a fairly slow transition to indoor conditions. Quick changes in environment can result in yellow foliage and leaf drop. To avoid injury, bring plants indoors before temperatures dip below 55° F, do not wait for frost warnings. Check for insect pests before you move the plants; it is easier to get rid of pests while plants are still outside. Rinse the plants' leaves, and soak pots in water for 15 to 20 minutes to drown most soil-dwelling pests.

Very few plants stay pest-free forever. Pest insects are more likely to be encountered on indoor plants than diseases because the interior environment rarely offers favourable conditions for foliar diseases to develop. However, when plants are grown under stressful conditions (such as low light and excess water), soil-borne pathogens often develop. Scales are 1/8 inch to 1/3 inch long with various colours, depending upon the species. The three main families of scales are armoured (the body covering can be separated from the body), soft (the body covering cannot be separated from the body), and Mealybugs. Scales suck plant juices from leaves and stems, causing stunting, leaf discoloration, and death of the tissue. As a result of their feeding, sticky "honeydew" (digested plant sap) is excreted (the exception is armoured scales). Honeydew offers a growing medium for a fungus called Sooty mold, which, when present, can detract from the plant appearance and block light from reaching the leaf surface. Scales are usually inconspicuous; by the time infestation is noticed, the population is usually very large.

Mealybugs are soft bodied, 1/5 inch to 1/3 inch long, and covered by white, waxy filaments, giving them a white, cottony appearance. Insects are frequently found on the new growth at the stem apex, where they suck plant juices, causing leaf wilting and abscission. Some species of Mealybugs appear first on the undersides of leaves. Mealybugs excrete sticky honeydew, which attracts Sooty mold. Aphids are soft bodied, pear shaped, 1/25 inch to 1/8 inch long, and are usually green in colour (but may be pink, blue, brown, yellow, or black). Aphids reside on new growth or on the underside of young leaves, where they suck plant juices, causing deformed, curled growth of new leaves, buds, and flowers. Aphids also excrete honeydew. Aphids are usually wingless but develop winged forms when colonies become too large.

Spider mites are the second most common pest problem on houseplants. The adult females are about 1/50 inch long, hardly visible with the unaided eye. Mites feed on the undersides of young leaves. Infected areas are greyish or yellow speckled. Webs form as a means of dispersal. Spider mites thrive in hot and dry conditions. Thrips, while uncommon on houseplants, predominantly feed on plants in patios and other outdoor areas. Thrips are small, slender, 1/25 inch to 1/12 inch long, and tan, black, or brown in colour, with lighter markings. Adults and larvae feed on shoot tips, flowers, and leaves by sucking sap and cell contents. Injured tissue has a whitish or silver-flecked appearance due to the light reflecting from the empty cell walls of the dead cells.

Another potential problem in the indoor garden is the occurrence of various diseases. For a disease to happen, three factors must be present: (1) a susceptible plant, (2) a viable pathogen, and (3) a favourable environment. Because the home has very low relative humidity and water is often applied directly to the growing medium (thus keeping the foliage dry), chances of a foliar disease occurring are minimal. Leaf spots are the most common problem, but they are usually not caused by a disease. For example, leaf scalds occur when water droplets on the leaves act as lenses and focus excessive light in one spot, bleaching the chlorophyll and killing the underlying tissue. Spots with patterns are signs of a disease, including a tan centre,

dark borders, and/or light-coloured borders called “halos.” Dark structures may be present on the underside; these contain a means of dispersal called spores.

Most importantly, avoid causing stress to plants. A healthy plant is much more likely to fight off a disease than a stressed one. Soil-borne pathogens are commonly found on stressed plants. Soil-borne pathogens affect plants at or below the soil line; disease development is usually well underway before symptoms are noted on plant parts aboveground. Soil-borne diseases commonly occur when the growing medium is kept excessively moist and fertility levels are high. Low light and over-watering create favourable environments for soil-borne diseases indoors.

Quarantining New Plants Some plants are characteristic hosts for problematic pests. For example, palms are especially prone to mites, and Hindu rope (*Hoya)* plants are especially prone to mealy bugs. One can easily miss an incipient infestation on a recently purchased plant. Thus, any new plant that is known to be especially prone to a difficult to control pest should be quarantined for at least a few weeks to make sure plant is not infested. To quarantine a plant, place it in a room without plants that is not adjacent to a room with plants (pests can be transported by drafts). This separation will allow us to determine a pest problem without infesting the rest of your indoor plants.

## 1.2 ECOLOGICAL IMPORTANCE OF INDOOR PLANTS

### 1.2.1 Improve air quality

There is general agreement amongst scientists that plants improve the indoor environment and are useful in fighting the modern phenomenon of Sick Building Syndrome (SBS). No specific cause of SBC has been identified but poor air quality, excessive background noise and inadequate control of light and humidity are all thought to be important factors. Because plants have large surface areas and exchange gases and water with their surroundings, plants can help tackle some of these issues.

### Particular benefits of interior plants include.

a. Reducing carbon dioxide levels

b. Increasing humidity

c. Reducing levels of certain pollutants, such as benzene and nitrogen dioxide

d. Reducing airborne dust levels.

e. Keeping air temperatures down.

### 1.2.2. Release Water

As part of the photosynthetic and respiratory process, plants release moisture vapour, which increases humidity of the air around them. Plants release roughly 97% of the water they take in. Studies at the Agricultural University of Norway document that using plants in interior spaces decreases the incidence of dry skin, colds, sore throats and dry coughs.

### 1.2.3. Provide Oxygen

Without plants, humans and animals would have less fresh air to breathe. Through the process of photosynthesis, plants release oxygen back into the atmosphere. Phytoplanktons provide most of the air we breathe. Green terrestrial plants make up the rest of atmospheric oxygen that's essential for the survival of living organisms.

### 1.2.4. Carbon sinks

During this time of climate uncertainty, it's important to realize the role plants can play to help mitigate the effects of climate change. One of the biggest environmental issues the world faces today is the burning of fossil fuels which has resulted in high levels of carbon dioxide in the atmosphere. Although climate change is a reality the world must face, society is still highly reliant on fossil fuels to supply energy needs. This is where plants come in to play. Terrestrial and oceanic plants are considered carbon sinks because of their ability to store carbon dioxide from the atmosphere.

### 1.2.5. Water Cycle Regulation

About 10% of the moisture in the atmosphere is released by plants through the process of transpiration. Plants uptake water through their roots and release water vapour through small pores on the underside of their leaves. Through this process of transpiration plants also help circulate water from the soil back into the atmosphere. Not only that, but plants help stabilize bodies of water such as rivers, lakes and streams. Plant roots improve soil stability, prevent landslides, and keep these ecosystems intact.

## 1.3. TAXONOMY OF SELECTED PLANTS

***a. Aglaonema costatum* N. E. Br.**

**Kingdom : Plantae**
**Division :Angiospermae**
**Class :Monocotyledonae**
**Series :Nudiflorae**
**Family :Araceae**
**Genus :Aglaonema**

*Aglaonema costatum*, also called as Fox's Aglaoema spotted ever green, is a species of the Aglaonema genus .This species was described by Nicholas Edward Brown in 1892. *Aglaonema costatum* is found in Continental southeast Asia from Langkawi Island to Wietnam.

### *b. Aglaonema commutatum* Schott

**Kingdom : Plantae**
**Division : Angiospermae**
**Class : Monocotyledonae**
**Series : Nudiflorae**
**Family : Araceae**
**Genus : Aglaonema**

*Aglaonema commutatum* is commonly called Chinese evergreen that resembles Dieffenbachia in appearance. It is commonly found in Philippines, North-eastern Celebs etc. Plants of the genus are native to humid, shady tropical forest habitat.

These are evergreen perennials with stems growing erect or decumbent and creeping. Stems that grow along the ground may root at the nodes. There is generally a crown of wide leaf blades which in wild species are often variegated with silver and green colouration. The inflorescence bears unisexual flowers in a spadix with a short zone of female flowers near the base and wider zone of male flowers nearer the tip. The fruit is a fleshy berry that ripens red. The fruit is a thin layer covering one large seed.

Aglaonema, helps to improve the air quality of your indoor spaces with the ability to filter indoor air pollutants and toxins. Furthermore, this gorgeous leafy indoor plant emits Oxygen, which assists in increasing productivity and enriching health and wellbeing both in living and working spaces

### *c. Cordyline fruticosa* (L.) A. Chev

**Kingdom : Plantae**

**Division : Angiospermae**

**Class : Monocotyledonae**

**Series : Coronariae**

**Family : Liliaceae**

**Genus : Cordyline**

Its original native distribution is un-known. But it is believed to be native to the region from Bangladesh, to main land Southeast Asia, South China, Taiwan, Island South East Asia, New Guinea and Northern Australia. It has the highest morphological diversity in New Guinea and is believed to have been extensively cultivated there.

Cordyline is a palm like plant growing up to three to four metre (9.8 to 13.1 Ft) tall with an attractive fan – like and spirally arranged duster of broadly elongated leaves at the tip of the slender trunk. It has numerous colour variations, ranging from plants with red leaves to green and variegated forms. It is woody plant with leaves 30 to 60 cm (12 to 24 inch) (rarely 75 cm or 30 inch) long and 5 to 10 cm (2.0 to 3.9 inch) wide at the top of the woody stem. It produces 40 to 60 cm (16 to 24 inch) long panicles of small scented yellowish to red flowers that mature into red berries. These berries have been described as “dry and fleshy“. Traditionally the plant has been found to represent itself as a treatment option for various disorders, such as fever, headache, diarrhoea, coughs, haemoptysis, small pox, madness,skin eruptions. It is also used in joint pains, rheumatic bone pains and swelling pain which are originated from sprains. The leaves and stem of this medical plant was also used for abortion.

***d. Kalanchoe Pinnata* (Lam.) Pers.**

**Kingdom : Plantae**

**Division : Angiospermae**

**Class : Dicotyledonae**

**Subclass : Polypetalae**

**Series : Disciflorae**

**Order : Celastrales**

**Family : Crassulaceae**

**Genus : Kalanchoe**

*Kalanchoe pinnata*, formerly known as *Bryophyllum pinnatum*, also known as the air plant, cathedral bells, life plant, miracle leaf and Goethe plant is a succulent plant native to Madagascar. It is found in parts of Asia, Australia, Newzealand, West Indies, Philippines, Macaronesia, Mascarenes, Brazil, the Galapagos islands, Melanesia, Polynesia and Hawaii. It is a succulent, perennial plant about 1m (39 inch) tall, with fleshy cylindrical stems and young growth of reddish tinge, which can be found in flower throughout most of the year. It is distinctive for the profusion of miniature plantlets that form on the margins of its leaves.

The leaves of this species are thick, fleshy,elliptical in shape, curved with a crenate or serrated margin often reddish. Simple at the base of the stem, the leaves are imparipinnate at the top, 10 to 30 cm (4 to 12 inch) long, with 3 to 5 pairs of fleshy limb lobes. The leaves are remarkable for their ability to produce bulbils. At their margin, between the teeth, adventitious buds appear, which produce roots, stems and leafs. When the plantlets fall to the ground, their root and can become larger plants. This is a fairly common trait in the section Bryophyllum. The fruits are follicles (10 to 15 mm) which are found in the persistent calyx and corolla.

The terminal inflorescence is a panicle, with many pendent, red-orange flowers. The calyx is formed of long tube, red at the base, veined with yellowish green (or green spotted with reddish brown) with four very small triangular lobes at the end. The tubular corolla, with a pronounced constriction separating the sub spherical part of the ovoid part, is terminated by four lobes which reaches 5 cm (2.0 in) in length. It is yellowish in colour with red-purple streaks. The eight stamens, each about 4 cm (1.6 in) long, are in two whorls, welded on the corolla. The ovary has four carpels, slightly fused together in the centre, with slender styles.

The leaves are astringent, antiseptic, diuretic and febrifuge. They are also used as a counterirritant against poisonous snake bites. The juice is used in the treatment of bilious diarrhoea, dysentery, cholera, acute nephritis, lithiasis, and phthisis. The fresh leaves are pounded and then applied to burns, used as poultices on boils and ulcers; as a treatment for headaches, as a remedy for ringworm, or are placed on the soles of the feet in order to stop haemorrhages. The dried leaves can be as a powder on bad ulcers. The juice is applied topically in the treatment of ear ache, conjunctivitis and ophthalmia.

### *e. Dracaena trifasciata* (Prain) Mabb.

**Kingdom : Plantae**
**Division : Angiospermae**
**Class : Monocotyledonae**
**Series : Coronariae**
**Family : Lilaceae**
**Genus : Dracaena**

It is most commonly known as the snake plant, Saint George sword, mother-in-law's tongue and viper's bowstring hemp. *Dracaena trifasciata* is a species of flowering plant native to tropical West Africa from Nigeria east to the Congo. *Dracaena trifasciata* is commonly called mother-in-law's tongue, Saint George's sword or snake plant , because of the shape and sharp margins of its leaves .It is also known as the Viper's bowstring hemp, because it is one of the sources for plant fibres used to make bowstrings. It is an evergreen perennial plant forming dense strands, spreading way of its creeping rhizome which is sometimes above ground, sometimes underground. Its stiff leaves grow vertically from basal rosette. Mature dark green with light grey –green cross banding and usually range from 70-9- cm.s long and 5-6 cm.s wide, though it can reach heights above 2 m in optimal condition. The flowers are greenish-white and are on 18-inch spikes in spring. Dracaena is one of the most effective houseplants in air purification. It helps to remove formaldehyde, benzene, trichloroethylene and carbon dioxide. These are chemicals linked with several health problems among them headaches, respiratory problems, anaemia, marrow disease, kidney disease among others.

***f. Aloe vera* (L.) Burm.f.**

Kingdom : Plantae

Division : Angiospermae

Class : Monocotyledonae

Series : Coronariae

Family : Liliaceae

Genus : Aloe

*Aloe vera* is considered to be native only to the southeast Arabian peninsula in the Al-Hajar mountains in the north eastern Oman. However, it has been widely cultivated around the world, and has become naturalised in North Africa, as well as Sudan and neighbouring countries, along with the Canary Islands, Cape Verde, and Madeira islands. It is a stem less or very short stemmed plant growing to 60-100 cm (24-39in) tall, spreading by offsets. The leaves are thick and fleshy, green to grey green, with some varieties showing whit flecks on their upper and lower stem surfaces. The margin of the leaf is serrated and has small white teeth. The flowers are produced in summer on a spike up to 90cm (35 in) tall each flower being pendulous, with a yellow tubular corolla 2-3 cm long. Like other Aloe species, *Aloe vera* forms arbuscular mycorrhiza, a symbiosis that allows the plant better access to mineral nutrients in soil.

## INDOOR PLANTS
## Photographs

***1.Aglaonema costatum***

***2. Aglaonema commutatum***

***3.Cordyline fruticosa***

***4. Kalanchoe pinnata***

***5.Dracaena trifasciata***

***6. Aloe vera***

## 2. AIMS AND OBJECTIVES

The aim of the study is to find out the rate of Oxygen evolution in Indoor plants based on Anthrone method.

The objectives of the current study are as follows:

- Collection of literature related with indoor plants
- Collection of different indoor plants from different localities.
- Identification with the help of suitable literature and experts.
- Providing different light sources for indoor plants.
- Estimate the total carbohydrate content in six indoor plants based on Anthrone method.
- To make a comparative analysis of Oxygen evolution capacity in Indoor plants.

## 3. REVIEW OF LITERATURE

The importance of Indoor Foliage plants and Human Emotions to Indoor Foliage plant (HyeSook Jang, GyungMeeGim, Sun-Jin Jeong, Jae Soon Kim,2018) was conducted on eight different indoor foliage plants that can be easily grown and of which leaves have ornamental values were selected .The correlation between environmental factors such as fine dust , stress and depression has been growing. In this regard, the results of this study that identified the effects of plants including stress relief, emotional relaxation and psychological stability support the usefulness of indoor foliage plants. Review of the effects of plants on indoor environments (AhuAydogan, RayanCerone, 2020 ) suggests that well – established technologies can remove only certain toxins from indoor environments . Utilization of the soil microorganisms in the root zone of the plant is vital to achieve high toxic remediation. In addition to cleaning the air, plants in Indoor environments offer psychological, physiological and cognitive benefits .This paper provides an overview of the effects of plants on indoor air quality on the broader benefits of incorporating vegetation into indoor environments.

Indoor plants, place quality and human behaviour (Randy Lee Genereux, 1982) investigated the role of environmental variables in person-environment interactions. It explains that the place with plants increased pleasure mood response, decreased arousal level facilitated persistence at a puzzle tasks and worsened quality of performance on a proofreading task. Role of plants in removing Indoor air pollutants (AS Pipal, A Kumar, R Jan, A Taneja, 2012) reviewed the researches of a number of authors which reveals the absorption and metabolism of NO2, NH3 and SO2 by various kinds of plants . Indoor potted – plants can remove air – borne contaminants such as volatile organic compounds (VOCs), CO, CO2, Benzene, Formaldehyde, Trichloroethylene , NOx over 300 of which have been identified in indoor air.

Effectiveness of Indoor plant to reduce Co2 in Indoor environment

(MohdMahathir Suhaimi, A M Leman, AziziAfandi, Azian Hariri, Ahmad Fu'adIddris,S N MohdDzulkifli and ParanGani, 2017) were performed on seven indoor plants to reduce CO2 with different light level. Each plant was put into the chamber individually with CO2 concentration approximately 1000 ppm, and light intensities set at 300 and 700 lux while temperature was fixed. It reveals that light intensity play an important role for the plant to absorb CO2 effectively. All the plants absorbed more Co2 when light intensity is increased.

Psychological and physiological benefits of plants in the Indoor Environment: A Mini and In-Depth View (Lee Bak Yeo, 2021) examine the relationship of plants with indoor environment and identifies how they influence people , psychologically and physiologically and how promote indoor environment quality . This paper provides notable insights to landscape architects, gardeners and even interior designers to choose the right species of plant in an Indoor environment, to maximise their psychological and physiological benefits at the same time, improving Indoor environment quality. Foliage plants for improving Indoor air quality (BC Wolverton, 1988) has produced a new concept in indoor air quality improvement. Both plant leaves and roots are utilized in removing trace levels of toxic vapours from inside tightly sealed buildings. Low levels of chemicals such as carbon monoxide and formaldehyde can be removed from indoor environments by plant leaves alone , while higher concentrations of numerous toxic chemicals can be removed by filtering indoor air through the plant roots surrounded by activated carbon. Lighting Indoor house plants (David Herbert Trinklein, 2002) reminds that lack of adequate light is the most common factors limiting the growth of plants in many areas of the home. Supplementary electric lighting is usually the easiest and least expensive way to provide enough light for plants that do not receive adequate natural light. Effectiveness of Indoor plants for passive removal of Indoor ozone (Omd A Abbass, David J Sailor, Elliott T Gall, 2017) determines ozone deposition velocities (vd) for five common indoor plants. The transient values was calculated, using measured leaf areas for each plant. The indoor plants tested had moderate ozone deposition velocity values ranging from about 0.5 to 5.5 m/h depending on period of time exposed to ozone. The ozone removal effectiveness ranges from 0.9% to 9% for leaf surface area to room volume ratio of 0.06$\bar{m}^{l}$ when accounting for values of air exchange and background loss typical of a residential environment.

Growing Indoor plants with success (Svoboda Vlkadimirova Pennisi, 2009) describes the factors affecting plant growth like Light, Temperature, Relative Humidity, Water, Nutrition and Soil. Indoor plants not only convert carbon dioxide to oxygen, but they also trap and absorb many pollutants so they are an ideal way to create attractive and restful settings while enhancing our sense of wellbeing. Minimum light requirements for Indoor gardening of lettuce (Maria Paz, Paul R Fisher, Celina Gomez, 2019) evaluated growth, accumulation of key phytochemical constituents and aesthetic quality of red- leaf lettuce grown from transplant to a harvest stage in an indoor environment using different light sources (LED vs fluorescent lamps) and light quantities (from 1.6 to 9.7 mol $\bar{m}^{2}$ d). As DLT increased, plants had more growth, higher aesthetic quality and superior nutritional quality. It affirms that a minimum DLI (Daily Light Integrals) of 6.5 to 9.7 mol $\bar{m}^{2}$ $\bar{d}^{l}$ is recommended when designing Indoor gardening systems for red-leaf lettuce plants. Seeing the lights for leafy greens in Indoor vertical farming ( Chui Engwong, Zhi Wei Norman Teo, LishaShen, Hao Yu, 2020) provide an overview of the current indoor vertical farming systems, the mechanisms of light perception by photoreceptors, and the effects of LED spectra or intensity on growth and phytonutrient accumulation of leafy greens. Lighting quality and quantity can be manipulated to improve yield and

phytonutrient contents of leafy greens. Blue wavelength has a more prominent positive impact on phytonutrient accumulation than red, little is known for other wavelengths.

Growth light provision for Indoor greenery: A case study (ChunLiang Tan, NycikHien Wong, PuayYok Tan, Mirza Ismail, Ling Yan Wee, 2017) was conducted to quantify the impact of indoor greenery on the ambient environment as well as its impact on growth light provision. Field measurement in a building with extensive indoor greenery and growth chamber study were conducted to measure the whole plant light compensation plant (LCP ) of two species of plants used in the indoor greenery design . Since electricity consumption is highly correlated with whole -plant ZCP, significant savings in energy can be achieved by (1) determining actual lighting requirements for each plant and (2) measuring day light availability onsite before installing greenery in the indoor environment. The effects of light – emitting diode lighting on green house plant growth and quality (Margit Olle, Akvile Virsile, 2013) gives an overview about LED light effects on photosynthetic indices, growth, yield and nutritional value in green vegetables and tomato, cucumber, sweet pepper transplants. The sole LED lighting, applied in closed growth chambers as well as combinations of LED wavelengths with conventional light sources fluorescent and high pressure sodium lamp light and natural illumination in greenhouses are overviewed. Red and blue light are basal in the lighting spectra for green vegetables and tomato, cucumber and pepper transplants; far red light, important for photo morphogenetic processes in plants also results in growth promotion.

Shade Tolerant Flowering plants: Adaptations and Horticultural implications (Lorraine Middleton, 2001) reviews the adaptations of plants that grow naturally in shady and low-light environments which lead to greater chances of success in horticulture. The adaptations include thinner leaves with a relatively higher chlorophyll content per unit leaf volume, lens- shaped epidermal cells , a red abaxial cell layer, camouflaging strategies, distichous phyllotaxis and flowers and fruit that are inconspicuous in size and colour. Many of the adaptations of plants have a pronounced effect on their ornamental value and can therefore also determine their differing possible horticultural uses.

Estimation of carbohydrates in plant extract by anthrone( E.W YEMM and A.J Willis, 1954) has been investigated with a range of naturally occurring hexoses and pentoses . The green colour is produced when carbohydrates are heated with anthrone in acid solution. The course of colour production varies widely with different sugars and test is much less sensitive for pentoses than for hexoses. Spectrophotometric determination of total carbohydrate (B R Hewitt, 1958)by anthrone reagent was used to measure the carbohydrate content of the plant material. Here a blank containing only the plant material and sulphuric acid were used to measure the carbohydrate content of the plant material at different stages of growth and when the cells contained different amounts of chlorophyll. The colour reactions given by anthrone reagent was used for the determination of carbohydrates by a spectrophotometric method.

# 4. MATERIALS AND METHODS

## 4.1. Collection of Indoor Plants:-

Six Indoor Plants belonging to different families were collected during the course of this study.

***Aglaonema costatum*** **N. E. Br.**

***Aglaonema commutatum*** **Schott**

***Cordyline fruticosa*** **(L.) A. Chev**

***Kalanchoe pinnata*** **(Lam.) Pers.**

***Dracaena trifasciata*** **( Prain ) Mabb.**

***Aloe vera*** **(L.) Burm.f.**

The collected plants were identified referring standard books and flora. Data relating to morphological and taxonomical characteristics were collected. Medicinal properties of the taxa were noted from standard literature including books, journals, periodicals and news papers. Methods used for the study are discussed below.

## 4.2. Treatment of Indoor Plants with different light sources.

Selected indoor plants are treated with different light sources. First they are exposed to natural light by doors and windows kept open during day time. Then they are provided with artificial light, fluorescent tube during night.

## 4.3. Testing of Oxygen evolution capacity by Anthrone method:-

Plants perform Photosynthesis in the presence of light. The amount of Carbohydrates produced can be estimated by Anthrone Method. The amount of Carbohydrate formed is an indirect measure of oxygen evolution during Photosynthesis.

## Anthrone Method:

Principle:- Carbohydrates are first hydrolysed into simple sugars using dilute hydrochloric acid. In hot acidic medium glucose is dehydrated to hydroxymethylfurfural . This compound forms with anthrone a green coloured product with an absorption maximum at 630nm.

## Materials:-

2.5 N-HCl

Anthrone Reagent: Dissolve 200 mg anthrone in 100ml of ice cold 95% H2SO4. Prepare fresh before use.

Standard Glucose: Stock – Dissolve 100mg in100ml water. Working Standard – 10ml of stock diluted to 100ml with distilled water. Store refrigerated after adding a few drops of toluene.

## Procedure:-

a.Weigh 0.5 g of the sample into a boiling tube.

b. Hydrolyse by keeping it in a boiling water bath for three hours with 5 ml of 2.5 N-Hcl and cool to room temperature.

c. Neutralise it with solid sodium carbonate until the effervescence ceases.

d. Make up the volume to 50ml and centrifuge.

e. Collect the supernatant and take 1 ml aliquotes for analysis.

f. Prepare the standards by taking 0, 0.2, 0.4, 0.6, 0.8 and 1ml of the working standard.` 0' serves as blank.

g. Make up the volume to 1ml in all the tubes including the sample tubes by adding distilled water.

h. Then add 4ml of anthrone reagent.

i. Heat for eight minutes in a boiling water bath.

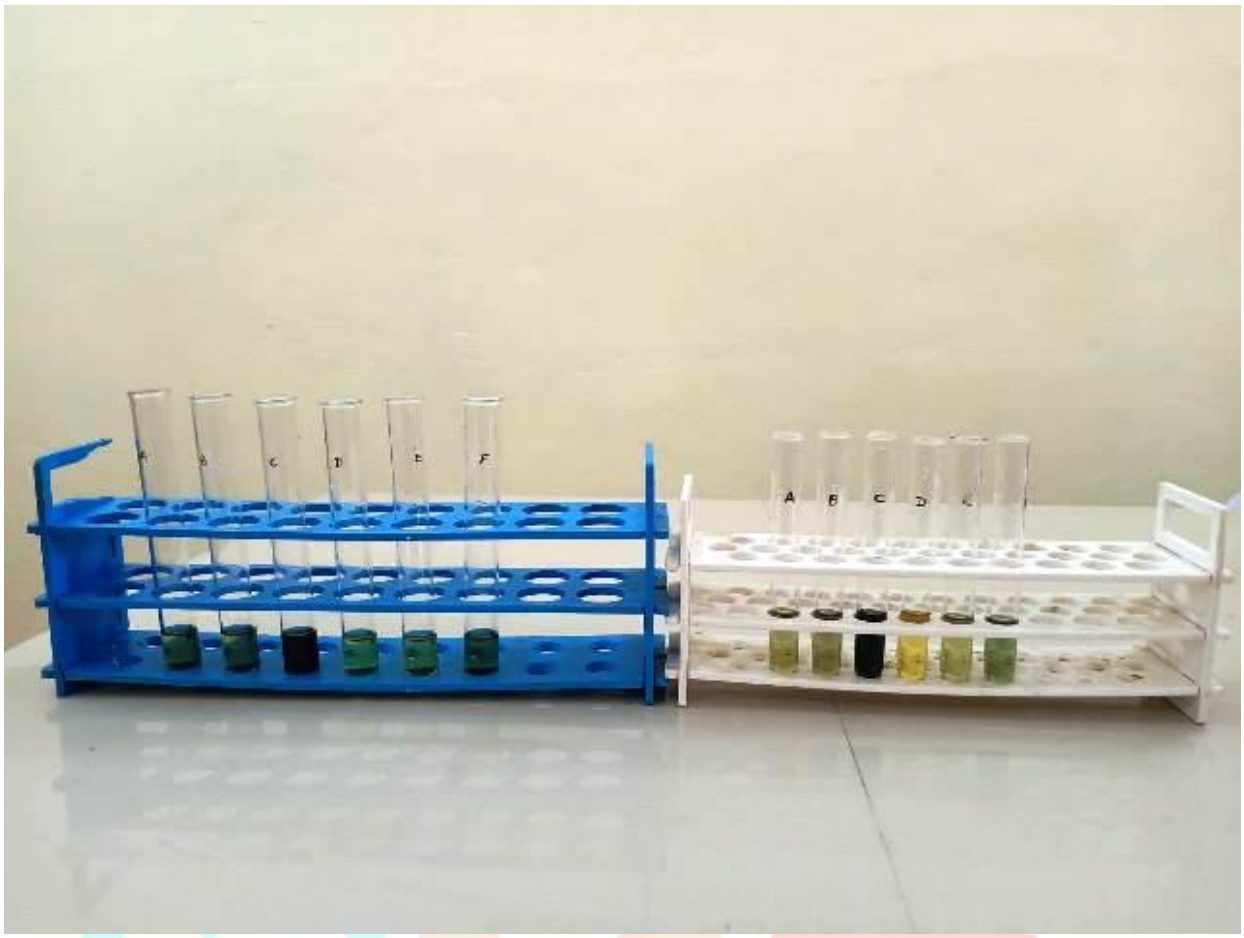
j. Cool rapidly and read the green to dark green colour at 630nm.

k. Draw a standard graph by plotting concentration of the standard on the X - axis versus absorbance on the Y- axis.

l. From the graph calculate the amount of carbohydrate present in the sample tube.

## 4.4. Comparative Analysis:-

Photosynthesis in Indoor Plants under natural light and artificial light were compared using Anthrone Test. When artificial light was provided the rate of Photosynthesis increased and thereby the oxygen evolved will be high.



## 5. RESULT

### Natural Light

### Standard

| Concentration of std | O D of Std | Factor [Con.of std/O D of std] |
|---|---|---|
| 0.2 | 0.184 | 20/0.184 = 108.6 |
| 0.4 | 0.390 | 40/0.390 = 102.5 |
| 0.6 | 0.552 | 60/0.552 = 108.7 |
| 0.8 | 0.686 | 80/0.686 = 116.6 |
| 1.0 | 0.988 | 100/0.988 = 101.2 |

Factor = 105

***Aglaonema costatum***

105 × 0.152×50 / 0.5 =1.596mg
Amount of Carbohydrate produced in 1 gm of leaf - 1.596×2 = 3.192mg

***Aglaonema commutatum***

105 × 0.449×50 / 0.5 = 4.7145mg
Amount of Carbohydrate produced in 1 gm of leaf - 4.714 ×2 = 9.428 mg

***Cordyline fruticosa***

105 × 1.217 × 50 / 0.5 = 12.778 mg
Amount of Carbohydrate produced in 1 gm of leaf - 12.778×2 = 25.556 mg

***Dracaena trifasciata***

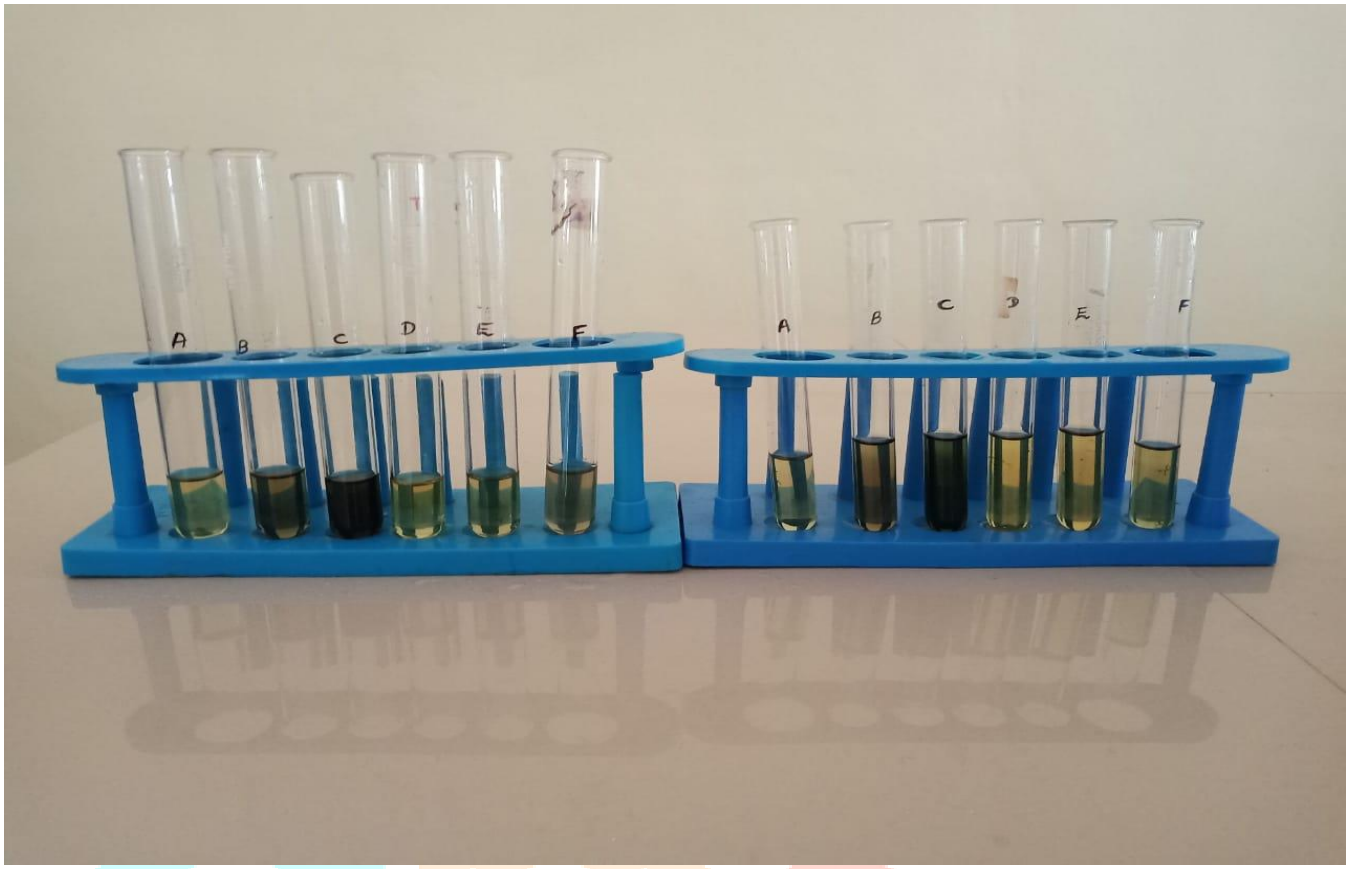
105 × 0.050 × 50/ 0.5 = 0.525 mg
Amount of Carbohydrate produced in 1 gm of leaf - 0.525 × 2 =1.05mg

***Kalanchoe pinnata***

105 ×0.168 ×50/ 0.5 = 1.764 mg
Amount of Carbohydrate produced in1gm of leaf - 1.764 ×2 = 3.528 mg

***Aloe vera***

105 × 0.325 ×50 / 0.5 =3.412mg
Amount of Carbohydrate produced in 1 gm of leaf = 3.412 × 2 = 6.824 mg




**When Natural Light is Provided**

When natural light alone was provided, *Cordyline fruticosa* produced more amount of carbohydrates (25.6 mg carbohydrate per gm of leaf) and *Dracaena trifasciata* the least (1.0).So, *Cordyline fruticosa* shows the highest rate of photosynthesis when compared to others. The rate of carbohydrate formation in other plants in descending order are :*Aglaonema commuatum* (9.4 mg), *Aloe vera* (6.8), *Kalanchoe pinnata* (6.8 mg) and *Aglaonema costatum* (3.1 mg).

**Natural light + Artificial light**

**Standard**

| Concentration of std | OD of std | Factor[con. of std/OD of std] |
|---|---|---|
| 0.2 | 0.176 | 20/0.176 =113.6 |
| 0.4 | 0.395 | 40 /0.395 =101.2 |
| 0.6 | 0.576 | 60 /0.576 =104.1 |
| 0.8 | 0.760 | 80 /0.760 =105.2 |
| 1.0 | 0.880 | 100/ 0.880 =113.6 |

Factor =110

***Aglaonema costatum***

110 × 0.307 ×50 / 0.5 =3.377 mg
Amount of Carbohydrate produced in 1 gm of leaf – 3.377 ×2 = 6.754mg

***Aglaonema commutatum***

110 × 0.574 ×50 / 0.5 = 6.314 mg
Amount of Carbohydrate produced in 1 gm of leaf – 6.314 ×2 = 12.628 mg

***Cordyline fruticosa***

110 × 1.678 × 50 / 0.5 = 18.458 mg
Amount of Carbohydrate produced in 1 gm of leaf – 18.458 ×2 = 36.916 mg

***Dracaena trifasciata***

105 ×0.131 ×50/ 0.5 = 1.441 mg
Amount of Carbohydrate produced in1gm of leaf - 1.441 ×2 = 2.882 mg

***Kalanchoe pinnata***

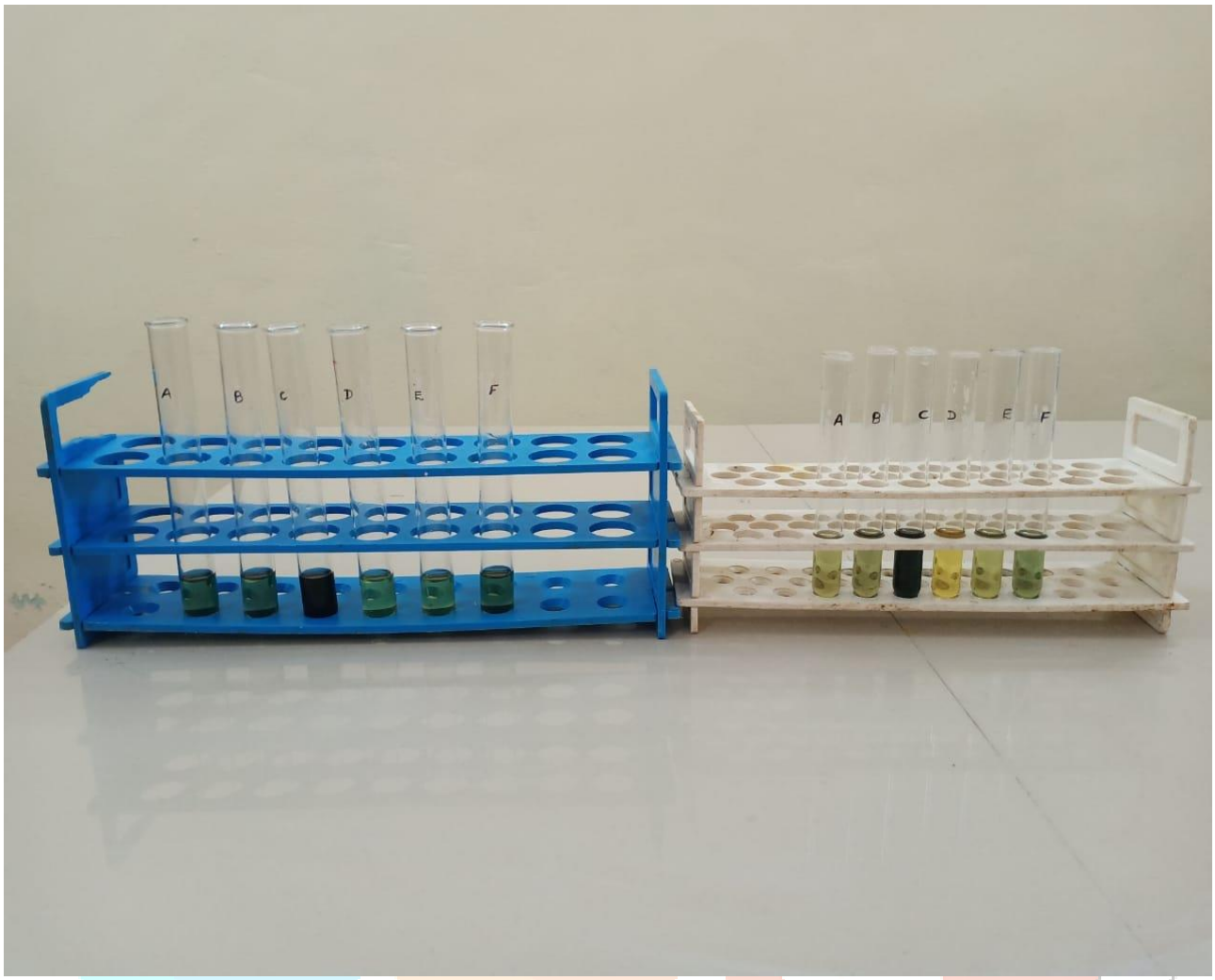
110 × 0.212 × 50/ 0.5 = 2.332 mg
Amount of Carbohydrate produced in 1 gm of leaf – 2.332 × 2 = 4.664mg

***Dracaena trifasciata***

105 ×0.131 ×50/ 0.5 = 1.441 mg
Amount of Carbohydrate produced in1gm of leaf - 1.441 ×2 = 2.882 mg

***Aloe vera***

110 × 0.384 ×50 / 0.5 =4.224 mg
Amount of Carbohydrate produced in 1 gm of leaf -4.224 × 2 = 8.448 mg

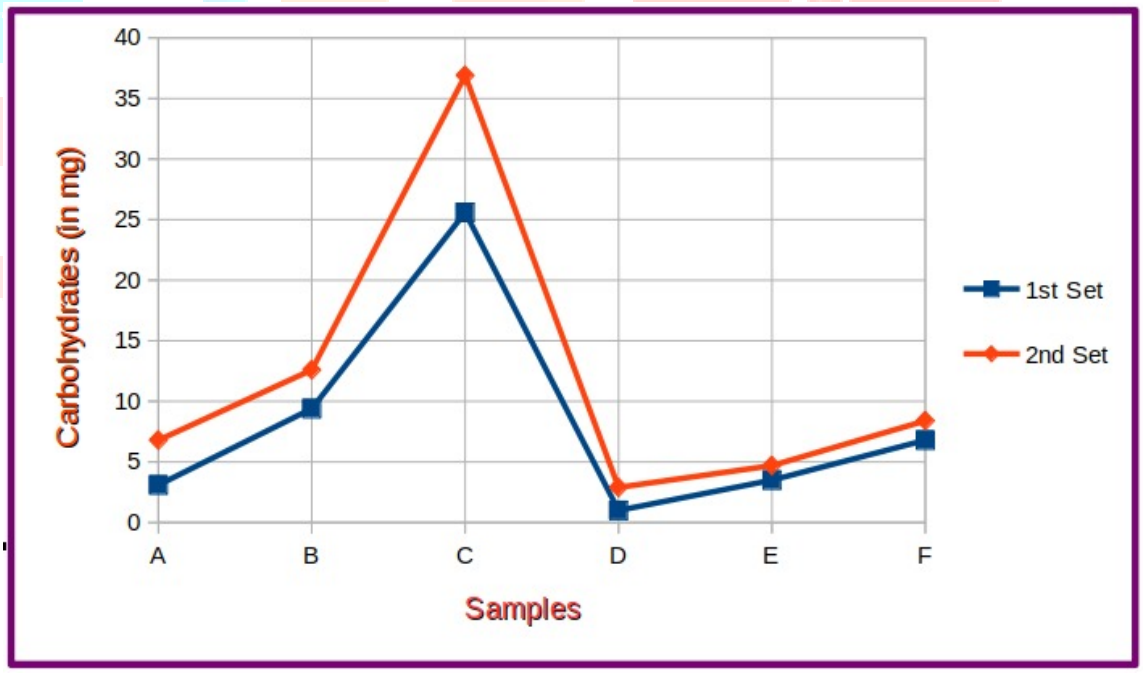



**When Both Natural and Artificial Light are Provided**

Next set of readings were taken by irradiating indoor plants with artificial light besides natural light. In this case also, *Cordyline fruticosa* shows highest rate of photosynthesis (36.9 mg) and *Dracaena trifasciata* the least (2.9 mg).Others: *Aglaonema commutatum* (12.6 mg), *Aloe vera* (8.4 mg), *Aglaonema costatum* (6.8 mg) and *Kalanchoe pinnata* (4.7 mg).

**Comparative Analysis based on Anthrone Method**

| Samples | Natural Light (in mg) | Natural and Artificial Light (in mg) |
|---|---|---|
| ***Aglaonema costatum (A )*** | 3.1 | 6.8 |
| ***Aglaonema commutatum(B)*** | 9.4 | 12.6 |
| ***Cordyline fruticosa (C )*** | 25.6 | 36.9 |
| ***Dracaena trifasciata (D )*** | 1.0 | 2.9 |
| ***Kalanchoe pinnata (E )*** | 3.5 | 4.7 |
| ***Aloe vera ( F )*** | 6.8 | 8.4 |




We have measured the rate of carbohydrate produced in the presence of natural light and artificial light. When artificial light was provided along with natural light, the rate of carbohydrate formation increased. A significant increase were observed in the cases of *Cordyline fruticosa* (25.6 mg to 36.9 mg), *Aglaonema commutatum* (9.4 mg to 12.6 mg) and *Aglaonema costatum* (3.1 mg to 6.8 mg).

## 6. DISCUSSION

The study includes a comparative analysis of oxygen evolution in six different indoor plants. For examining oxygen evolution we have estimated the carbohydrate formed by anthrone method. The amount of carbohydrate formed is an indirect measure of evolved oxygen. Since, rate of formation of carbohydrate is greater in ***`Cordyline fruticosa'*** than other. So oxygen evolution is higher in ***Cordyline fruticosa***.They have a vigorous root system which help in the easier absorption of water and minerals. Thick stems

**Joseph** conduct water and minerals efficiently to the leaves where they can be converted into usable products by photosynthesis. The glossy upper surface of the leaf indicates that it has more chloroplasts (in palisade cells) which help in photosynthesis. Also the thick cuticle layer on the upper surface of the leaf makes it shiny. After the stomata open and carbon dioxide enters the leaf, the cuticle protect the mesophyll layer, which contains the photosynthetic cells that receive and process the carbon dioxide to manufacture glucose. They have broad leaves and so have a large surface area allowing them to absorb more light and contain openings called stomata to allow carbon dioxide into the leaf and oxygen out. Not only have that leaves had a thin shape means a short distance for CO2 to diffuse in and oxygen to diffuse out easily. The upper surface of leaf is greener than its lower surface because of the presence of mesophyll cells which contains chlorophyll. Due to more amount of chlorophyll on the upper surface more light energy is trapped hence more amount light of green wavelength is reflected.

Among the six plants selected, oxygen evolution is least in ***Dracaena trifasciata***. It is a CAM plant that means they show Crassulacean Acid Metabolism. Their stomata will be closed during day– time. By closing stomata during the day, gas exchange does not occur. It limits the total amount of photosynthesis the plant is capable of during sunlight hours. They do not have extensive root system to absorb water and minerals from the soil. The leaves grow in cluster from rhizomes. So all the leaves do not receive adequate amount of sunlight and hence the photosynthesis is decreased. No prominent midrib and veinlets can be seen. The decrease in vein thickness can be related to decrease in photosynthesis.

## 7. CONCLUSION

People have been bringing plants into their homes for thousands of years. Indoor plants are a wonderful addition to a home. We all are aware of benefits provided by plants especially the indoor plants. Physically, they contribute to cleaner, healthier air for us to breathe, thus improving our well-being and comfort. They make our surroundings more pleasant, and they make us feel calmer. Interior plants have been associated with reduced stress, increased pain, tolerance and improved productivity in people. Some of these attractive looking plants can be extremely dangerous as they are highly toxic. Although indoor plants are known to remove certain Volatile Organic Compounds (VOCs), they also emit a variety of VOCs which have adverse short and long term health effects on humans. The six plants selected for study have a number of benefits. *Cordyline fruticosa* consumes large amount of CO2 from the atmosphere. It releases large amount of O2, as a byproduct of photosynthesis. *Aglaonema sp*. emit oxygen, which assists in increasing productivity and enriching health and well-being. They act as filters of indoor air pollutants and toxins. *Kalanchoe pinnata* also releases oxygen to the atmosphere. But they are not as efficient as *Cordyline fruticosa* and *Aglaonema sp*. *Aloe vera* and *Dracaena trifasciata* takes in CO2 and releases oxygen at night. In *Dracaena trifasciata* the oxygen release is comparatively lesser because its leaves grow vertically from a basal rosette. Both purify air by removing harmful chemicals like formaldehyde and benzene.

## 8. SUMMARY

Six Indoor plants belonging to different families were collected: *Aglaonema costatam , Aglaonema commutatum , cordyline fruticosa, Kalanchoe pinnata , Dracaena trifasciata* and *Aloe vera*. *Aglaonema* sp.s are evergreen perennial and slow growing herbs with stem growing erect or decumbent and a crown of leaf blades. *Cordylinefruticosa* is a woody plant growing up to 3 to 4 metre tall with an attractive fan –like and spirally arranged cluster of broadly elongated leaves. *Dracaena trifasciata* is an evergreen perennial plant whose leaves grow vertically from a basal rosette. The plant exchanges oxygen and carbon dioxide using Crassulacean Acid Metabolism. *Kalanchoe pinnata* is a succulent perennial plant with fleshy stems and leaves. *Aloe vera* is an evergreen succulent perennial which is stemless and has thick, fleshy leaves. Selected indoor plants are treated with different light sources. First they are exposed to natural light and then provided with artificial light. Indoor plants perform photosynthesis and produce carbohydrates and releases oxygen. The amount of carbohydrates formed can be estimated by Anthrone Method. It is an indirect measure of oxygen evolution during photosynthesis. Photosynthesis in indoor

plants under natural and artificial light were compared using Anthrone Test. Among six plants the rate of carbohydrate formation is higher in *Cordyline fruticosa* . So highest amount of oxygen will be released by *Cordyline fruticosa* and the least by *Dracaena trifasciata* . Oxygen evolution progressively decrease from *Aglaonema* sp.s , Aloe vera to *kalanchoe pinnata*.

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