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Mitigating the Impact of Climate Change on Vegetable Farming: An Evaluation of Artificial Planting Technique

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Abstract: *A worldwide issue, global warming results from human activity changing the climate and having a negative impact on people, animals, and plants. However, in terms of plants, the sun provides the primary elements required for healthy growth of photosynthetic plants, which use the energy from the sun to create food for themselves. Light with varying wavelengths that serve distinct functions during the photosynthetic process are the essential elements that are captured from the sun. The wavelength of the ultraviolet (UV) component of sunlight varies, characterized as UV A (315–400 nm) and UV B (280–315 nm) are the primary components that must be precisely proportioned for a profitable farming. In order to lessen the impact of climate change on vegetable farming, this research suggests integrating light emitting diodes (LEDs) in artificial growing machines as well as planned irrigation systems as an alternate source of ultraviolet sunshine. To provide the necessary UV light combination, blue, red and white colours of light-emitting diodes (LEDs) were combined using diffusers. The red, blue, and white LEDs were used for two weeks, each 12 hours a day, to influence the plants growth, with red promoting photosynthesis, white improving it, and blue encouraging stem and leaf growth. An Arduino Uno was used to program both the hardware and software components of the automated growth machine. The outcome of planting varied vegetable plant under LED lights was contrasted with the outcome of planting the identical set of plants under direct sunlight. After the first and second weeks of planting, the plants' performances under both circumstances are comparable.*

Keywords: *Global Warming, Photosynthetic Process, Artificial, Arduino Uno, Vegetable Plant, Light Combination.*

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1. INTRODUCTION

Global warming is a global problem brought on by human activity that alters the temperature and has an adverse effect on people, animals, and plants. The areas with the least amount of human activity are most affected by climate change. Global warming is especially detrimental to the agricultural industry. Africa is the region most impacted by the unpredictability of the weather and climate, with devastating droughts and floods as well as increase in illnesses and vectors. Even though Africa only makes up 2–3% of global carbon emissions, the continent is hardest hit by the effects of climate change [1-4]. Temperature increase brought on by the atmospheric emission of Green House Gases (GHG) is the cause of global warming and significant climatic changes brought about by global warming have been seen [5], and their impact is being felt throughout Africa in all human endeavours. Every nation is looking for a solution to lessen the effects of global warming, even if these effects differ from place to place. Africa has the greatest effects yet makes the least contribution, yet climate change has detrimental effects on the environment, human health, water resources, forestry, tourism, economy, and agriculture [6]. Due to the impact of global warming on the ecosystem required to support agricultural operations, agricultural outputs is most impacted in Africa [7, 2, 3]. Weather and climate still have a big influence on agricultural productivity, even if the Green Revolution and improved technology have led to considerable advancements in agricultural production. Africa is already experiencing a significant increase in temperature; in addition, there are currently floods and droughts due to a 40–60% decrease in the amount of water present in the huge basins of Niger, Lake Chad, and Senegal. Due to their reliance on rainfall for agricultural purposes, the majority of Africa is susceptible to the negative effects of climate change [7, 1-3], which include altered vegetation patterns and drought. As a result, it is estimated that 42% of West Africa's range area and livestock are gradually disappearing [8]. In order to lessen the effects of climate change on vegetable growth in Nigeria, this study aims to create an artificial habitat for vegetable development. Although plants use a process known as photosynthesis to create organic matter from inorganic material by absorbing light from the sun. This photosynthetic process allows plants to grow food.

Between 1 and 100 mm is the range of light that the sun emits into space, and it contains visible, infrared, and ultraviolet radiations. Colours in the visible light spectrum are wavelength dependent because the range is closer to the ultraviolet spectrum, the higher wavelength appears red, and the lower wavelength is either blue or violet. Light-emitting diodes (LEDs) are an excellent source of light for plant growth. The light spectrum has long been tailored for plant growth using the quantum yield of photosynthesis [9, 10]. The reason red and blue lights are so important is because they are essential to the photosynthetic activity of leaves [11, 12]. In addition to leaf photosynthesis, plants have a large number of photoreceptors that allow them to sense specific wavelengths that regulate their growth. Ultra-violet (UV) radiation is a crucial component of solar radiation. UV light is one kind of electromagnetic radiation that is produced by sunshine. The UV light in question is composed of three distinct classes with varying wavelengths: UVA ranges from 315 to 400 nm, UV B from 315 to 280 nm, and UVC from 280 to 100 nm. UV A and UV B are essential for life even though UV C is not typically found on the earth's surface because of the kind of environment that exists there [13].

The activity of the UVB photoreceptor UVR8 has led to numerous investigations on plant responses to UVB (280–315 nm). Approximately 95% of the sun's UV radiation at sea level is attributed to UVA radiation (315–400 nm), yet there isn't any proof as of yet that UVA, unlike UVB, has a distinct photoreceptor. Alternatively, UVA may be absorbed by blue light photo-receptors such as cryptochromes and phototropins [14]. Plants' attitudes toward UVA, which are determined by these photoreceptors, have not, however, been thoroughly investigated. Therefore, it is yet unknown how UVA functions in relation to plant growth and development, for instance, in plants grown indoors. Plant growth is primarily dictated by morphological and physiological processes, which are heavily influenced by the amount of light present. Plants do not necessarily need to be outside to benefit from UV radiation. By using indoor produced lights to artificially generate these rays, growers may provide their plants with the same benefits as those grown outdoors. Tetrahydrocannabinol (THC) and p-containing oils and resins are elevated when UV exposure is balanced, which results in increased root mass, more branching and less stretching, increased resistance to fungi, insects, and germs, enhanced flavour and aroma and stronger plants [15].

Therefore, this research seeks to explore technology to achieve indoor vegetable planting and reduce the impact of climate change on Nigeria and Africa agricultural systems by using the design and construction of an irrigation housing system with automated artificial UV lighting.

2. LITERATURE REVIEW

2.1 Climate Change

Agriculture and forestry are the two industries most severely impacted by climate change brought on by global warming [16]. Agriculture is the most affected because it depends on climate conditions and the use of natural resources to sustain food production for the world's growing population. Thus, there is a connection between food security and climate change. The escalating issues brought about by frequent but brief rainfall, more frequent flooding, and soil erosion result in a major loss of cropland and damages to soil infrastructure. The increased evapotranspiration resulting from warmer air and land surface temperatures is also a significant effect to consider as well as the rate at which soil and plant moisture are being lost. All these factors allude to the reality that climate is the primary limiting factor for agricultural activity in several African locations, most of which are developing nations [17]. Changes in rainfall patterns have a major impact on the presence and absence of some pathogens and vectors, which in turn have considerable health implications for humans and animals affected by the climate change [10]. Additionally, marine life, food security, tourism, and biodiversity are all impacted by the elevated temperatures [18]

2.2 Ultraviolet-B

Depletion of the stratosphere ozone layer results in increased UV-B radiation at the earth's surface, which is one outcome of the current trend of climate change. With a shorter wavelength than other UV light, ultraviolet B causes severe damage to the proteins and chloroplasts that are essential to green plants' photosynthetic processes. The first protein complex involved in photosynthesis, called photosystem II, is created with the help of genes that are disrupted by UVB light [19, 20]. UVB primarily targets the photosystem II. UVB has an impact on the efficiency, growth rate, nitrogen and carbon metabolism, and other components of photosynthesis. UVB also modifies transpirational water loss rate. Secondary impacts of UV-B radiation include changes in stomatal conductance, photosynthetic pigments, and the morphology of leaves and canopies [19]. On the other hand, blue and red light are needed for photosynthesis in plants, not UV radiation. As a result, photosynthesis proceeds more swiftly and photosystem II functions better in the absence of UVB, leading to healthy crop development. [21[states that UVB has an indirect impact on mesophyll and a direct effect on plant stomata. Future predictions indicate that UVB will likely have a greater effect on plants and photosynthesis. As shown in Figure 1, UV B with a high temperature adversely affect plant development and photosynthesis, while UV B with water stress makes it harder for crops to survive. Similarly, UV B with high photosynthetically active radiation (PAR) causes net photosynthesis while moderate photosynthesis is achieved when UV B combines with low PAR. In the same vein, UV B with blue light under high PAR results in breakdown of photosynthetic pigment.

2.3 Ultraviolet-A

A portion of solar irradiance known as ultraviolet-A radiation (UV-A: 315–400 nm) causes a wide range of physiological reactions in plants. A portion of solar energy known as ultraviolet-A radiation (UV-A: 315–400 nm) is responsible for important chemical and physical reactions in plants. Under comparison to UV-B radiation, plants grown under UV-A radiation grow more quickly and better [6, 17, 23]. UVA increases plants' ability to photosynthesize [24].

UVA-stimulated leaf flavonoids are highly species-and compound-specific. A large portion of UVA's effects on growth and development are distinct from UVB's, and their response pathways are also very diverse [25]. Most of the effects of UVA on growth and development differ from those of UVB in terms of their response pathways [26]. In contrast to UV-B radiation, some studies have also demonstrated that UV-A radiation negatively impacts photosynthesis, which lowers the characteristics of plants. The disparity found in the literature could be the result of unclear responses from plants growing in UVA radiation, even though UVA light does not harm plant's DNA [27, 19].

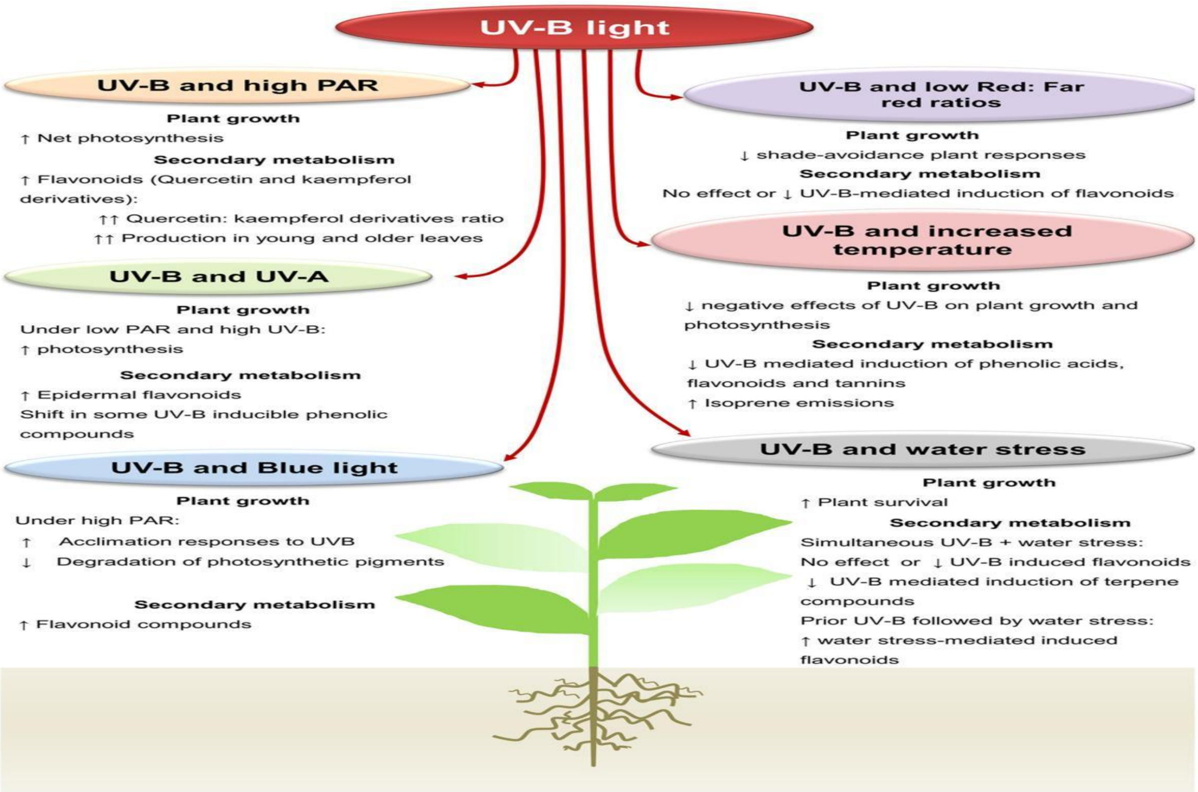

Figure 1: Ultraviolet-B effect on plant in different conditions [22]

2.4 Light Emitting Diode

A semiconductor diode known as a light-emitting diode (LED) (Figure 2) generates light when a conducting current or voltage is applied. It's a p-n junction diode, and light is produced when current flows through it. Electrons that have gathered enough energy can recombine with the device's holes when the terminals get the correct voltage, releasing energy in the form of visible light. Red and blue lights from LEDs are emitted, and these spectrums of light greatly promotes plant development. The energy band gap of the semiconductor, however, controls the colour of light that the LED emits. Since LEDs are usually small, integrated photosensitive agents can be used to characterize and modify the emission pattern. LED is clean, eco-friendly, and energy-efficient. Because LED light is adaptable, it may be used in a wide variety of configurations for hydroponic plants and all types of soil. LED is affordable [28[.

Similar to sunlight, LEDs also offer a dependable light source; however, unlike sunlight, LEDs are controlled. LEDs provide a great degree of control over the light spectrum and are very efficient, flexible, and versatile. Using LEDs allows farmers to customize and choose what is best for their crops' maximum production, which accelerates crop growth and shortens the time needed for harvest [29, 30].

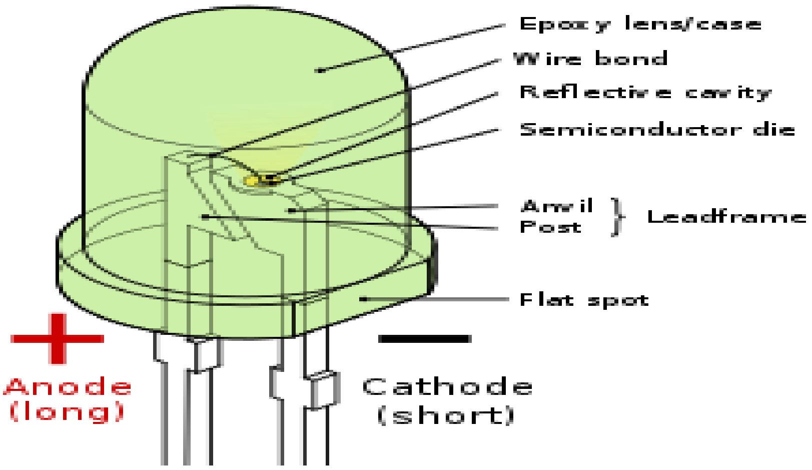

Figure 2: Light emitting diode

2.5 Blue and red lights effects on plant growth

Many plants that are cultivated just in red light, even those that are grown indoors using red LED light sources, have elongated, stretched leaves that make the plants tall. It is common for plants grown under red light only to lack desirable growth traits. However, when a very little amount of blue light is added to red light, the plants' tendency to develop more slowly is inhibited. Because of this, plants grown indoors under conditions of 10% to 20% blue light and 80% to 90% red light are smaller, have fewer leaves, and have shorter stalks [13]. In contrast to red light, which has longer wave with wavelengths between 620 and 750 nm, blue light has shorter waves, ranging from 450 to 495 nm. Essentially, red light affects fruit, stem extension, blooming, and leaf growth, while blue light promotes vegetative and structural growth.

2.6 Irrigation System

Irrigation is the practice of artificially (manually or mechanically) watering crops, pastures, and plants using pipes, sprinklers, canals, sprays, pumps, and other man-made water sources and channels as opposed to totally depending on rainfall. An irrigation system improves farming by giving plants a source of water in addition to rain [27]. Since water is an essential resource for growth, irrigation is a method for satisfying the water needs of plants or crops. It also facilitates effective root penetration into dry soils, which helps plants acquire the nutrients they require for growth and development and high productivity [7, 36]. Ensuring that leaves have a consistent and suitable water status is essential for photosynthetic efficiency [31]. During photosynthesis, light energy is converted to chemical energy and produces sugars and a pigment known as chlorophyll absorbs light energy and uses it to change carbon dioxide, soil water, and light energy into glucose, a type of sugar. As a consequence of this, oxygen is also released. The entire process helps plants grow, develop, and meet their energy needs. Light is directly needed for the first stage while water is the source of the oxygen generated during green plant photosynthesis [32]. Numerous bodies of water, including lakes, dams, rivers, ponds, wells, reservoirs, canals, and tube wells can be used locally for irrigation purposes. The kind of crops, the kind of soil, and seasonal variations are some other factors that influence the quantity of time, water required, level, and pace of watering. Irrigation is a useful tool in places where agricultural cultivation is not geographically feasible [36]. Plants can flourish in areas and conditions that would not normally be conducive to their development with the help of irrigation [33]. Due to lack of access to conventional rainfall, plant requires water to grow therefore, irrigation is required to provide water to the growing vegetables. Decreased water availability will affect the growth and development of vegetables [34]

2.6.1 Drip Irrigation

Commonly known as trickling irrigation, drip irrigation is a kind of irrigation. One kind of localized irrigation method is drip irrigation, which delivers water droplets directly and gradually to plant roots. The irrigation system's high efficiency stems from its ability to significantly lower water evaporation and runoff from plant roots. Additionally, it is highly flexible for all soil types and land topographies, making it an excellent irrigation method for regions with poor water availability or high water-costs.

2.6.2 Sprinkler Irrigation

Sprinkler irrigation is a kind of irrigation that works similarly to rainfall in nature, distributing water via a network of pipes, typically through pumping. After then, sprinklers are used to shoot the water into the air, breaking it up into tiny water droplets that fall to the ground.

3. MATERIALS AND METHODOLOGY

3.1 Materials

Hardware components such as an RTC ds1302 clock module, acrylic housing, socket, water pump, watering can, water leaf, Amaranthus, jute mallow, red, blue, and white LEDs, Arduino Uno, relays, inverter, automatic growing machine, and software for the Arduino IDE are among the materials used in this study.

3.2 Methods

3.2.1 Planting of the vegetables

Three types of vegetables were planted: jute mallow, water leaf, and Amaranthus. In order to ascertain and contrast the effects of natural and artificial sources of UV light on vegetables, these vegetables were planted under two different conditions: naturally (under UV light) (Figure 3) and artificially (under LED light) (Figure 4 & Figure 5). A watering can was used every day to water the vegetables growing naturally, whereas an automatic vegetable growth system with a pump that sprinkled water in a drip-like manner from a jerry can on the veggies was used to irrigate the artificially grown vegetables. The 43 x 45 x 60 cm^3 mechanized growth apparatus resembled an acrylic housing. The pump is rated for 3.6 watts at 12 volts DC. Two 12 V batteries and a 200 Ah battery that powered the pump were used to power an inverter too, which was consequently used to power the automated growth machine thereby guaranteeing a continuous power supply. The battery was additionally charged using a battery charger, and the Arduino circuit was powered by a rectifier circuit with a 5 V DC output. The Arduino Uno, which acts as the autonomous growing machine's brain, was programmed with code. The ds1302 RTC module proved to be helpful in monitoring the duration of the experiment. The socket was switched on to power the red, blue, and white LEDs. During the two weeks, the artificial lights (red, blue, and white) produced by the LEDs lasted approximately 12 hours a day, whereas the natural UV light lasted roughly 9 hours. The three LED lights each have a different effect on the growth of the plants and supply the elements that the plants need to flourish. Red light promotes photosynthesis, crop germination, flowering, and yield. White light improves photosynthesis, while blue light encourages the growth of stems and leaves.

Figure 3: Natural condition

Figure 4: Automatic growing machine set up

Figure 5: Automatic condition

3.2.2 Arduino Uno

Based on the Atmega 328p micro-controller, the Arduino Uno is utilized (Figure 6) [35]. A built-in USB connector on the Arduino board allows programming of the microcontroller chip, which is integrated into the board and allows for the storage of programs. Control circuits such as the RTC module, relays, and motors are interfaced with by the Arduino board [37].

Figure 6: Arduino Uno board [35]

3.2.3 Software design and development

The Arduino IDE software was used in writing the codes and debugging programs and were uploaded to the Arduino micro-controller (Figure 7 & Figure 8).

After uploading the code, the water pump connected to the automatic growing machine functioned in the morning between 10:00 - 10:05, and 5:00 – 5:08 in the evening of each day for the two weeks.

4. RESULTS AND DISCUSSION

4.1 Results

4.1.1 Natural conditioned planting

The jute mallow began the two weeks of natural planting with an initial height of 1.7 cm and three leaves, but at the end of the second week, it had grown to a height of 3.8 cm and four leaves, according to observations recorded in Figure 9. When compared to Amaranthus, which started off with an initial height of 3.3 cm and two leaves at the end of the first week and increased to 4.9 cm and four leaves at the end of the second, water leaf had an initial height of 2.8 cm and five leaves at the end of the first week and increased to 4.7 cm and eight leaves at the end of the second week. Amaranthus outgrew water leaf and jute mallow in terms of height, according to the observation, however water leaf had more leaves than both of these plants together.

4.1.2 Planting in artificial condition

In a similar vein, vegetables grown artificially were watched for a period of two weeks (Figure 10). By the conclusion of the first week, the initial heights of the jute mallow, water leaf, and Amaranthus were 2 cm, 2.2 cm, and 3 leaves, respectively. However, by the end of the second week, the height of the plants of jute mallow, water leaf, and Amaranthus was 4 cm for jute mallow, 3 cm for water leaf, and 6 cm for Amaranthus. It is clear that Amaranthus was taller than water leaf and jute mallow, although water had more leaves than either plant.

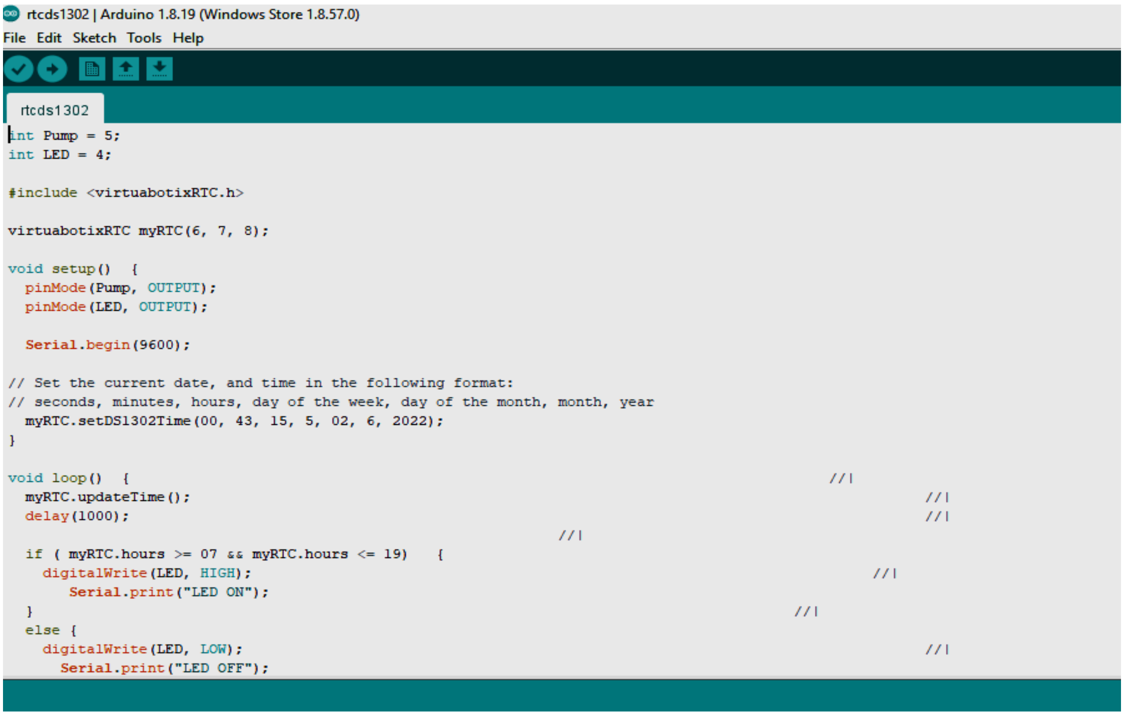

Figure 7: Arduino IDE codes

Figure 8: Uploaded Arduino IDE code

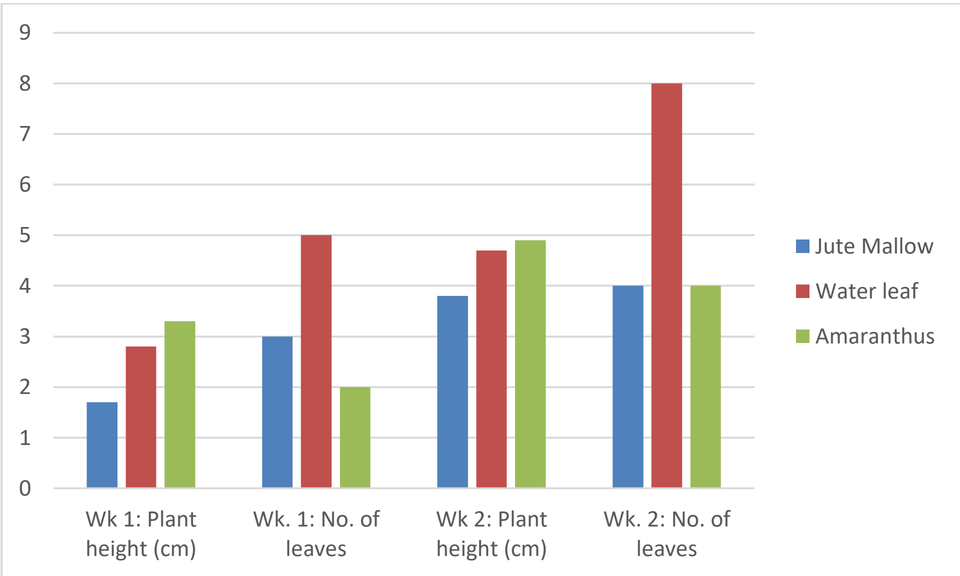

Figure 9: Comparison of 3 distinct veggies under natural condition

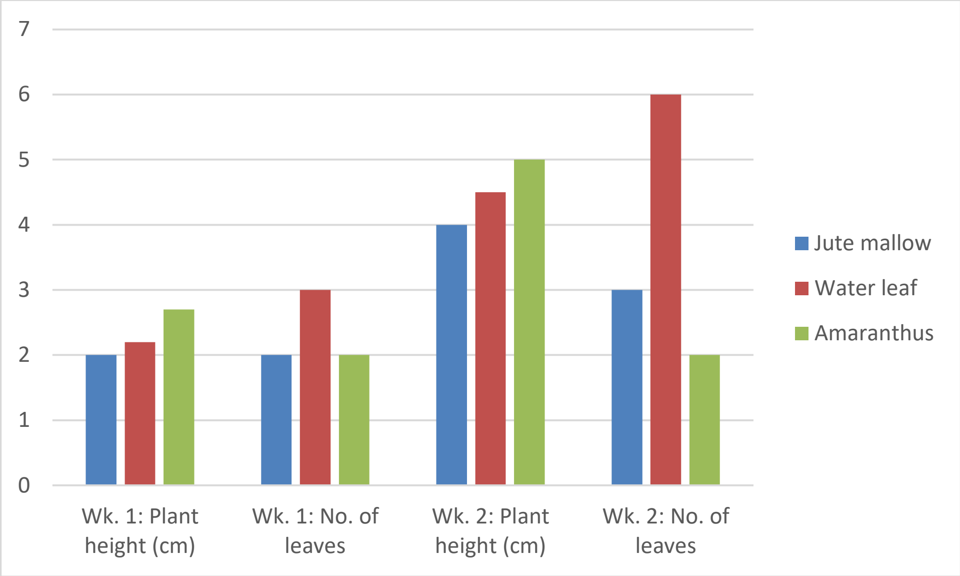

Figure 10: Comparison of 3 distinct veggies under artificial condition

4. CONCLUSION

As a substitute for natural planting techniques, this study has created an artificial planting system and compared its outcomes with those of a natural planting method. The impact of climate change on vegetable growing can be significantly reduced by using the artificial planting technique that this study has shown. In order to confirm this, three different kinds of vegetables were grown in an artificial growth machine and in direct sunshine. When plants are cultivated artificially, they eventually mature and produce leaves that are similar to those that develop naturally. The results of the study demonstrated that water leaf, Amaranthus, and jute mallow could all be grown in artificial environments, reached maturity, and produced edible plants. One technique that is primarily applicable in people's homes is the artificial planting system. By using this strategy, food security can be ensured while both reducing hunger and the effects of global warming. It is proven that artificial UV light can be produced for the purpose of growing vegetables. Each vegetable develops similarly in every instance; however, while growth variances are noted, overall, the acrylic enclosure with artificial UV light was developed and the plant was effectively grown. In comparison to the natural method, the technique uses less water and doesn't utilize any fertilizer. This artificial system essentially demonstrated the significance of a managed, steady, and consistent supply of artificial light and water with little to no human involvement. In addition to offering the necessities and having a large capacity for veggies, it is also reasonably priced. The changing climate warrants the recommendation of this planting strategy for vegetable and other crop farming, with the assurance of healthy crops independent of climate change effects.

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