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Acclimatization of the Growth of Brassica Juncea to Temperature Stress: Future of IoT Technology in Sustainable Agriculture

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Abstract
Agriculture and global warming are correlated with each other, particularly, it may affect nutrient cycles, microbial activities, and physiological activities of the crops. Agricultural development plays a crucial role in the growth of the economy of developing countries. The agriculture sector is a major source of employment in most of the developing countries. Over the year, there were changes and productivity loss due to the abiotic stresses and imbalance of nutrients of the plants. A continuous increase in temperature may affect the yields of crops up to 17%. Each plant has different characteristics in growth and some plants are susceptible to high temperature, some are quite the opposite. A Brassica Juncea L. belongs to a mustard family Brassicaceae or Cruciferae that are susceptible to high temperature. So, in this work, an attempt has been made for Brassica Juncea L. to grow and yield under temperature stress by controlling the temperature with the use of the Internet of Things (IoT). The experiment has been conducted where Brassica Juncea neither production nor consumption. IoT sensors are used to monitor the temperature and humidity in two different scenarios. This paper analyses the factors that affect the growth of Brassica Juncea and provide a solution to increase productivity.
Keywords: Agriculture, Brassica Juncea, IoT, Temperature Stress

1. Introduction
Temperature stress is a major problem often tackled during the growth of plants which reduces the yield of crops. Over the year there were changes and loss in productivity due to the abiotic stresses and imbalance of nutrients (Szymańska et al., 2017). Agriculture is the main resource for the economy setter of the country (Shekhar et al., 2017). Moreover, every country's population depends on agriculture for their livelihood. So, it is crucial to come up with sophisticated technology for better harvesting experiences and higher production (Goap et al., 2018). A continuous increase in temperature has affected the yields of crops, harvest, and production which may lead to insufficiency in food demand.

High-temperature stress often leads to low germination rates, growth retardation, problems in photosynthesis which may lead to the destruction of plants (Kai and Iba, 2014). Brassica juncea L. belongs to the mustard family (Brassicaceae or Cruciferae) and has different names such as Indian Mustard, Brown Mustard, and Chinese Mustard (Szollosi, 2011). It has been widely grown in Eastern India, China, and some European countries. It has a range of medicinal values and widely consumed by humans, extraction of oil, and other purposes (Woods et al., 1991). Oilseed rape (Brassica Nupus) and turnip rape (Brassica Rapa) are usually grown in the moderate temperature while Indian mustard or Chinese mustard (Brassica Juncea L.) is usually found in the subtropic of Asia. It is known to be a good medicine from many years back and is used for fighting different kinds of aches like arthritis, foot ache, lumbago, stomach disorder, and rheumatism, etc (Rahmatullah et al., 2010). Brassica Juncea L. can usually be found in a place with high humidity and an average temperature of 27-degree Celcius. It is a cool-season winter crop and can be found in cool places. A Brassica Juncea L. can grow in a subtropical climate where the percentage of rainfall is much higher and the

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optimum temperature of 18-degree Celcius (Cardoso, n.d.). It is rich in Vitamin A, Vitamin K, Vitamin C, Vitamin E, Vitamin B (Mara Duma et al. , 2014)

Internet of Things and Machine Learning techniques are becoming so popular in the field of agriculture (Kissoon, 2017.). In the Modern world, new technology has transformed the way of farming and it helps farmers to do their tasks much faster and smarter than ever before (Juhi Reshma and Pillai, 2018). The conventional way of farming gradually changes to smart farming. It is important to encourage leveraging advanced technology in farming to increase the quantity and improve the quality of agricultural products.

Abiotic stress is one of the destructive stress in the process of the plant's growth. It adversely affects the farmers and often makes them devastated. However, in many countries, the labor force has been replaced by automated machines that are more efficient and accurate. The stress detecting mechanism has also improved as the Internet of Things and Machine Learning technology can precisely monitor and identify the pests or the stress at the initial stage. Nowadays, automated devices can monitor temperature, humidity, water intensity and minerals obtained, etc that can communicate with the farmers in real-time.

In this paper, a test has been carried out for a Brassica Juncea to identify the acclimatization of temperature stress. Brassica Juncea L. were planted in two different environments to identify the sustainability of temperature stress. IoT technology has been used to monitor temperature and humidity. It has been carried out for approximately 41 days. The main objective of the paper is to analyze the temperature stress of Brassica Juncea and suggest the way to improve the productivity of the crops under high temperature also.

This paper is organized as follows: Section 2 discusses the existing works. Section 3 deals with the significance of the work. Section 4 elaborates the proposed system and section 5 explains the implementation procedure. Section 6 explores the experimental analysis. Finally section 7 concludes the work.

2. Literature Survey

Over the past years, research has been going on the optimal technique for the detection of temperature stress on the plant's growth. As the temperature is an important environmental factor in the growth of plants, it has a significant dependence on the temperature and humidity (Yan, 1999). Some articles regarding high-temperature stress in paddy and rice are also found (Shah et al., 2011), (Jagadish et al., 2007), (Prasad et al., 2006), (Rang et al., 2011).

Indian mustard (Brassica Juncea L) is subjected to a high temperature of 30 to 40-degree Celcius and estimates the changes in antioxidative enzymes when exposed to a high temperature which is after treated with salicylic acid that changes the relationship between the activity of antioxidative enzymes and the degree of tolerance. The hypothesis confirmed that whether salicylic has done any better improvement in the growth when the plant affected by temperature stress (Hayat et al., 2009).

An experiment has been carried out to determine the effect and degree of temperature stress in Brassica Nupus Conola and Brassica Juncea and also evaluated the degree of susceptibility of the plants. Moreover, it has been found that the ability to recover from the temperature and water stress in subjection to different environments (Gan et al., 2004).

Inconsistency in weather and environmental changes causes several changes in the metabolic and physiological activity in plants. High temperature is one of the environmental factors that limit the growth of plants. It is one of the main causes of economic losses and farmer's devastation. The objective of the experiment is to examine the role of phytohormones in reducing the heat effects in terms of seedling mortality in Brassica Juncea L. (M.L. Chhabra et al., 2009)

Temperature stress is one of the main factors that affects the growth of plants all over the world. It determines the growth rate of sensitive plants of three Brassica species under high-temperature stress. Also, the variation in high temperature among the Brassica species and assess whether Brassica Juncea L. is more tolerant towards high temperature as compared with other Brassica species. The different species were also evaluated for their ability to recover from high-temperature stress (Angadi et al., 2000).

High-temperature stress is one of the environmental stresses which adversely affects the growth of plants and reduced productivity. A change in protein content, metabolism, and physiological activity has occurred. The main objective is to study how the growth of seedling is affected by high temperature and the role of 24-epiBL

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in reducing the high-temperature stress by regulating the activity of various enzymes which act as an antioxidant in Brassica Juncea L. (Kumar et al., 2012).

3. Significance of the work

Due to global warming and the rapid increase in temperature, there is a stress that affects the growth of Brassica Juncea L. which is also called Indian Mustard or Chinese Mustard. Mustard Leaf is an eccentric type of a plant in terms of temperature where the optimum temperature for the plant to yield is 20/15 ºC. Due to the high temperature in the Tropical region, Brassica species are more susceptible and strain in the growth (M.L. Chhabra et al., 2009). Many other species of plants are harvested in many places around 35 ºC. When Brassica Juncea L. is exposed to high temperature, the process of growing and sprouting have been affected and delayed and tends to grow slower than the normal process. A Brassica Juncea L. is susceptible to the high temperature having a very low tolerance. On the contrary, Brassica Juncea L. is adaptive towards high humidity as this type of plant is growing in moist and humid places. There may be arbitrary thoughts that some plants are not growing in some places simply without any biological reasons. However, there is a specific reason why these plants are not found in some particular place because of certain circumstances such as biotic and abiotic stress. Plant stresses are a common activity during the process of photosynthesis which obstructs the growth of a plant (Rhodes and Nadolska-Orczyk, 2001). So, it is crucial to find out what hinders the process of photosynthetic activity in the early stage to avoid deterioration of the growth of the plants. The main objective of this work is to emphasize the regular monitoring of the temperature stress of the plants leads to higher productivity. Thus it helps to increase the economy of the developing countries. This paper also insisted that the use of technology like IoT and machine learning in agriculture would help the farmers to increase the production of the crops.

4. System model

Temperature stress is one of the main factors that obstruct the growth of plants. Apparently, because of global warming increases each year, yields and harvests of crops gradually deteriorated the productivity (Hasan et al., 2019). Nowadays, it is anticipated that a proper strategy will be mandatory to have a productive agricultural system. This will only be brought up by introducing technology into the system of farming. Soon, perhaps, there will be many places on the earth where agriculture would not be able to carry out because of pollution and weather change. Technology will be the only mode that will sail us through hardship.
Figure 1 depicts the system model of the system. As the figure shows, two pots are installed where one pot is under the protected greenhouse named Pot A and the other subjected to get direct sunlight named Pot B. A healthy seeds of Brassica Juncea L. were planted in both of the pots and the test has been carried out. During this test, the whole process was monitored. The pots were equipped with temperature and humidity sensors that are controlled and regulated by Arduino Uno.

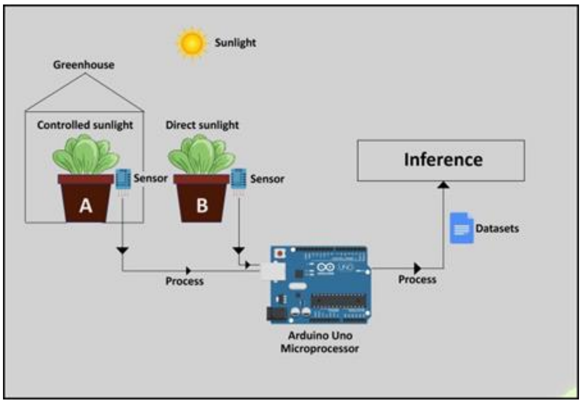

Figure 1: System model

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The test has been taken place in South Asian countries lying in the Tropical climate that normally has a high temperature. Some plants like Brassica Juncea L. and Canola etc are sensitive towards high temperatures and could not grow and yield in particular places. Therefore, a test has been conducted to conclude that there is temperature stress in the growth of Brassica Juncea L.
Data are being generated from sensors in the form of variables such as Day, Time, Date, Temperature, Humidity,etc. The datalog is stored in the form of comma-separated value (CSV) file. The height of the plants (in cm) has also been measured.

5. System Implementation

An experiment has been carried out in the coastal area, Pondicherry University which is in Pondicherry (Union Territory) in the Southern part of India. It is located on the East Coast of Southern India which is known to be in the temperature homogenous zone (Dash et al., 2013). It has as high as 37 ºC during summer humidity as high as 93%. As it is located in a coastal region it has a comparatively hot atmosphere.
The seeds of Brassica Juncea L. have been planted in the pots identically. Two pots are used and are labeled as Pot A and Pot B where Pot A is a pot with controlled temperature and humidity, on the other side, Pot B with uncontrolled temperature and humidity. The place where the experiment is deployed is covered with brown sandy soil or red soil where it has moderately alkaline subsoil (Sundarapandian et al., 2016).
The equivalent soil is engaged for the experiment for both Pot A and Pot B. These pots were placed in such a way both will acquire sunlight in equal intensity. For controlling the temperature of Pot A, a transparent Silpaulin which is generally used as a standard material for a greenhouse in the implementation of the experiment. The parameters like the types of soil, water, sunlight, and minerals, etc. are all controlled for both the pots. Both Pot A and Pot B are watered at the same time and equal formation. Moreover, both the pots are watered before sunrise and sunset to avoid imbalanced evapotranspiration.

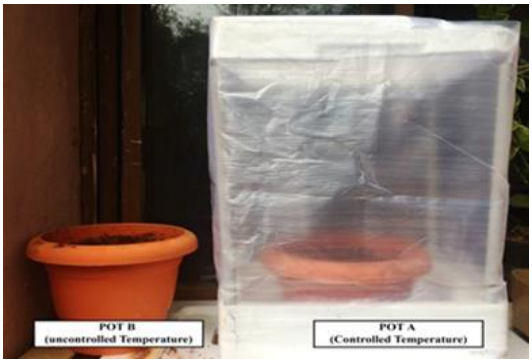

Figure 2. Pots with controlled and uncontrolled temperature and humidity

Figure 2 shows that Pot A is placed inside the translucent box made like a greenhouse to protect excessive heat from the sun and retain humidly. Whereas Pot B is placed right outside without any sun protection just beside Pot A to make sure both the Pots get the same amount of light and heat from the sun. After 2 days of the conduct of the experiment, the plant in Pot A starts getting sprouted while it took 5 days to sprout in Pot B.

A DHT10 SIP sensor is used and it is connected to an Arduino Uno. A DHT10 SIP is an IoT electronic sensor that senses the temperature and humidity of the corresponding environment. Also, an Arduino Uno is a microcontroller board based on the ATmega328P that has the capabilities of controlling different tasks and parameters for different purposes. Basically, two sensors of DHT10 are used in the experiment where one is placed inside the greenhouse which defines Pot A and the other with uncontrolled Pot B which are both connected to the controller Arduino Uno.

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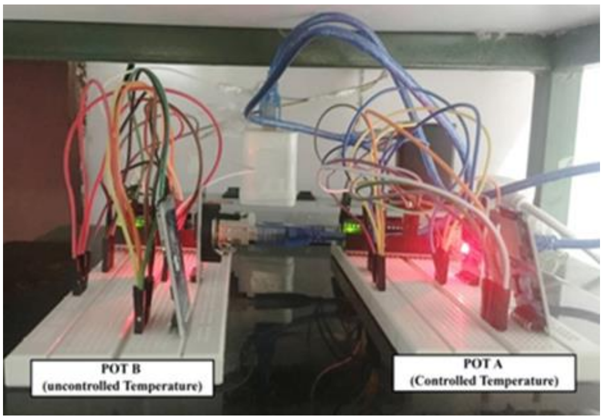

Figure 3. Arduino Sensors installed for Pot A and Pot B

Figure 3 shows two Arduino Uno is installed for both the Pots A and B along with the sensors such as DHT10 Temperature and Humidity sensors, DS3231 RTC is a precision real-time clock with 32bit EEPROM which maintain time and date accurately. Micro SD card reader module is a slot that supports Micro SD card for maintaining the log.

After a week of observation, the plant in Pot A begins to sprout while there was a delay in sprouting in Pot B. The height (in cm) of the plants is recorded every day corresponding to temperature and humidity.

Figure 4. Sprouting of Pot A and Pot B

Figure 4 shows the status of PoT A and Pot B after a week. This experiment has been taken for about 1 month and there is a drastic difference between controlled and uncontrolled temperature and humidity. This experiment shows that there is a stress of temperature and humidity from yielding.

A total of 41 days have been taken for observing the plants' growth. The data that is generated by the sensors are in the form of labeled data such as humidity, temperature, and height of the plants in centimeters. Data is generated from sensors are stored in the form of variables such as Day, Time, Date, Temperature, Humidity. The height and other data are stored for further processing.

Figure 5 shows the output of the experiment where the different leaves of Brassica juncea of Pot A and a single leaf in Pot B are placed together to see the difference. As it is shown in frame 4, multiple leaves are grown in Pot A whereas in Pot B there is only one branch striving to survive. Thus, the result shows that there is temperature stress in the growth of Brassica Juncea.

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Figure 5. Plants growth in Pot A and Pot B

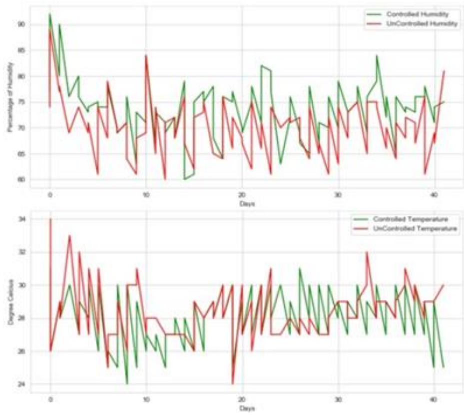

Figure 6. Temperature and Humidity of Pot A and Pot B

Figure 6 shows the degree of Temperature and percentage of Humidity within 41 days for the controlled temperature and humidity of Pot A and uncontrolled temperature and humidity of Pot B. It shows that there is a difference of temperature and humidity of Pot A and Pot B. A temperature is higher in Pot B than the temperature in Pot A whereas the percentage of Humidity is higher in Pot A than in Pot B. Figure 7 shows that Pot A has a significant growth in height over Pot B.

The collected data is statistically analysed to prove the hypothesis.

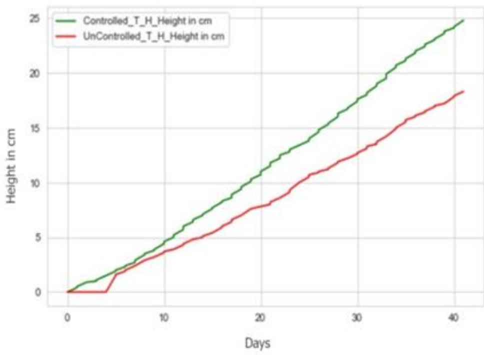

Figure 7. Height of plants Pot A and Pot B

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6. Experimental Analysis

From the experiment, it is observed that a Mustard leaf (Brassica Juncea) can yield precisely at a moderate temperature and in a higher percentage of humidity. In order to prove that the T-test has been used to measure the significant difference between the plant growth in controlled and uncontrolled temperature. The values are obtained from the experiment and used Equation (1) to find out the T-score.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \qquad (1)$$

The temperature has been considered and the value of the mean of the controlled temperature samples is $\bar{x}1 = 27.9375$ and the squared standard deviation is $s12 = 0.18938922$. In an uncontrolled environment, the value of the mean is $\bar{x}2 = 28.3625$ and the squared standard deviation is $s22 = 0.18249653$. The standard error on the difference between the samples is 0.263008. The parameter humidity with controlled samples, the value of the mean is $\bar{x}1 = 73.7$ and the squared standard deviation is $s12 = 0.63604792$. With the uncontrolled samples, the value of the mean is $\bar{x}2 = 70.025$ and the squared standard deviation is $s22 = 0.61468707$. The standard error on the difference between the samples is 0.884532.

As there is a significant difference in the value mean, squared standard deviation and standard errors, there is an effect in the height of *Brassica Juncea*. From the sample of the height *Brassica Juncea L.* with controlled temperature and humidity, the value of the mean is $\bar{x}1 = 11.655$ and the squared standard deviation is $s12 = 7.556637$. Whereas with the sample of the height of *Brassica Juncea L.* with uncontrolled temperature and humidity, the value of the mean is $\bar{x}2 = 8.49$ and the squared standard deviation is $s22 = 5.569733$. The standard error on the difference between the samples is 1.047268. Null hypothesis and alternate hypothesis are stated to find a significant difference in the growth of the plants.

Null Hypothesis (H0): There is no temperature stress in the growth of *Brassica Juncea L.* and there are no significant differences between controlled and uncontrolled temperature and humidity.

Alternate Hypothesis (H1): There is temperature stress in the growth of *Brassica Juncea L.* and there is a significant difference between controlled and uncontrolled temperature and humidity

The main objective is to reject the Null Hypothesis that a degree of temperature and a degree of humidity does not affect the height of the Mustard plant(*Brassica Juncea*) statistically. It has been implemented in python. For the test, Temperature, humidity, and Height in cm of Pot A and Pot B are considered. A degree of freedom denoted as “df” is the maximum number of possibilities that can vary in the n number of samples. It is denoted by (n-1) where n is the total number of the sample size. A critical value which is denoted as “cv” is a rejection boundary of the null hypothesis in Gaussian Distribution with the value of 0.05 in both the tails. A P-value is a probability to obtain the most accurate result of the hypothesis. A T-test signifies that if the ($p\text{-value} > 0.05$), it will fail to reject the Null hypothesis. However, if the $p\text{-value} < 0.05$ the Null hypothesis will be rejected and accept the Alternative hypothesis.

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Table 1. Results of the correlation of different parameters

Correlation of Parameter	***T-value***	***Degree of Freedom***	***Critical Value***	***P-value***
Pot A and Pot B Temperature	-2.262	198	1.653	0.025
Pot A and Pot B Height in cm	-2.262	198	1.653	0.025
Pot A and Pot B Humidity	-2.123	198	1.654	0.032

From the implementation, it has been observed that Table 1 shows the t-value of the two parameters Temperature and Humidity for Pot A and Pot B is -2.262. The T-score of Height in Pot A and Pot B is -2.123. The degree of freedom scores for the three-parameter is 198. The critical value of Temperature and Humidity in the pots is 1.653 where Height in the pots scores 1.654. The p-value for temperature and humidity for both the pots is 0.025 and 0.032 for the height of both the pots which all lies inside the rejection region in a Gaussian Distribution which is less than a critical value 0.05, so, the null hypothesis is rejected and the alternative hypothesis is accepted. Thus, the result has concluded that there is a significant difference in the growth of Brassica Juncea. L when it is subjected to a different environment that is controlled and uncontrolled temperature and humidity.

7. Conclusion

Temperature stress affects the productivity of the crops. In this paper, Brassica Juncea is considered which can yield in a moist and humid place and also it is vulnerable to high temperatures. This work emphasizes the challenges in the growth of the plants. It can be overwhelmed with the use of technology. So the farmers can grow and yield the crops in different environments with controlled conditions.

In this work, Brassica Juncea is planted in a controlled and uncontrolled temperature environment. As a result, there was a significant difference in the growth of the plants even with high temperature. Hence, it has been proved that the intensity of heat absorbs by the plants has a huge impact on the growth of the plants. So the farmers can take this into account to improve the growth of the crops to increase productivity.

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