# Comprehensive Study on the Influence of Diode Laser Irradiation on Germination Efficiency and Seedling Development in Brinjal

Sania Arif[1,*], Tingying Zhang[1], Sara Kalsoom[1], Rubab Aness[1], Fakhar Abbas[2], Tayyaba Raiz[1], Ahmad Sikandar[3], Mariam Hassan[4], Rabia Khalid[1] and Zareena Kausar[1]

[1]Department of Physics, University of Agriculture, Faisalabad-38000, Pakistan
[2]Department of Physics, University of the Punjab, Lahore-05422, Pakistan
[3]Department of Botany, Government College University, Faisalabad-38000, Pakistan
[4]Oilseeds Research Institute Ayub Agricultural Research Institute Faisalabad-38850, Pakistan
*Corresponding author: saniaarif626@yahoo.com

## Abstract

Lasers have gained significant scientific interest due to their high potential. They are now widely used in industries and agriculture to improve sprouting rates, seedling growth, crop yield, and in land leveling. Current study is focused to evaluate the pre sowing laser irradiation effect on brinjal seeds. In this project diode laser of 1mw power and wavelength of 630nm was used to irradiate the potato seeds. The seeds treated for three different exposure time and energy 10, 15 and 20mJ. Each treatment has 3 replications. For this purpose, healthy, uniform and small size egg plant seeds were selected. These seeds were directly placed in a sample holder, which was driven by 12V DC battery, under the diode laser pulse. The brinjal seeds were treated with a diode pulse laser for 10, 15, and 20 seconds, with untreated seeds serving as the control. The germination and growth of laser-treated seeds were compared to the control. Biophysical parameters such as germination percentage, emergence time, vigor index, shoot length, root diameter, and chlorophyll content were measured, along with biochemical parameters like mineral content, fats, and vitamin C. Statistically analysis showed the positive effect of laser irradiation on brinjal seeds.

**Keywords:** Diode Laser, Brinjal Seed, Seedling Development Enhancement

**Cite this Article as:** Arif S, Zhang T, Kalsoom S, Aness R, Abbas F, Raiz T, Sikandar A, Hassan M, Khalid R and Kausar Z, 2025. Comprehensive study on the influence of diode laser irradiation on germination efficiency and seedling development in brinjal. In: Kausar R, Nisa ZU, Jamil M and Bashir I (eds), Integrated Health and Sustainability: Plants, Wildlife, and Genetic Resilience. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 9-14. https://doi.org/10.47278/book.HH/2025.002

A Publication of Unique Scientific Publishers

**Chapter No:** 25-002

**Received:** 18-Feb-2025
**Revised:** 25-Apr-2025
**Accepted:** 18-May-2025

## Introduction

Due to the demands of the food production industry and growing consumer demand for fresh vegetables and agricultural products from various ecological zones, new and safer ways of increasing productivity are needed to meet the needs of an expanding population (Chen & Chang, 2005). Chloroplasts are essential for plant growth through acquiring some process of biochemicals, including some synthesis such as lipids, pigments, amino acids, sensing stimuli of the environment, and plant hormones (Dondini et al., 2015). The quality of seed is the major factor impacting the germination rate and production of plants. Physics is the study of the nature and properties of energy and matter and their relationship between them (Boote et al., 2010). The subject of physics consists of mechanics, heat, sound, and other radiation. They may also study about light, plants, stars, and other waves. Physics uses workings from the other natural sciences (Wang et al., 2017). We use physics in our everyday lives to express force, energy, motion, and other different terms. LASER beams can be produced by visible light, X-rays, and infrared light (Aguilar et al., 2015). LASER is a source of coherence. It is different from other lights. In the field of agriculture, the laser has been mainly focused on enhancing the yield efficiency, promoting the growth rate of plants, and improving the plant disease (Ćwintal & Goliasz, 2018). A laser is an instrument that emits a radiation of coherent light by an optical amplification process. There are two types of structures: hard and soft laser. Initially, in late 1950, the discovery of the microwave created radio waves and amplified microwaves. The hard laser consists of LLLT (low-level laser therapy) (Garcia et al., 2023). The Maiman source laser was composed of a rod of ruby with ends of silver to reflect the irradiation of light, which was exited with a spring-shaped flash lamp. A laser creates light through itself by an optical oscillator as compared to an optical amplifier. The main advantage of lasers is that they are a very different source from other different light sources through their coherence. In the laser, the spatial coherence indicates a good output of a narrow beam that is called diffraction-limited. The beam of a laser can be seen to small, tiny particles (spots) attain high irradiance (Asghar et al., 2017). Laser source and magnetic field were used to produce higher and better germination of brinjal seed crops (Allen, 1992). Sowing material should be dried, cleaned, and improved by priming, scarification coating, and arranging of growing (sowing) material (Salvo et al., 2010). The very important qualities in crops are their ability to produce healthy and good fruits. Studies held at some distance on treated seeds with laser irradiation have indicated that the treatment enhanced the ability of seeds to germinate quickly (Asghar et al., 2016). Farmers require batter varieties for production and adopt for challenges of climate change. Because brinjal seeds have taken a long time to germinate, other vegetables crop in a broad range of pests, weeds, and diseases of plants. Common diseases are damping off, fruit rot, and bacterial wilt (Khalifa, 2024). Unpredictable weather, such as temperature and flooding, can damage the quality of fruit (Hunt et al*.,* 2012). Brinjal seeds are kwon as warm-weather-grown vegetables. So the brinjal seeds are sowing in the warm spot, and after 14 to 15 days the seeds start germinating. Its germination rate depends upon some factors, such as content of moisture, seed age, and heat (Younis et al*.,* 2010). The temperature between 60 and 95 degrees 0F is required to germinate the brinjal seeds. The seeds, after 70–180 days, reached maturity. It depends upon the quality of seeds. Some brinjal seeds quality can be hairy. They are growing large and oval-shaped. The repaired amount of soil PH within the range of 6.0 to 7.0 is required for the germination of brinjal. Harvest brinjal (fruits) within 90-100 day duration. Growing within 2 sets of seeds can be converted into four-inch pots within 2 to 3 weeks after growing.

**Effect of Laser Irradiation on the Yield of Brinjal**

Brinjal (*Solanum melongena L.*) is an economically important vegetable rich in carbohydrates, protein, minerals, and vitamins. This non-tuberous, perennial Solanaceous plant is grown annually. Solanaceous crops like eggplant, pepper, and tomato are known for their high phenolic content and strong antioxidant properties. Eggplant offers health benefits, including reducing cholesterol and serving as a fiber source (Swathy et al., 2016). It is also recommended by the National Diabetes Education Program (NIH, USA) for managing type 2 diabetes (Muthusamy et al., 2012). This brinjal variety is particularly vulnerable to abiotic stressors like heat, drought, and waterlogging, as well as biotic stresses like fungal, insect pests, and root lesion nematodes, which all severely impede growth and lower yield (Rupal et al., 2020). It has been reported that, in agricultural environments, laser irradiation improves crop plant germination, growth, development, and yield. In this chapter, Brinjal seeds were irradiated with a 632 nm wavelength semiconductor diode laser having a diameter of 1 mm and 1 mWmm-1 surface densities treated at 5 mJ, 10 mJ, and 15 mJ energies with a time period of 10 seconds, 15 seconds, and 20 seconds, and the setup of the laser was calculated.

**Materials and Methods**

A laser source is very helpful for the process of biological object irradiation. Lasers had been extensively utilised in the agriculture field for some years (Rezvani et al., 2021).Beams of laser irradiation were utilised for the conversion of DNA through cytoplasm toward chloroplasts and also used for the chloroplasts perforation in to cell penetration of several plants (Fonseca et al., 2010). The current analysis was conduct to evaluate the impact of semiconductor diode laser source on brinjal (*Solanum melongena*) seeds, the sprout rate and growth indices during the growth of seeds. The impact of the laser source (irradiation) on the particular enzyme activities and germination levels of plants were also calculated.

For this purpose, the 630 nm wavelength of the diode laser was used. The high-power diode laser, boasting an impressive 1 $MW/cm^2$ power density and a precise 1.5 mm beam diameter, enables cutting-edge applications in industrial manufacturing, medical treatments, and advanced research. Pre-sowing treatment of laser irradiation on brinjal (*Solanum melongena*) seeds has performed with different amounts of energy and time periods.

**Plant Material**

The brinjal seeds (*Solanum melongena*) utilized in this experiment are well ripened; for this purpose, uniform, healthy, and small-sized brinjal seeds were utilized in this research. For this purpose, healthy and uniform seeds were collected.
The brinjal seeds were divided into two categories.

- Control seeds (without laser irradiation treatment)
- Treated Seeds (laser irradiation was used for the treatment of seeds)
- One bag was considered a control, and the other three bags were exposed to laser.

Seeds were spilt up into 4 groups. Group 1 was considered a control, and 3 other groups of seeds were exposed to the source of laser. Each treatment contains three replications, such as $R_1$ replication, $R_2$ replication, and $R_3$ replication.

**Laser Treatment of Brinjal Seeds**

Brinjal Seeds were irradiated with a 632nm wavelength semiconductor diode laser having a diameter of 1mm and 1$mWmm^{-1}$ surface densities treated at 5mJ, 10mJ, and 15mJ energies with a time period of 10seconds, 15seconds, and 20seconds, and the setup of the laser was calculated elsewhere. The diameter of the laser diode can be changed. The treated seeds and control seeds were germinated and sown below some natural order (conditions) (Chen et al., 2010*).* The seeds of brinjal were put in the specimen holder under the source laser pulse. At 12V of DC voltage, the sample cover (holder) was working. For the uniform laser source, the specimen was rotated below the diode pulse laser source for different durations of energy and time shown in Table 1 (Shafique et al., 2017). The irradiation time of exposure was estimated with the help of a timer. Irradiation of energy was calculated by formula. After the germination of seeds the biophysical properties such as growth rate, mean emergence, germination rate, root length, shoot length, plant yield, and some biochemical indices such as fats, mineral analysis, and vitamin C will be calculated.

**Table 1:** Relation between treatment and with their energies (Shafique et al., 2017)

| Serial No | Treatment | Exposure time (sec) | Energy (mJ) |
|---|---|---|---|
| 1 | $T_0$ | Control | Control |
| 2 | $T_1$ | 10 | 10 |
| 3 | $T_2$ | 15 | 15 |
| 4 | $T_3$ | 20 | 20 |

**Experimental Design**

Three treatments such as $T_1$, $T_2$, and $T_3$ with three replicates such as $R_1$, $R_2$, and $R_3$ were used here. Each treatment of seeds was carried out shown in Table 2 (Haq et al., 2007). The research work was conducted in RCD (randomized completely design).

**Table 2:** Scheme about seeds Plantation (seeds germination rate in laser method) (Haq et al., 2007).

| T(Treatment) | R(Replication) | | |
|---|---|---|---|
| | $R_1$ | $R_2$ | $R_3$ |
| $T_0$ | $T_0R_1$ | $T_0R_2$ | $T_0R_3$ |
| $T_1$ | $T_1R_1$ | $T_1R_2$ | $T_1R_3$ |
| $T_2$ | $T_2R_1$ | $T_2R_2$ | $T_2R_3$ |
| $T_3$ | $T_3$R1 | $T_3R_2$ | $T_1R_3$ |

**Statistical Analysis of Germination and Related indices**

To examine the germination, three plants were carried through each replication, such as 1 small replication, 1 medium replication, and 1 large replication. Then these 3 plants length was estimated after seven days, fourteen days, twenty-one days, and twenty-eight days of germination by using measuring tape. After three months (90 days) of growing, plants were chosen for the analysis of further chemical indices and physical parameters. For finding a remarkably different difference between plants through controls, one investigation of variance (ANOVA) was used.

**Measurements and Germination Parameters**

The sowing seed data was noted. Total time period counted when the seeds started growing from their time period (date) of sown was estimated. All the selected data was calculated statistically.

**Data Collection**

The growth rate had been approximately started after seven days of seed sowing. It was analyzed that growth was completed between 28 and 30 days after seed sowing. Some studies on some biochemical and biophysical indices of sprout and plant germination as the time of research was recorded.

Data was noted on different indices such as physical indices, biochemical indices, and biological indices as

**Physical Indices**

- Starting sowing time period to 50% germination of plant
- Vigor index 1
- Chlorophyll content
- Mean growth time
- Germination percentage
- Shoot and root length
- Diameter of tubers
- Moisture content
- Total Yield of brinjal

In which some of the parameters explained here

**Germination Percentage**

If the seeds root length growing rate 0.05 centimeter long then brinjal seed was growing. Impact of the source of semiconductor diode laser on growing seeds was noted. The total data was counted in seven days of time period of sowing. The noted of data was still continued until when the constant growing of seeds was attained. Percentage of germination was calculated with the help of this formula (Menges & E.S, 1991).

$$percent\ of\ Germination\ = \frac{Number\ of\ germinated\ seeds}{total\ number\ of\ seeds}\ x\ 100\%$$

**Starting Sowing Time Period to 50% Germination of Plant**

The time noted through the seeds sowing to growing percentage ($T_{50}$) was estimate with the help of this relation:

$$T50 = \frac{ti + \{(N/2) - nj\}(tj - ti)}{nj\ -\ ni}$$

Where,

N = Final number of germination

$n_i$, are cumulative seeds number by time $t_i$ and $n_j$ are cumulative seeds number germinated by counts at time period of $t_j$.

**Mean Growth Time**

The data for germination was taken for 30 days. Mean germination time was calculated by using this formula:

$$MET = \sum \frac{\mathrm{Dn}}{n}$$

Where
D = Numbers of days calculated from the beginning of emergence
N = Total No of seeds, which were germinated on day D

**Diameter of the Tubers**

The diameter of brinjal tubers was estimated by using DVC (digital vernier caliper). Purely accommodate the brinjal tuber between vernier caliper jaws and tighten the jaws estimated the reading and measurement with the help of a digital scale on the base of the vernier calliper.

**Biochemical Indices**

Plant nutrition is basically the chemical element that is vital for the germination and nourishment of plants (Dick, 1994) Plant nutrients exist in 3 groups, which all depend upon the quantity of plants required, not the importance of different individuals. For necessary plant growth elements, 2 criteria were explained by (Epstein in 1984) In the absence of nutrition, the plant seeds are not able to complete a cycle of normal life and the all element is the element of some necessary plant particles or metabolism. Approximately there are sixteen essential minerals in plants. Almost in them, $O_2$ oxygen and C carbon are acquired from air. Some other nutrients containing $H_2O$ water are acquired from soil. These sixteen nutrients are classified into two main groups.

- Non-Mineral Nutrients
- Mineral Nutrients

**Non-Mineral Nutrients**

These involve H (hydrogen), C (carbon) and $O_2$ (oxygen). These are located in $H_2O$ (water) and air. Hydrogen is necessary for plants building sugars and growing of the plant. Hydrogen is properly acquired from the $H_2O$ water. Oxygen is essential for cellular breathing (respiration). During the photosynthesis process plants convert $H_2O$ and $CO_2$ in to $O_2$ and other organic reach compounds and also produce glucose but it needed oxygen respiration (Jayaraman et al*.,* 2021). For this outcome plant collapse (break down) this produce (ATP) (Adenosine Triphosphate) and glucose C (Carbon) is the foundation of many bio-molecules plants such as protein, starches, cellulose, and carbohydrates etc.

**Mineral Nutrients**

Mineral nutrients are basically these elements found on earth and required for the development of the human body. They provide us sodium, iron, calcium, and so on. There are thirteen mineral nutrients. These consist of iodine, zinc, iron, etc. These get to the soil, deliquesce in $H_2O$ (water), and are involved in root plants (Maathuis, 2014). Nutrients of minerals are not sufficient in soil for a plant to germinate strongly. For this process, fertilizers help to enhance the nutrients in the soil.

**Results and Discussion**

Brijal is very important for our health because they have many qualities, such as high fiber and having many nutrients. It is mostly cultivated and belongs to the Solanium family. Many different methods may be utilized to enhance its growth rate and germination rate because brinjal is used on a huge scale and cultivated in large areas. The current experimental work was carried out to estimate the impact of laser irradiation-treated seeds on the growing indices of brinjal tubers. Research work was done to measure out the different characteristics, such as biochemical and biophysical characteristics, of brinjal seedling. Basically the experiment was performed in the statistics method (completely randomized design) CRD. This research work was performed in the sessions of October 2018 to March 2019. Data related to growth was measured weekly.

**Parameters of Germination**

- Germination percentage
- After 50% germination days
- Mean growth rate
- Vigor index 1
- Shoot length of plants
- Chlorophyll content
- Brinjal Tubers diameter
- Moisture content
- Yield of brinjal tubers
- Minerals content
- Vitamin C
- Fat and some others extraction

**Germination Percentage**

Growth rate is the total germination of brinjal seeds after that it had been sowing in the field area and it had been active or inactive in different time periods. When the seeds were sowing (planted), they remained slow (inactive) but still the correct (suitable) surroundings for growth, such as oxygen in adequate quantity, adequate quantity of water, enough quantity of temperature, and some quantity of light. Seeds absorbed some quantity of water and quantity of oxygen, and seed coats were opened, and then radicals appeared in the seed. The starting term of a plant was growing (Wang et al., 2017) assumed that the laser irradiation impact on germination of brinjal seeds. It was noted that the seeds of brinjal were treated at different levels of energy. The percentage rate of germination of 97 percent, 98 percent, and 99 percent was needed in seeds irradiated at 10mJ, 15mJ, and 20mJ laser energies shown in Figure 1. However, control treatment showed a germination rate percentage of 98%.

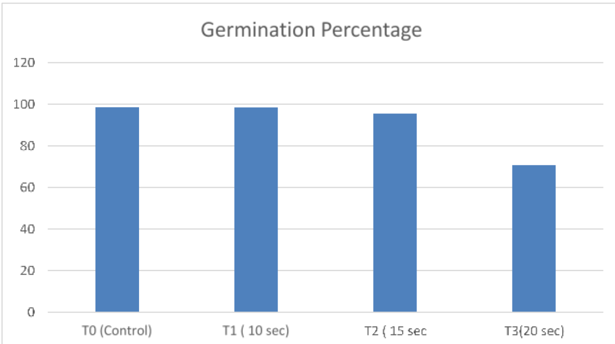


**Fig. 1:** Pre-sowing effect of laser irradiance on germination percentage of brinjal tubers.

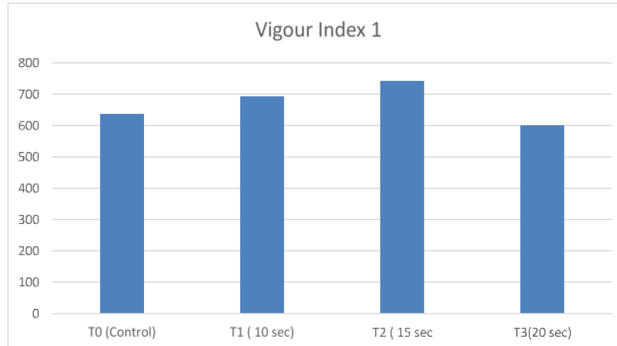


**Fig. 2:** Pre-sowing irradiation of laser impact on Vigour Index 1 of brinjal tubers

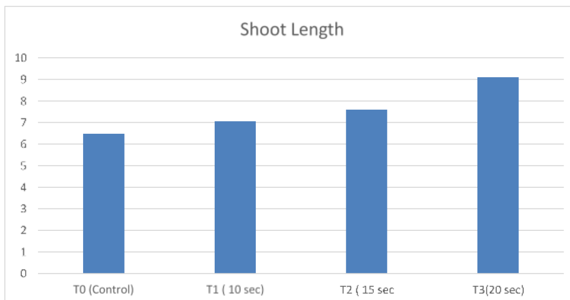


**Fig. 3:** Pre-sowing effect of laser effect on brinjal tubers Shoot Length

**Vigor Index 1**

By estimating the percentage of growth of every replication of every treatment and length of seedling, index of vigor1 was estimated. The outcomes achieved were examined statistically, as shown in Figure 2. The ANOVA application showed that the laser source of irradiation had not shown the impact of ($P > 0.05$) on the index of Vigour of brinjal seeds.

**Shoot Length**

For the measurements of shoot length 9 averaged plants from each treatment were randomly selected. The collected data for the shoot length analyzed statistically shown in Figure 3 which shows non- significant results.

**Future Perspectives**

The outcomes from this investigation showed that benefits of economical may be required by utilized technology of laser in the process of growing of brinjal tubers, and so that further experiments in how understands to these advantages (benefits) is warranted. Diagnosis of different disease in the plants and detection of early accurate are foundation of plants germination and the depletion of both losses such as quantitative losses quantitative losses in the yield of crops. Detection of early accuracy in the diseases of crops challenges till remains in Pakistan. This is due to the large numbers of farmers and due to officers of agricultural extension lack knowledge about diagnostic plant disease. So this is the time period that in which technology of Laser also utilized for exactly diagnosis and observation of diseases in plants to acquired maximum production of yield.

**Conclusion**

The laser irradiation has amazing characteristics, like high brightness, monochromatic, polarization, directionality, coherence, and high beam density, which can be helpful not only in the field of all engineering spheres but also be utilized in the fields of biology and agriculture (plant growing). In the agriculture field, small changes happen in the bio physiological levels of plant seeds, and then plants can restore their germination and development based closely on the different types of laser irradiation, its range of wavelength, and levels of energy. The outcomes of the experiment analysis showed that the pretreatment of laser outstanding influenced the different parameters of seed development and germination. Similarly, an experiment was conducted by utilizing radiation from a laser source on pea plant seeds. Irradiation of a laser source accelerates plant germination and enhances vigor index, shoot length, root diameter, and chlorophyll content. In this experiment, the outcomes also showed clearly that semiconductor laser sources of irradiation of seeds of plant embryos could increase the different activities of minerals that riot (rose) to the seeds radiated by using different energy levels of diode lasers, and different levels of activated minerals of these plants were positively connected with their improved growth rate.

## References


Aguilar, J., Gramig, G. G., Hendrickson, J. R., Archer, D. W., Forcella, F., & Liebig, M. A. (2015). Crop species diversity changes in the United States: 1978–2012. *PloS one*, 10(8), e0136580. https://doi.org/10.1371/journal.pone.0136580

Allen, R. G. (1992). New approaches to estimating crop evapotranspiration. In *International Symposium on Irrigation of Horticultural Crops, 335* (pp. 287-294).

Asghar, H. N., Rafique, H. M., Khan, M. Y., & Zahir, Z. A. (2017). Phytoremediation of light crude oil by maize (*Zea mays L.*) bio-augmented with plant growth promoting bacteria. *Soil and Sediment Contamination: An International Journal, 26*(7-8), 749-763.

Asghar, H. N., Rafique, H. M., Khan, M. Y., & Zahir, Z. A. (2017). Phytoremediation of light crude oil by maize (Zea mays L.) bio-augmented with plant growth promoting bacteria. *Soil and Sediment Contamination: An International Journal*, *26*(7-8), 749-763. https://doi.org/10.1080/15320383.2017.1414771.

Asghar, T., Y. Jamil, M. Iqbal., & M. Abbas. (2016). Laser light and magnetic field stimulation effect on biochemical, enzymes activities and chlorophyll contents in soybean seeds and seedlings during early growth stages. *Journal of Photochemistry and Photobiology B: Biology*, *165*(2), 283-290. https://doi.org/10.1016/j.jphotobiol.2016.10.022.

Boote, K. J., Jones, J. W., Hoogenboom, G., & White, J. W. (2010). The role of crop systems simulation in agriculture and environment. *International Journal of Agricultural and Environmental Information Systems (IJAEIS), 1*(1), 41-54.

Chen, C. C., & Chang, C. C. (2005). The impact of weather on crop yield distribution in Taiwan: some new evidence from panel data models and implications for crop insurance. *Agricultural Economics, 33*, 503-511.

Chen, C., Wang, E., & Yu, Q. (2010). Modelling the effects of climate variability and water management on crop water productivity and water balance in the North China Plain. *Agricultural Water Management, 97*(8), 1175-1184. https://doi.org/10.1111/j.1574-0864.2005.00097

Ćwintal, M., & Goliasz, S. (2018). Influence of microelements and attractants on the elements of yield structure and yield of white clover (*Trifolium repens L.*) seeds. *Agronomy Science, 73*(3), 15-27. https://doi.org/10.24326/asx.2018.3.2

Dick, R. P. (1994). Soil enzyme activities as indicators of soil quality. In *Defining Soil Quality for a Sustainable Environment, 35*, 107-124.

Dondini, M., Jones, E. O., Richards, M., Pogson, M., Rowe, R. L., Keith, A. M., & Smith, P. (2015). Evaluation of the ECOSSE model for simulating soil carbon under short rotation forestry energy crops in Britain. *Gcb Bioenergy, 7*(3), 527-540.

Epstein, R. (1984). The principle of parsimony and some applications in psychology. *The Journal of Mind and Behavior*, *30*(1), 119-130. https://doi.org/10/43853318.

Fonseca, B. B., Beletti, M. E., Silva, M. S. D., Silva, P. L. D., Duarte, I. N., & Rossi, D. A. (2010). Microbiota cecal, morfometria do íleo, pH do inglúvio e desempenho zootécnico de frangos de corte sob suplementação com probióticos. *Revista Brasileira de Zootecnia, 39*, 1756-1760.

Garcia, A., Gaju, O., Bowerman, A. F., Buck, S. A., Evans, J. R., Furbank, R. T., & Atkin, O. K. (2023). Enhancing crop yields through improvements in the efficiency of photosynthesis and respiration. *New Phytologist, 237*(1), 60-77.

Hunt, W., Birch, C., & Vanclay, F. (2012). Thwarting plague and pestilence in the Australian sugar industry: Crop protection capacity and resilience built by agricultural extension. *Crop Protection, 37*, 71-80

Jayaraman, S., Naorem, A. K., Lal, R., Dalal, R. C., Sinha, N. K., Patra, A. K., & Chaudhari, S. K. (2021). Disease-suppressive soils—beyond food production: a critical review. *Journal of Soil Science and Plant Nutrition, 21*, 1437-1465.

Khalifa, R. M. (2024). Canola Response to Alternate Furrow and cut-off Irrigation Combined with Bio-Mineral Fertilizer Applications at North Delta Region. *Journal of Soil Sciences and Agricultural Engineering, 15*(3), 67-80.

Maathuis, F. J. (2014). Sodium in plants: perception, signalling, and regulation of sodium fluxes. *Journal of Experimental Botany, 65*(3), 849-858.

Menges, E. S. (1991). Seed germination percentage increases with population size in a fragmented prairie species. *Conservation Biology*, *5*(2), 158-164. https://doi.org/10.1111/j.1523-1739.1991.tb00120.

Muthusamy, A., Kudwa, P. P., Prabhu, V., Mahato, K. K., Babu, V. S., Rao, M. R., ... & Satyamoorthy, K. (2012). Influence of Helium-Neon laser irradiation on seed germination in vitro and physico-biochemical characters in seedlings of Brinjal (*Solanum melongena L.*) var. Mattu Gulla. *Photochemistry and Photobiology*, *88*(5), 1227-1235. http://doi.org/10.53911/JAE.

Rezvani, M., Nadimi, S., Zaefarian, F., & Chauhan, B. S. (2021). Environmental factors affecting seed germination and seedling emergence of three Phalaris species. *Crop Protection, 148*, 105743.

Rupal, G., Swathy, P. S., Mahato, K. K., & Muthusamy, A. (2020). Impact of physical and chemical pre-treatments on in vitro seed germination of brinjal (*Solanum melongena L.*). *Journal of Applied Horticulture*, *22*(1), 27-32. https://doi.org/10.37855/jah.2020.v22i01.06.

Salvo, L., Hernández, J., & Ernst, O. (2010). Distribution of soil organic carbon in different size fractions, under pasture and crop rotations with conventional tillage and no-till systems. *Soil and Tillage Research, 109*(2), 116-122.

Shafique, H., Jamil, Y., ul Haq, Z., Mujahid, T., Khan, A. U., Iqbal, M., & Abbas, M. (2017). Low power continuous wave-laser seed irradiation effect on Moringa oleifera germination, seedling growth and biochemical attributes. *Journal of Photochemistry and Photobiology B: Biology*, *170*(2), 314-323. https://doi.org/10.1016/j.jphotobiol.2017.04.001.

Swathy, S. P., Kiran, K. R., Rao, M. S., Mahato, K. K., Rao, M. R., Satyamoorthy, K., & Muthusamy, A. (2016). Responses of He-Ne laser irradiation on agronomical characters and chlorogenic acid content of brinjal (*Solanum melongena L.*) var. Mattu Gulla. *Journal of Photochemistry and Photobiology B: Biology*, *164*(1), 182-190. https://doi.org/10.1016/j.jphotobiol.2016.09.010.

Wang, Y., Snodgrass, L. B., Bethke, P. C., Bussan, A. J., Holm, D. G., Novy, R. G., & Endelman, J. B. (2017). Reliability of measurement and genotype× environment interaction for potato specific gravity. *Crop Science, 57*(4), 1966-1972.

Younis, M. E. B., Hasaneen, M. N. A. G., & Abdel-Aziz, H. M. M. (2010). An enhancing effect of visible light and UV radiation on phenolic compounds and various antioxidants in broad bean seedlings. *Plant Signaling & Behavior, 5*(10), 1197-1203.