DF-405
[1-6]

RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Enhancement of Germination of *Oryza sativa* L. (Rice) Seeds using Solar Concentrators

K.H.C. Sandaruwani[1], B.F.A. Basnayake[1], M.I.M. Mowjood[1], R.T.K. Ariyawansha[2]

10.18805/ag.DF-405

ABSTRACT

Background: The initial stage of plants and sunlight as the energy source are very critical for plants. A boost of biochemical reactions given by concentrating solar energy at the initial stage of plants may continue accelerated growth and yield. Rice is a high-demand crop. Therefore, in this research study, the germination of rice seeds was studied under different radiation levels using a spherical solar concentrator (SSC).

Methods: The germination percentage of rice seeds was observed under different radiation levels. Experimental setup 1 consisted of 60 cm below the SSC (SSC 60 cm) and open environment (OE) whereas Experimental setup 2 consisted of 45 cm below the SSC (SSC 45 cm) and OE.

Result: SSC (60 cm) and SSC (45 cm) manifested 1.2 and 1.5 times higher solar energy than the OE, respectively. In experimental setup 1, it was observed germination percentages of 65.2 and 58.8 in SSC (60 cm) and OE, respectively whereas, in the experimental setup 2, 86.9 and 77.5 in SSC (45 cm) and OE, respectively. It can be assumed that plants grown under SSC during the nursery stage, reach the fullest potential at maturity as a result of increased flux density and lower soil temperature under the SSC.

Key words: Germination, Rice, Solar concentrators, Solar radiation.

INTRODUCTION

For any kind of work, the beginning is very important. A good start most probably results in a better ending as well. In living beings (animals, plants) also, the initial stage is very important. Germination is "the process in which seed embryo starts growing, which leads to the development of seedling" (Jhade, 2019). Seed germination is the most crucial stage in the plant development process. Physiological and biochemical changes that happen during germination directly affect seedling survival, vegetative growth and ultimately yield and quality (Ali *et al.* 2017; George and Rice, 2016).

The vigour, optimal growth and development of plants are dependent on solar radiation within the required spectrum for plant growth (Kumari *et al.* 2017). Therefore, the Sun is the main energy source of the earth (www.dnr.louisiana.gov). Solar radiation provides the energy for all the metabolic processes in plants (Campilo *et al.* 2012). All those metabolic processes consist of biochemical reactions. Almost all the biochemical reactions are catalyzed by enzymes (Chaudhury, 2010). If a higher amount of energy is given, the rate of biochemical reactions increases when there are adequate substrates. A previous study by Sritharan *et al.* (2019) revealed that when solar energy is concentrated at the early growth stage of tomato (*Solanum lycopersicum* L.) plants, it enhances seed germination, shows higher plant growth, early flowering, early yield and reduced transplanting shock.

The most important variable affecting seed germination is the temperature (Milbau *et al.* 2009). Every species has a minimum and a maximum temperature range where germination can occur. Germination cannot be taken place below and above these extreme temperatures. Botey *et al.* (2021) reported low germination of *Solanum aethiopicum* L. seeds at lower (15°C) and higher (35°C) temperatures. Gibberellins promote germination. Temperature directly influences on upregulation of genes that control the production of gibberellins. Germination occurs when the embryo elongates and the radical protrudes from the seed coat. This process is facilitated by enzymes. Enzymes degrade endosperm tissue and rupture the seed coat. Chemical signaling induced by temperature regulates the production of enzymes (Finch-Savage and Leubner-Metzger, 2006). Furthermore, Amiri *et al.* (2017) revealed that the combination of different light qualities and gibberellic acid affect on morphological characteristics of plants.

Solar concentrators can be used to get a higher amount of solar energy to the specified surface area. Those are

[1]Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, 20400, Sri Lanka.
[2]School of Technology, Faculty of Engineering and Technology, Sri Lanka Technological Campus (SLTC Research University), Padukka 10500, Sri Lanka.

Corresponding Author: K.H.C. Sandaruwani, Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, 20400, Sri Lanka. Email: khcs93@gmail.com

How to cite this article: Sandaruwani, K.H.C., Basnayake, B.F.A., Mowjood, M.I.M. and Ariyawansha, R.T.K. (2022). Enhancement of Germination of *Oryza sativa* L. (Rice) Seeds using Solar Concentrators. Agricultural Science Digest. DOI: 10.18805/ag.DF-405.

Submitted: 11-09-2021 **Accepted:** 07-07-2022 **Online:** 29-07-2022

devices that allow the collection of sunlight from a large area and focus it on a small receiver (Muhammad-Sukki *et al.* 2010). There are different types of solar concentrators such as parabolic concentrators, spherical concentrators, hyperboloid concentrators, Fresnel lens concentrators, quantum dot concentrators, *etc*. Out of these concentrators, spherical solar concentrators are more useful as larger areas are always exposed to sun rays, can concentrate solar radiation coming from any direction and are less affected by changes in the position of the sun (Devaraj *et al.* 2016).

Many studies indicate that higher solar radiation increases the growth and yield of plants (Deng *et al.* 2015; Barmudoi *et al.* 2016). Therefore, the provision of artificial light is becoming more popular in areas where solar radiation is less. But, instead of artificial light, it would be very beneficial to give higher energy to the plants with freely available solar radiation with solar concentrators. But it would be very costly to use solar concentrators to cover a large crop field. Nursery management is very important for any crop as it facilitates better care and attention during the early growth stage. Since the early growth stage is very important for any crop, it can be expected to have a boost of growth rate by concentrating solar energy only at the early growth stage of plants, especially during the germination process. Therefore, if the concentration of solar energy is done only at the nursery stage of the plants, it would be more practical and cost-effective.

Rice is one of the most important crops in the world. It is the most popular food crop in the developing world and the staple food of more than half of the world's population (ricepedia.org). Rice plays a major role in the agriculture sector of Sri Lanka being the staple food. It occupies 34% of the total cultivating area in Sri Lanka (https://doa.gov.lk/rrdi/index.php). Rice contributes 1.6% of the country's GDP (Wijesinghe *et al.* 2015). It is projected that the demand for rice will increase by 1.1% per year and to meet this task, rice production should increase at a rate of 2.9% per year (https://doa.gov.lk/rrdi/index.php). Rice production can be increased in two ways; increasing the cultivating area and increasing the yield per unit area. Since the availability of arable land becoming lower, the challenge is to increase yield per unit area. Thus, the increment in the production of rice is very important. Also, rice is grown in nurseries to give better care and ultimately to increase the yield. Therefore, in this research study, the germination of rice seeds under two different radiation levels was studied compared to direct sunlight to evaluate the possibility of accelerating the germination.

MATERIALS AND METHODS

The experimental setup of the research study was established at the site of Meewathura farm, Faculty of Agriculture, University of Peradeniya. This research study was conducted from January to March 2020. The Spherical Solar Concentrator Refracted through Glass Water Media (SSC) designed and fabricated by Sritharan *et al.* (2019) was placed at the experimental site for concentrating solar radiation (Fig 1). Afterward, the refracted beam of solar radiation at different heights (25, 30, 45, 60 and 90 cm) below the SSC was studied. Solar power was measured using Solar Power Meter (TES 1333R). Then, 60 cm and 45 cm below the SSC were selected for further experiments. BG 252 rice variety was selected and dry seeds (without soaking) were placed in nursery trays (306 seeds per nursery tray) filled with coir dust. Each nursery tray was kept under the SSC and open environment (exposed to direct sunlight).

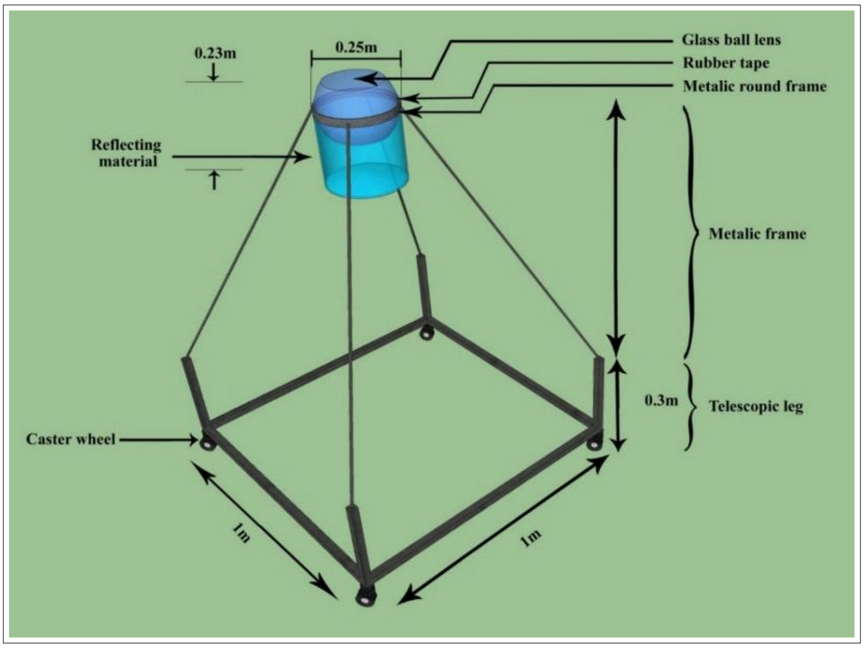

Fig 1: A schematic digram of the Solar Concentrator Refracted through Glass Water Media (SSC) (Sritharan *et al.* 2019).

Experimental setup 1 consisted of 60 cm below the SSC (SSC 60 cm) and open environment whereas Experimental setup 2 consisted of 45 cm below the SSC (SSC 45 cm) and open environment. Germination was observed and the percentage was calculated by using the below equation (Eq. 01). Soil surface temperature was measured using an IR thermometer (AS530).

Germination percentage =

$$\frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100 \quad \text{(Eq. 1)}$$

RESULTS AND DISCUSSION

Solar power

The variation of solar power with SSC (60 cm) and SSC (45 cm) compared to the open environment is displayed in Fig 2 and 3, respectively. Both solar power under the SSC (60 cm) and SSC (45 cm) were higher compared to the open environment throughout the day. The correlation between cumulative solar power in the open environment and the SSC (60 cm) indicates that solar power under the SSC (60 cm) is 1.2 times higher than in the open environment (Fig 4). Fig 5 shows the correlation of cumulative solar power in a day between the open environment and SSC (45 cm). It indicates that 45 cm below the SSC gives 1.5 times higher solar energy than the open environment. SSC (45 cm) proved 2 times higher solar energy than the open environment from 11 am to 1 pm. Although it provided higher solar energy, it may not have caused harm as the refracted beam did not concentrate in one place for a longer period. Also, the glass and water media in the SSC might filter harmful radiation.

Temperature

Variations of the temperature of the soil surface in the nursery tray within a day in different treatments are shown in Fig 6 and 7, respectively. Although solar power is higher under the SSC, soil surface temperature under both SSC (60 cm) and SSC (45 cm) are lower than open environment throughout the day. Statistical analysis for cumulative temperature in SSC (60 cm) and SSC (45 cm) are displayed in Table 1. That may be due to SSC filter infrared radiation present in the solar radiation or else evaporative cooling may take place at a higher rate as energy is higher under the SSC. Florence *et al.* (1950) stated different types of glasses can absorb infrared rays in different wavelength regions.

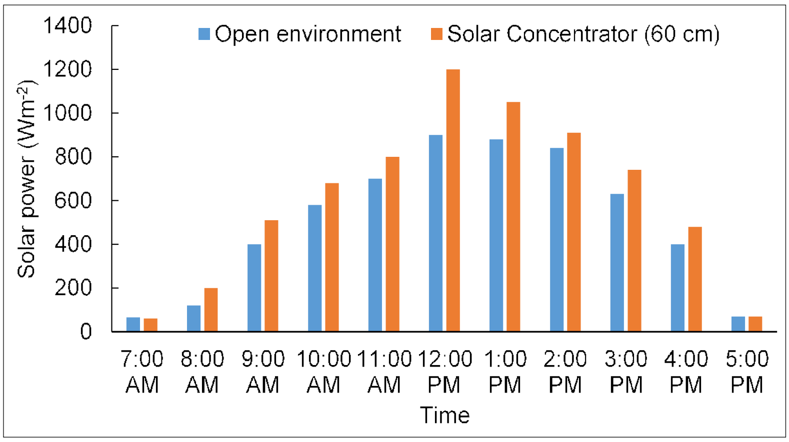

Fig 2: Variations of solar power within a day in the SSC (60 cm).

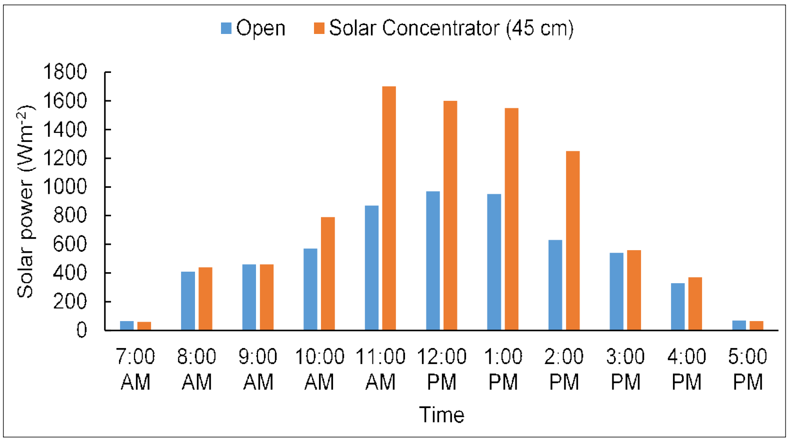

Fig 3: Variations of solar power within a day in the SSC (45 cm).

Germination results

The seed germination percentage of the treatments with SSC (60 cm) and SSC (45 cm) are given in Table 2. It took 7 days to initiate germination from the sowing as dry seeds were placed without soaking. In each experimental setup, the highest germination percentage could be seen in the SSC compared to the open environment. The germination process involves several biochemical transformations. These transformations are governed by energy. Higher solar energy availability under the SSC might be the reason for higher germination under the SSC. Also, final germination in the SSC (45 cm) is higher than in the SSC (60 cm). Higher solar energy received in the SSC (45 cm) over SSC (60 cm) may be the reason.

Temperature is related to energy. Farooq *et al.* (2005) have observed earlier and synchronized germination as a

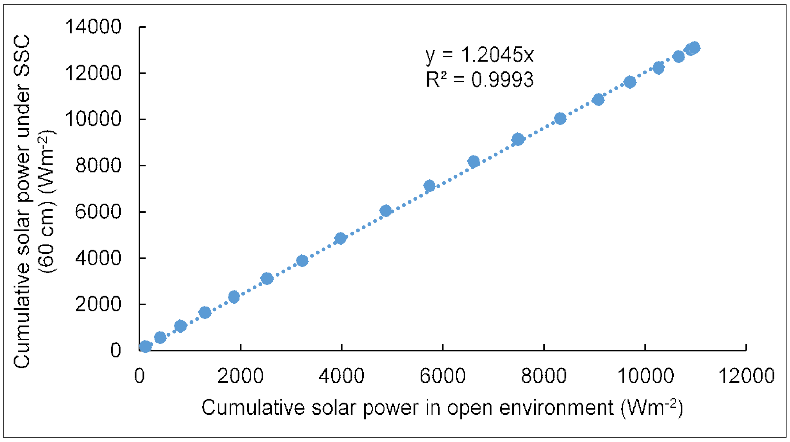

Fig 4: Correlation of cumulative solar power in the open environment and the SSC (60 cm).

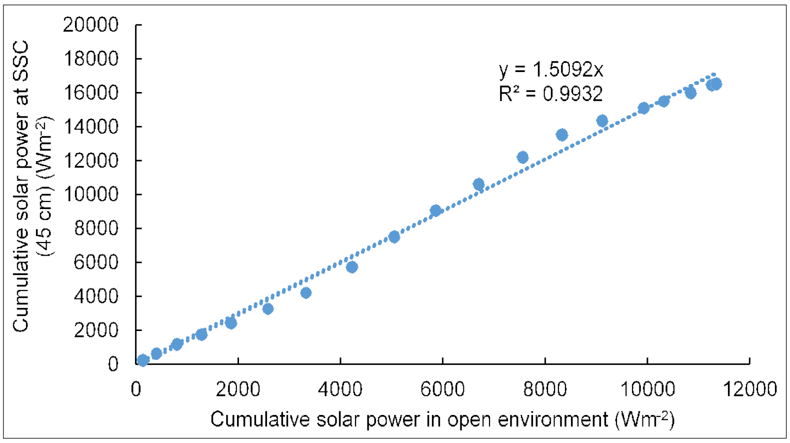

Fig 5: Correlation of cumulative solar power in the open environment and SSC (45 cm).

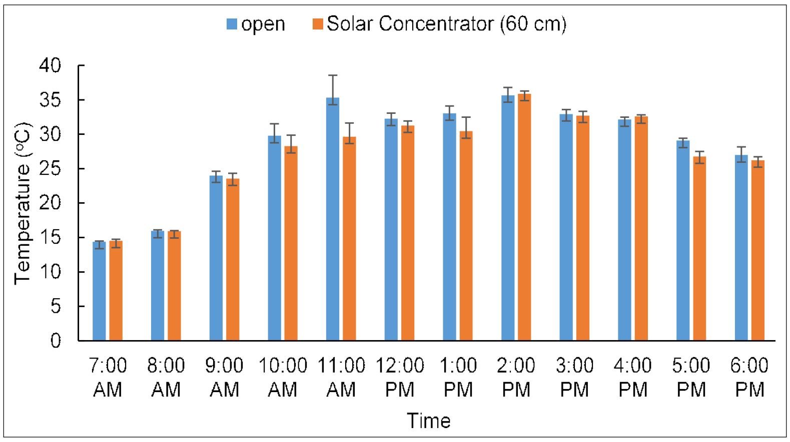

Fig 6: Variations of temperature on the soil surface in nursery trays within a day with the SSC (60 cm).

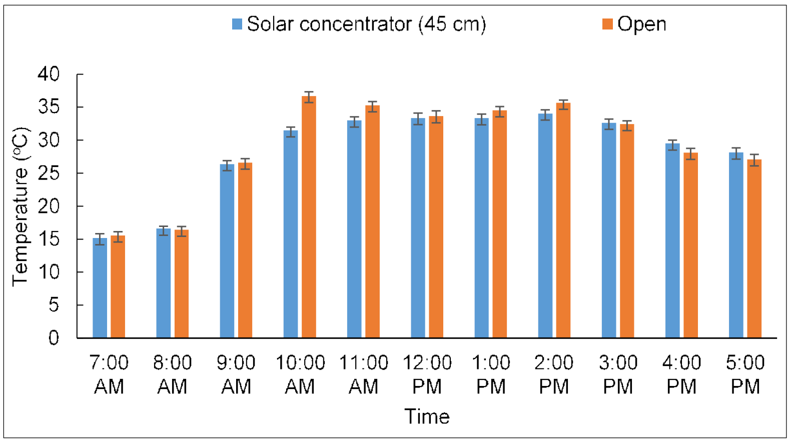

Fig 7: Variations of temperature on the soil surface in nursery trays within a day with the SSC (45 cm).

result of the thermal hardening of indica rice seeds. Farooq *et al.* (2004) also reported that pre-sowing temperature treatments significantly affect germination and seedling vigor. The reason for the enhancement of germination due to thermal treatment is the pre-enlargement of the embryo (Austin *et al.* 1969). However, it is contradictory to our results since soil temperatures reduced with the increased influx of energy.

General discussion

The reason for this ambiguity may be due to the dispersion of light by the SSC refracted through glass water media most likely towards photosynthetically active radiation (PAR), which is light in the 400 to 700 nanometer wavelength range. Additional support to this hypothesis could be that the ultraviolet spectrum would have been shifted towards longer wavelengths because the recorded energy levels were much higher. Furthermore, the position of the concentrated light was continuously shifting, thus preventing the scorching of the sprouts. Interestingly, if the intensity of a sun fleck light exceeds the photosynthetic photon flux density (PFD) level of photosynthetic saturation, a part of the extra energy is stored in high-energy metabolite pools and then it can be used for successive CO_2 fixation for a few seconds (Kirschbaum and Pearcy, 1988; Pearcy *et al.* 1990). The light intensity of the SSC is much more than the sun fleck effect but may not be limited to the assimilation of CO_2 since the leaf canopy density in the nursery was low. Nevertheless, constraints may arise like high humidity influencing photosynthetic rate according to Nishimura *et al.* (2000). The best possible conditions could be to increase CO_2 and reduce humidity in a controlled nursery environment.

It is also important to consider physiological balances during different stages of growth, more so in the initial stages. According to the findings of Yang and Lee (2001), for rice plants to grow, adequate amounts of chlorophylls are acquired to provide sufficient amounts of photosynthetic assimilates and different growth stages need matched amounts of chlorophylls to meet the developmental requirements. The same authors concluded that high

Table 1: Statistical analysis for variation of temperature on the soil surface.

Experiment	Mean value of cumulative soil surface temperature (K)	
	SSC	Open environment
Experimental setup 01 (SSC 60)	3605.57[b]	3619.23[a]
Experimental setup 02 (SSC 45)	3299.68[b]	3328.95[a]

[a,b] = Means bearing the same letters in the row are not significantly different at 5% probability level.

Table 2: Germination results.

Experiment	Germination %			
	Day 1	Day 2	Day 3	Day 4
Experimental setup 01				
SSC (60 cm)	6.2	50.3	58.5	65.2
Open environment	6.2	44.8	55.2	58.8
Experimental setup 02				
SSC (45 cm)	9.2	40.5	66.3	86.9
Open environment	6.9	43.5	73.5	77.5

temperatures had pronounced negative effects on the growth of rice plants, although chlorophyll content was higher. In other words, the SSC plants must have reached the fullest potential in maturity for the nursery stage of growth at lower soil temperatures, if there were no constraints on available nutrients.

CONCLUSION

SSC (60 cm) and SSC (45 cm) indicated 1.2 and 1.5 times higher solar power compared to the open environment. But temperature under SSC is significantly lower than the open environment at 5% probability level. Germination percentages were higher in the experiments with the SSC compared to the open environment. SSC (45 cm) reported 86.9% of germination while the open environment displayed 77.5%. Higher solar energy given by SSC enhanced germination and initial growth.

RECOMMENDATION

Solar concentrators can be used to accelerate germination (approximately 12%) and the following growth during the nursery stage in areas where sufficient sunlight is not available. Adverse temperatures can be avoided by increasing moisture content in the soil to facilitate evaporative cooling and designing moving solar concentrators. Also, the movement of solar concentrators can be used to enhance light use efficiency as plant leaves can store extra energy for a few seconds (Kirschbaum and Pearcy, 1988; Pearcy *et al.* 1990). Further research should be carried out to investigate the optimum solar energy. Accordingly, the size and velocity of the movement of solar concentrators should be adjusted.

Conflict of interest: None.

REFERENCES

Ali, A.S. and Elozeiri, A.A. (2017). Metabolic processes during seed germination. Advances in Seed Biology. 141-166.

Amiri, A., Kafi, M., Kalate-Jari, S. and Matinizadeh, M. (2017). Morphology and Responses of *Tulipa gesneriana* L. to light quality in combination with GA and cold storage time. Indian Journal of Agricultural Research. 51: 568-573.

Austin, R., Longden, P.C. and Hutchinson, J. (1969). Some effects of ‘hardening’carrot seed. Annals of Botany. 33: 883-895.

Barmudoi, B. and Bharali, B. (2016). Effects of light intensity and quality on physiological changes in winter rice (*Oryza sativa* L.). International Journal of Environmental and Agriculture Research. 2: 65-76.

Botey, H.M., Ochuodho, J.O., Ngode, L., Dwamena, H. and Osei-Tutu, I. (2021). Temperature and light effects on germination behaviour of African eggplant (*Solanum aethiopicum* L.) seeds. Indian Journal of Agricultural Research. 56: 122-128.

Campillo, C., Fortes, R., Prieto, M.D.H. and Babatunde, E.B. (2012). Solar radiation effect on crop production. Solar Radiation. 1: 494.

Chaudhury, S. and Igoshin, O.A. (2010). Dynamic disorder in quasi-equilibrium enzymatic systems. PLoS One. 5(8): e12364.

Deng, N., Ling, X., Sun, Y., Zhang, C., Fahad, S., Peng, S. and Huang, J. (2015). Influence of temperature and solar radiation on grain yield and quality in irrigated rice system. European Journal of Agronomy. 64: 37-46.

Devaraj, M. and Priyan, S.S. (2016). Solar energy collection using spherical sun power generator. International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering. 4: 3-5.

Energy and Time. Accessed on July 20, 2020. Available on: www.dnr.louisiana.gov/assets/TAD/education/ECEP/sources/a/a.htm

Farooq, M., Basra S.M.A., Hafeez, K. and Warriach, E.A. (2004). Influence of high and low-temperature treatments on seed germination and seedling vigor of coarse and fine rice. International Rice Research Notes. 29: 69-71.

Farooq, M., Basra, S.M.A., Ahmad, N. and Hafeez, K. (2005). Thermal hardening: A new seed vigor enhancement tool in rice. Journal of Integrative Plant Biology. 47: 187-193.

Finch-Savage, W.E. and Leubner-Metzger, G. (2006). Seed dormancy and the control of germination. New Phytologist. 171. https://doi.org/10.1111/j.1469-8137.2006.01787.x

Florence, J.M., Allshouse, C.C., Glaze, F.W. and Hahner, C.H. (1950). Absorption of near-infrared energy by certain glasses. Journal of Research of the National Bureau of Standards. 45: 121-128.

George, M.R. and Rice, K. (2016). Plant growth and development. Ecology and Management of Annual Rangelands. Davis, CA: Department of Plant Science. Pgs. 73-95.

Jhade, R.K. (2019). Types and Stages of Seed Germination. Accessed on July 20, 2020. Available on: http://www.jnkvv.org/PDF/060420201422255.pdf.

Kirschbaum, M.U.F. and Pearcy, R.W. (1988). Gas exchange analysis of the fast phase of photosynthetic induction in Alocasia macrorrhiza. Plant Physiology. 87: 818-821.

Kumari, P., Kumar, P.V., Kumar, R., Wadood, A. and Tirkey, D.A. (2017). Effect of weather on grain yield of direct seeded upland rice varieties in Jharkhand, India. Indian Journal of Agricultural Research. 51: 562-567.

Milbau, A., Graae, B.J., Shevtsova, A. and Nijs, I. (2009). Effects of a warmer climate on seed germination in the subarctic. Annals of Botany. 104: 287-296.

Muhammad-Sukki, F., Ramirez-Iniguez, R., McMeekin, S.G., Stewart, B.G. and Clive, B. (2010). Solar concentrators. International Journal of Applied Sciences. 1: 1-15.

Nishimura, S., Tang, Y., Itoh, K. and Koizumi, H. (2000). Photosynthetic light-use efficiency in rice (*Oryza sativa* L .) leaf under light with fluctuating intensities at two different ambient humidities. Plant Production Science. 3: 79-83.

Pearcy, R.W., Roden, J.S. and Gamon, J.A. (1990). Sunfleck dynamics in relation to canopy structure in soybean [*Glycine max* (L.) Merr.] canopy. Agricultural and Forest Meteorology. 52: 359-372.

Rice as a crop. Accessed on July 10, 2020. Available on: www.rice pedia.org.

Rice Research and Development Institute. Accessed on July 05, 2020. Available on: https://doa.gov.lk/rrdi/index.php

Sritharan, S., Ariyawansha, R.T.K. and Basnayake, B.F.A. (2019). Design and Development of a Solar Concentrator Through Glass-Water Media to Trigger Crop Productivity. In: Proceedings of Peradeniya University International Research Sessions (iPURSE 2019), University of Peradeniya, Peradeniya, Sri Lanka 11th-12th September 2019.

Wijesinghe, P. and Wijesinghe, R. (2015). Technical efficiency of paddy farming in low country wet zone. Hector Kobbekaduwa Agrarian Research and Training Institute. Accessed on July 06, 2020. Available on: http://www.harti.gov.lk/images/download/reasearch_report/new1/186.pdf.

Yang, C.M. and Lee, Y.J. (2001). Seasonal Changes of Chlorophyll Content in Field-Grown Rice Crops and Their Relationships with Growth. Proceedings of the National Science Council, Republic of China. Part B, Life Sciences. 25(4): 233-238.