

Effect of Pulsed Concentrated Solar Radiation on Seeds and Plants

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Role of sunlight for plant growth through photosynthesis is well known. The systematic use of concentrated sunlight is being made in medicine, biology and chemistry since last three decades. To avoid the burning effect of concentrated sunlight, Pulsed Concentrated Solar Radiation (PCSR) was developed, in which seeds of biological objects are exposed intermittently. The PCSR increased the germination, plant growth, development and productivity in many crops with early maturity by 3 to 6 d. The treatment accelerates the metabolism, which leads to active growth of embryo. This treatment has been reported to increase the content of nucleic acids, sugars, vitamins, quality of produce and even acts as a promising mutagenic factor.

Introduction

By the turn of century, India's population is likely to explode beyond the one billion mark. Nearly 220 millions tonne of food grains will be required to feed this number of people¹. In order to meet the increasing demand for food, the crop productivity has to be increased. It can be increased by the use of fertilizers, insecticides, irrigation, and growth hormones. But these practices are very expensive. Hence, it becomes necessary to look for new methods to increase the crop output. One such method reported is the use of concentrated solar radiation for seed treatment. The systematic use of this method has been started in medicine, biology and chemistry only three decades ago². Though favourable results were obtained the concentrated sunlight often caused the burning of the seeds. To avoid such deleterious effect, PCSR was developed.

PCSR is used as pre-sowing treatment of seeds, tubers, pollen of plants and plants in culture. This treatment resulted in enhanced germination, growth, development and crop productivity. Seedlings from irradiated seeds show more intense growth, development and early maturity by 3 to 6 d³.

It improves the quality of the produce and also induces resistance to frost and diseases⁴. Evstigneev⁵ has reported physiological mutations when the pollen grains were exposed to pulsed radiation. The most advantageous features of the treatment are: (i) Simple and safe operation, (ii) Effective on a large group of plants, (iii) No adverse effect, and (iv) Universal availability of solar radiation.

Equipment: Solar Seed Irradiator

Various systems⁶⁻¹⁰ have been developed in the USSR for irradiation of biological materials like seeds, cultures and plants with pulsed concentrated solar irradiation. To

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overcome the problem of non-availability of sunlight, artificial light source like xenon lamp is being used in the USSR for the irradiation of seeds, irrespective of seasons¹¹.

Some work on similar line has been carried out at Central Salt and Marine Chemicals Research Institute, Bhavnagar for the first time in India. The solar seed irradiator fabricated at this Institute, consists of cylindrical parabolic mirror, having focal length of 0.8 m and total area 2.25 m² with aperture width 1.5 m. The reflecting surface is provided by glass mirror strips of 25 mm width fitted on the metal framework which has the desired parabolic shape. The seeds to be irradiated are kept in glass tubes of 5.0 cm diam, kept inside the rotating tube holder, which is fixed on a metal frame in such a way that linear focus falls on the seeds in glass tubes. The rotating speed fixes the pulse/min at which seeds are irradiated and these speeds can be adjusted through the pulleys and belt drive coupled with electric motor which is connected to the reduction gearing. This enables to change the speed of shaft from which rotatory movement is transferred to tube holder (Figure 1),

Since the concentrated solar radiation applies to living materials only, the temperature is liable to rise rapidly.

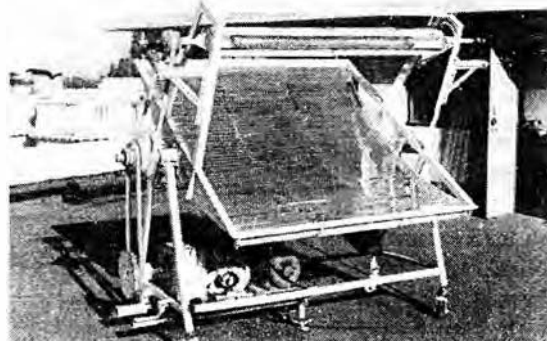


Figure 1 — Solar seed irradiator

Hence, care must be taken to avoid overheating and maximum temperature of the object should not exceed 50°C⁸. The above parameters must be standardized before undertaking any irradiation programme.

Effect on Seed Germination

Stanko² has reported unusual hardening and change in physiological state of seeds, which causes the difference in the degree of water uptake and swelling of irradiated seeds as compared to untreated seeds. Seeds of barley absorbed 35 to 65 per cent more water and number of swollen seeds increased by 15 to 45 per cent, whereas treated seeds of cotton absorbed 5 to 22 per cent more water and gave 22 per cent more germination than the untreated seeds⁸. Thus, pre-sowing irradiation of seeds, even in their earliest stages of activity significantly effects the physiological processes, creating the prerequisites for the enhancement of germination, growth, development and crop productivity. Gomkale and Kurian¹² have reported that PCSR is effective in augmenting the germination and early seedling growth in seeds in cotton and groundnut. Similar reports have been reported for cotton³, ambari seeds¹³, kenaf seeds¹⁴, and corn seeds¹⁵. Both pot and field experiments showed increase in seed germination after treatment with PCSR.

Effect on Growth and Yield

Galkina and Sadykov¹⁶ reported acceleration of growth of cotton and rice. Umarov¹⁷ from large-scale experiments has shown that it increased the yield of cotton by 8 to 10 per cent. Such increase in the yield of cotton is attributed to the enhancement in germination rate of seeds, the number of buds/plant and number of bolls. Stanko² has reported that the plants grown from irradiated seeds have more radiant energy over the entire spectrum and photosynthesizes more vigorously than control plants. In wheat PCSR is effective in the production of heavier and larger seeds apart from increased yield.

Seedlings from irradiated seeds show more intense growth and development than control. The budding phase was found to be early by 3-6 d with increased yield³. The increased productivity is due to activation of photosynthesis under the influence of concentrated pulse light which, in turn, activates the exchange of substances in the organism. The result is an intensified flow of assimilants and product of photosynthesis to the root system and their translocation to the aerial organs.

The beneficial effect of pulsed concentrated solar radiation is stable. This treatment significantly increases the yield of many crops viz., cotton^{18,19}, rice²⁰, wheat²¹, and ambari^{22,14}. Shakhov⁴ has reported that the PCSR increases the leaf area and yield in melons and water melons. The treatment has been reported to increase growth, development and nitrogen fixation in algae viz. *Stratonostoc linckiaef. muscorum* and *Gloeotheca rupestris*. Twenty per cent increase in biomass production with an additional N-fixing capacity of 63 per cent was observed by

Kuchkarova *et al.*²³. Treatment with PCSR of rice seeds in suspension of blue green algae, i.e., *Nostoc muscorum* showed an increase in germination, better growth and increased yield¹¹. The effect of irradiation is strain and time specific.

Effect on Quality

The beneficial effect of PCSR is also reflected in the quality of agricultural produce. It effects the metabolism and increases the sugar content of the crops, vitamin C in tomato and cucumber, starch in potato, sugar in beat, fibre length in cotton⁴ and free amino acids in wheat and barley²⁴. The treatment helps in inducing resistance to frost and diseases. Quality of the seeds is also improved by this treatment, viz. germination ability and germination energy of seeds. Such seeds on sowing gave stand density of 4-5 plants higher /10 m² more than control¹⁶. The treatment accelerates ripening and improves the quality of bast of ambari with respect to fibre content, N increase in strength, and flexibility²⁵. Umarov *et al.*¹⁵ have reported improvement in the quality of Kenaf (*Hibiscus cannabinis*) seeds with respect to sowing, germination energy and 1000 grain weight.

Effect at Biochemical and Genetic Level

This treatment can trigger off many life processes¹⁷. The beneficial effect in cotton may be attributed to the intensified breakdown of the major storage products such as protein, fat, and starch by enzymes. Azimov and Rakhimov²⁶ have reported that the light pulse irradiation induces lipase activity can be taken as an index of growth of cotton plant by light pulse stimulation. Similar results are reported by Zodape and Chauhan²⁷. Evstigneev⁵, has reported the appearance of electronically excited free radicals in seeds by PCSR, which activates many hydrolytic enzymes. This activation is important, both for germination process and the subsequent stages of development. The treatment intensifies the germination capacity and enhances the carbohydrates, amino acids, and nucleic acid metabolism in wheat. An increase in the content of amino acids like arginine, histidine, and lysine is important in the synthesis of nucleoproteins. It is well known that certain amino acids are induced by light to attach themselves to the uracyl in the nucleic acids²⁴. Application of pulsed concentrated solar radiation in cotton seeds increases the overall content of nucleic acids by 28 to 35 per cent compared with control (RNA increases was 29 to 30 per cent and DNA 4 to 13 per cent).

Evstigneev⁵ has reported increased chlorophyll content in wheat leaves. This treatment can increase or decrease the electrical conductivity of chlorophyll solution and other compounds. On transfer of electrons between the molecules in the solution which were neutral prior to irradiation, PCSR resulted in an increase in the electrical conductivity due to the formation of ions which are responsible for the transport of the charges. Pulsed irradiation with a particular

spectral composition and period of exposure results in photo-induced mutation. Prolonged pulsed irradiation of tomato seeds led to the formation of new and more productive mutant forms²⁴.

Conclusions

Application of PCSR has profound effect on the physiological, genetical and biochemical parameters. Such treatment will be of practical use towards crop production since it influences germination, growth, yield, and quality.

Since we have carried out limited study on the effect of PCSR, a lot of work remains to be carried out in this fertile field to elucidate the mechanism of action of PCSR. Thus the use of PCSR may open new vistas in the field of physiological research and may go a long way to augment the crop productivity. In order to meet the demand of food for increasing population, there should be simultaneous increase in the production of food grain. In this situation high yielding varieties and the economic method for increasing the yield will have to be adopted. Hence, it is felt that pulsed concentrated solar radiation would be a boon for India.

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