Development of Plasma System for the Seeds Treatment to Improve Germination and Growth

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Abstract. Pre-sowing treatment of seeds to improve germination, growth and yield of crops has been in use in agriculture traditionally by physical and chemical treatments. In recent times, treatment of seeds with low magnetic fields has been shown to improve growth and yield of crop plants. Physical treatment of seeds with low magnetic field of 100 – 200 mT strength improves germination and early seedling growth of soybean and maize seeds. There have been several studies on the impact of plasma on the seeds since plasma treatment improves germination of seeds and subsequent growth of the seedlings. This has been observed in the seeds of wheat, soybean, clover, rye, barley, pea and lupin. After plasma treatment shoot weight increased by 30% in wheat under experimental conditions. The mechanism of plasma induced bio-stimulation of germination and growth of seeds is yet to be analyzed in detail. There are different methods to increase the germination and growth of seeds by plasma treatment like DC Glow discharge plasma, RF Glow discharge plasma, Dielectric Barrier Discharge plasma (DBD) and plasma activated water (PAW). We at center of excellence for plasma research have developed a plasma glow discharge system for the Germination and Growth of seeds with glow discharge plasma treatment.

INTRODUCTION

There have been several studies on the impact of plasma on the seeds since plasma treatment improves germination of seeds and subsequent growth of the seedlings. This has been observed in the seeds of wheat [1], soybean [2], clover, rye, barley, pea and lupin. Plasma activated water improves germination and growth of radish, tomato and sweet pepper [3]. After plasma treatment shoot weight increased by 30% in wheat under experimental conditions [4]. In soybean, seedling growth including shoot length, shoot dry weight, root length and root dry weight significantly increased after plasma exposure of seeds. Non-thermal discharge plasma in atmospheric air produces reactive radicals, especially reactive oxygen and nitrogen species (ROS and RNS). Evidence has been obtained about the penetration of plasma radicals into the inner parts of the seed and their effect on the metabolic processes of the seed. In wheat and oat, seed composition of phenolic compounds was changed in the seeds after exposure to plasma [5]. The seed coat acts like a partially permeable membrane allowing the passage of small molecules or ions but blocking the passage of bigger molecules. Air plasma treatment changes the wetting properties of seeds due to oxidation of their surface that leads to faster germination and greater yield. Increases in the concentration of free radicals in the seeds play an important role in acceleration of seed metabolism.

The early biochemical events that lead to germination of seeds include degradation of reserve food materials in the seeds, like starch in maize and proteins in soybean. Higher seed reserve utilization after plasma treatment has been observed in soybean seeds by calculating seed reserve depletion percentage and seed reserve utilization efficiency. This degradation is enzymatically carried out by a class of enzymes known as ‘hydrolases’; starch is degraded by amylase to glucose and proteins by proteases to amino acids. The reserve food material in the seeds is also degraded non-enzymatically by free radicals which react with bigger biomolecules cleaving them randomly.
Improved germination of seeds and vigorous growth of seedlings is often related to higher production of free radicals by chemical or physical treatments. It is interesting to note that plasma exposure also enhances the reactive oxygen and reactive nitrogen species at the surface of the seeds as evidenced by previous studies on plasma biology. These radicals also have the ability to penetrate into the seeds [6]. It is possible that these radicals may act as bio-stimulants for the activation of enzymes that can degrade the reserve food materials in the seeds. Alternatively the free radicals themselves can degrade the biomolecules and hasten the process of metabolism in the seeds. There is no data available at present on both of these possibilities.

PLASMA

Plasma is one of the four fundamental states of matter (the others being solid, liquid, and gas). When air or gas is ionized, plasma forms with similar conductive properties to that of metals. Plasma is the most abundant form of matter in the Universe, because most stars are in plasma state. Plasma comprises the major state of matter of the Sun. Heating a gas may ionize its molecules or atoms (reducing or increasing the number of electrons in them), thus turning it into plasma, which contains charged particles: positive ions and negative electrons or ions. Ionization can be induced by other means [7], such as strong electromagnetic field applied with a laser or microwave generator, and is accompanied by the dissociation of molecular bonds, if present. Plasma can also be created by the application of an electric field on a gas. The presence of a non-negligible number of charge carriers makes the plasma electrically conductive so that it responds strongly to electromagnetic fields. Like gas, plasma does not have a definite shape or a definite volume unless enclosed in a container; unlike gas, some common plasma is found in stars and neon signs. In the universe, plasma is the most common state of matter for ordinary matter, most of which is in the rarefied intergalactic plasma and in stars. Much of the understanding of plasmas has come from the pursuit of controlled nuclear fusion and fusion power, for which plasma physics provides the scientific base.

FIGURE 1. Systematic Diagram: For Plasma Enhanced Chemical Vapor Deposition (RF-PECVD) & Plasma Treatment
PLASMA ENHANCED CHEMICAL VAPOR DEPOSITION (RF- PECVD)

Fractionally ionized plasmas have great interests in germination of seeds, coating and material processing. In such plasmas, the energy exchange between the electron and neutral gas is very inefficient. So, the bulk plasma is more positive than any object present and in contact with plasma. The voltage between the plasma and substrate drops at the sheath region and the ions in the sheath feel an electrostatic force and are accelerated towards the substrate. Thus, the substrate exposed to plasma receives energetic ion bombardment. CVD performed in a plasma environment leads to increase in the nucleation, growth kinetics, and hence plays an important role in the process of sputtering of the impurities called Plasma Enhanced Chemical Vapor Deposition (PECVD) [8]. In this process, the temperature of the plasma up to 500 watt will be at room temperature which is most important in case of seeds treatment because at high temperature the seed will die and will not germinate. The plasma environment in PECVD performs mainly two basic functions; reactive chemical species are formed by cracking of relatively stable molecules via electron impact collisions and supplies energetic radiation such as positive ions, metastable species, electrons, and photons. PECVD performed with RF plasma is called RF-PECVD.

EXPERIMENTAL SET-UP

A system has been designed, fabricated and installed in SVVV [9], Indore for producing Plasmas through Plasma Enhanced Chemical Vapor Deposition (PE-CVD) technique and dc glow discharge for different plasma applications. The Plasma system consist of

1. Plasma chamber consist of a cylindrical stainless steel vacuumed chamber with Capacity 30Lit, Height (30cm) and diameter of (36cm) with cathode assembly Electrode (two circular electrodes, one of which has movable shift denoted "Anode" and fixed electrode denoted" cathode
2. RF power supply (13.56MHz, 600 Watt): For the RF electric discharge of gas
3. Turbo Molecular Pump & Rotary Pump: inbound vacuum pumps system: For Rough Vacuum and to achieve vacuum of the order of 3*10⁻⁶mbar
4. Residual Gas Analyzer: For the detections of the species inside the Chamber with a range of 300amu
5. Ion gauge heads and readers: For the measurement of vacuum inside the chamber From atmosphere pressure to 3*10⁻⁹ mbar

FIGURE 2. Installation of System and Production of Plasma
6. High Voltage DC- power supply (2 KV, 1 amp): For the DC electric discharge of Gas
7. Mass flow controller: To control the flow of gas with preciseness
8. Digital pirani gauge head and redder: For the measurement of vacuum inside the Chamber up to 3*10^{-3} mbar
9. Argon, H2& O2 and Nitrogen gas for the treatment of seeds
10. UV – Visible Spectrophotometer for Biochemical estimations of enzymes and free radicals will be done by spectro photometric methods.

CONCLUSION

A system has been designed fabricated and installed at the Center of Excellence for Plasma Research, Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore for the treatment of different types of seeds with different types of gases at different powers and timing of exposure and pressure for the Germination and Growth of seeds. The system is fully operational and preliminary Glow Discharge & RF plasmas with N2 gas has been successfully obtained in the system. This system has two electrodes and seed will be placed at cathode, where a stand is attached with it, which can hold 50 seeds for the plasma treatment. Different seeds can be treated without disturbing the vacuum of the system. After primary production of plasma we are going to start treatment of different seeds to see the germination and growth.

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REFERENCES: