Minireview Paper

Plasma Treatment –A tool to improve seed quality – A Review

Abstract

Plasma is a partially ionized gas composed of positive and negative ions, electrons, neutrals, molecules, photons and UV-light. It is the "fourth state of matter". There are number of pre-sowing treatments that are employed to enhance seed quality *viz*., seed priming, coating and biological seed treatments, etc. In recent times, a new technique namely plasma treatment is evolved for this purpose. The plasma can be generated in many ways however for seed treatment the glow discharge method is commonly used due to its properties like seed quality improvement, seed enhancement and decontamination of pathogens present on seed coat surface. In glow discharge method plasma is formed by passage of electric current through a low pressure gas (argon). It is created by applying a voltage between two electrodes in a glass tube containing argon gas. When the voltage exceeds a certain value, the gas in the tube ionizes, transforms into plasma. The ionized gas begins the conducting of electricity, causing it to glow. Plasma can be generated either under low pressure or at atmospheric pressure. Plasma pre-treatment of seeds stimulates their germination and leads to suppression of fungal and bacterial plant pathogens. Crop yields are improved by treating the seeds in a low temperature plasma discharge generated between spaced electrodes connected to a source of high frequency electrical power.

Here, a dry seed treatment i.e. plasma treatment is employed to increase the seed coat permeability without increasing the moisture content of seed unlikely priming and other such treatments. Plasma treatment has been successfully applied in agriculture for seed quality improvement, seed enhancement and pathogenic micro-organisms inactivation.

Keywords: Plasma, Seed treatment, Ionized gas, Seed quality, Glow discharge

1. Introduction

Plasma, the fourth state of matter, is an ionized gas. The term 'Plasma' was coined by Tonks and Langmuir in 1929. It is a partially ionized gas composed of positive and negative ions, electrons, neutrals, molecules, photons and UV-light. In the simplest case, it is formed by applying a potential difference (of a few 100 V to a few kV) between two electrodes that are inserted in a cell or reactor (or that form the reactor walls). The reactor is filled with a gas (an inert gas or a reactive gas) at a pressure ranging from a few mTorr to atmospheric pressure. A positive effect of low temperature plasma treatment on germination of various agricultural crops has been found **(Sera B *et al* [1])**. Due to the potential difference, electrons that are emitted from the cathode by the omnipresent cosmic radiation are accelerated away from the cathode, and give rise to collisions with the gas atoms or molecules (excitation, ionization, dissociation. Plasma can be reached by applying sufficient energy to a gas. Today, plasma is used for varieties of industrial applications ranging from arc welding, metal hardening, nuclear fusion, creation of nano structure, functional polymer coating and change in surface hyrdrophilicity (**Filatova I *et al* [2]).** Plasma in nature can be found in the form of **Lightening-** when a power full current forms between two highly charged areas in atmosphere, it passes through a long skinny column of the air heating it up to five times the temperature of the surface of sun. Thus, forming a trail of plasma. In the **Universe** 99 per cent of observable universe is made up of plasma. **Sun-** plasma makes up the sun and is visible in the solar flare that erupts from its surface and the **Stars** are giant balls of plasma, the tremendous heat generated by fusion reaction has same effect on the atom of gas. And the artificially generated plasma can be found as Neon and Fluorescent light, when it is turned on, an electric current ionizes the gas in the bulb (argon with little mercury) to become plasma that interacts with phosphor to create light and plasma TV. There are number of pre-sowing treatments that are employed to enhance seed quality *viz*., seed priming, coating and biological seed treatments, etc. In recent times, a new technique namely plasma treatment is evolved for this purpose. It has been shown in a number of previous studies that plasma pre-treatment of seeds stimulates their germination and leads to suppression of fungal and bacterial plant pathogens (**Filatova *et al* [3]).** Crop yields are improved by treating the seeds in a low temperature plasma discharge generated between spaced electrodes connected to a source of high frequency electrical power (**Krapivina *et al* [4]**). The plasma can be generated in many ways however for seed treatment the glow discharge method is commonly used due to its properties like seed quality improvement, seed enhancement and decontamination of pathogens present on seed coat surface **(Tian X B *et al* [5]).** In glow discharge method plasma is formed by passage of electric current through a low pressure gas (argon). It is created by applying a voltage between two electrodes in a glass tube containing argon gas. When the voltage exceeds a certain value, the gas in the tube ionizes, transforms into plasma. The ionized gas begins the conducting of electricity, causing it to glow **(Mehta [6]).** Plasma can be generated either under low pressure or at atmospheric pressure. Ionization of a gaseous molecule to produce plasma is carried out by applying sufficient discharge voltage and frequency.

Here, a dry seed treatment i.e. plasma treatment is employed to increase the seed coat permeability without increasing the moisture content of seed unlikely priming and other such treatments. Plasma treatment has been successfully applied in agriculture for seed quality improvement, seed enhancement and pathogenic micro-organisms inactivation (**Filatova *et al* [7]).** The problem of poor or slow germination can be solved through many techniques and one of them is plasma treatment. Plasma treatment has become an important factor widely used in biotechnology, medicine & food industry (**Padureanu [8]).** In the present studies, plasma treatment was used to investigate and study their individual as well as combined effects on the seed quality of vegetable crops.

2. Generation of plasma

Plasma is one of the four fundamental states of matter (the others being solid, liquid and gas). It has properties unlike those of the other states. Plasma can be created by heating a gas or subjecting it to a strong electromagnetic field, applied with a laser or microwave generator at temperatures above 5000^{o}c. this decreases or increases the number of electrons in the atoms or molecules, creating positive or negative charged particles called ions **(Wikipedia)**. Plasma can be generated either under low pressure or at atmospheric pressure. Ionization of a gaseous molecule to produce plasma is carried out by applying sufficient discharge voltage and frequency. It is created by applying a voltage between two electrodes in a glass tube containing argon gas. When the voltage exceeds a certain value, the gas in the tube ionizes, transforms into plasma. The ionized gas begins the conducting of electricity, causing it to glow **(Mehta, [6]).** Plasma can be generated either under low pressure or at atmospheric pressure. Lightning and technical plasmas are generated by an electric breakdown in a gas. The ignition process leads to a subsequent current flow that generates an electrical discharge. Depending on the power source that feeds the plasma, we distinguish direct current (dc), low frequency alternating current (ac), and radio-frequency (rf) discharges **(Pixel A [9]).** Generation of plasma by gaseous electrical discharge is discussed as, various types of discharge, including corona discharge, glow discharge and arc discharge and the characteristics of the plasma produced will be introduced. The electrical power sources used for the generation of these plasma including DC, AC, RF, microwave and pulsed capacitor discharge are introduced **(Wong C S and Mongkolnavin R [10]).**

3. Types of Plasma

- Capacitively coupled plasma
- Cascaded Arc Plasma Source
- Inductively coupled plasma
- Wave heated plasma
- Arc discharge
- Corona discharge
- Capacitive discharge
- Piezoelectric direct discharge plasma
- **Glow discharges**
- Dielectric barrier discharges (DBD)

Glow Discharge

A glow discharge is plasma formed by passage of electric current through a low pressure gas. It is created by applying a voltage between two electrodes in a glass tube containing gas. When the voltage exceeds a certain value called the striking voltage, the gas in the tube ionizes, becoming a plasma and begins conducting electricity, causing it to glow with a colored light. Cold plasma seed treatment is a modern eco-agricultural high technique that could increase crop yields (**Jiafeng J *et al* [11]**). Gas plasma is a gas in which some of the atoms or molecules have become ionized; in other words, electrons have become separated, and the gas plasma thus contains electrons, ions, and the original atoms or molecules **(Siliprandi R A [12])**. We used oxygen as the process gas to strike and apply plasma, with the oxygen gas supplied from a gas bottle. **Preechayan *et al* [13]** concluded the ability of constructed one atmospheric glow discharge plasma on a reduction of contaminated aflatoxin producing fungi from agricultural products.Thus, in the study we used low temperature plasmas, often called glow discharges, to treat seeds, and we used air as the process gas for reasons of cost and the ability to create reactive oxygen species in the plasma glow. **Stone *et al* [14]** reported that electric glow discharge and radiofrequency (RF) electric field treatments were studied for inducing germination of impermeable cottonseed in selection 16-B-7 of *Gossypium hirsutum* L. The positive effect of non-thermal plasma treatment on radish seeds for 20 minutes duration was found effective for increase of length of roots and sprouts (**Mithai *et al* [15])**. A further advantage is the speed of the process, such erosion to relevant thickness can be done within time frames of a few minutes.

For our treatment of hard coated seeds, we intend for the reactive oxygen species to attack the seed coat and make it thinner and more permeable to water, so that water can get inside and swell the embryo for germination. Based on non-ionizing low level radiation, it could activate the vitality of seed without gene mutation, so there is no genetic risk (**Zivkovic S *et al* [16]).** Some Fabaceae seeds also have a thin layer of lipids on their outer surface, which makes the seed surface water-repellant. **Krapivina *et al* [4]** reported that crop yields are improved by treatment of the plant seeds in a low temperature plasma discharge. Finally, reactive oxygen species should also be able to destroy fungal spores. Gas plasmas are, however, not a “natural” state of gases. They must be produced within a confined space that contains a suitable gas and plasma is established by the application of an electric field across the gas. Stimulating effect of low temperature plasma on seed germination characteristic of red clover seeds revealed that plasma dose of 260W are effective for getting early and high germination rate for red clover seeds **(Munkhuu *et al* [17]).** In our laboratory, we create plasmas by putting an electric potential across a gas inside a glass chamber. A positive effect of cold plasma treatment on seed germination and seedling growth of soyabean was depicted (**Ling *et al* [18])**. When the seeds are put on to the lower electrode and the drive voltage applied, the plasma starts to glow and the seeds are immersed in the glow and the reactive oxygen species it contains **(Griesser S *et al* [19])** We also had to check that the air plasma treatment would not damage the embryo. Air plasmas do not produce heat and hence, we assumed, can be used for thinning seed coats without embryonal damage. **Spatenka *et al* [20]** reported the influence of cold plasma treatment on germination enhancement of wheat and oat caryopsis. The seed coat operates like a partially permeable membrane, allowing passage of certain, especially small, molecules or ions, but acting as a barrier to others (**Sera B *et al* [21]**).

4. Different processes occuring inside a plasma

Plasma is an ionized gas consisting of equal concentrations of positive and negative charges and a large number of neutral species. In the simplest case, it is formed by applying a potential difference (of a few 100 V to a few kV) between two electrodes that are inserted in a cell or reactor (or that form the reactor walls). The reactor is filled with a gas (an inert gas or a reactive gas) at a pressure ranging from a few mTorr to atmospheric pressure. Due to the potential difference, electrons that are emitted from the cathode by the omnipresent cosmic radiation, are accelerated away from the cathode, and give rise to collisions with the gas atoms or molecules (excitation, ionization, dissociation. Air plasma treatment changes the wetting properties of seeds due to oxidation of their surface that leads to faster germination and greater yields, increases the concentration of free radicals in seeds which plays an important role in acceleration of the seed metabolism (**Filatova I *et al* [22]).** Cold radiofrequency air plasma treatment of seeds supplied the effective method of modification of their surface properties including wettability, and also leads to decrease in the apparent contact angle of seeds **(Bormashenko *et al* [23]).**

Excitation Collision

It gives rise to excited species that decay to lower levels by the emission of light and the process makes that gas discharge plasma typically emits a characteristic glow.

Ionisation Collisions

It creates ion-electron pairs, the ions are accelerated toward the cathode, where they release secondary electrons and these electrons are accelerated away from the cathode and can give rise to more ionization collisions.

Dissociation Collisions (in the case of a molecular gas)

It yields the formation of radicals, which are very reactive, can chemically react with the walls of the reactor, resulting in coating formation (by deposition) or surface modification.

A combination of secondary electron emission at the cathode and ionization in the gas, gives rise to self sustained plasma.

Why plasma technology in seed technology?

- Fast economic and pollution free method to improve seed performance
- Decontaminating off the pathogens from seeds
- No loss of seed quality
- Alternative to chemicals causing harm to human health and environment

5. Conclusion

- Plasma treatment is an effective technology in improving seed germination rate
- It also enhances speed of germination in both normal and stress conditions
- Seed surface enrichment and inactivation of seed pathogens

- It is cost effective and ecologically sustainable
- Its quick treatment with no side effect
- The oxygen plasma treatment technique applied to hard seed coated seeds has shown encouraging results. It has shown that the plasma treatment does not cause any adverse genetic effect.
- Plasma removes effectively very thin lipid layer that makes seeds water repellant, as shown by much better wetting of seeds after treatment.
- Plasma probably reduces the length of the biopolymer chains that makes up the seed coat, enabling better water transport through the seed coat for swelling of the embryo.
- Key advantage of plasma treatment is that it is a dry process. (Seeds comes out looking the same & can be stored until sowing is to be done).

Future line of work

- Plasma treatment is an effective technology in improving seed germination rate
- It also enhances speed of germination in both normal and stress conditions
- Seed surface enrichment and inactivation of seed pathogens
- It is cost effective and ecologically sustainable
- Its quick treatment with no side effect

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