Increment of nitrogen content in shallot seeds by corona glow discharge plasma irradiation

D T Sugianto1,*, I Puspitasari2, A I Susan3, E Sasmita3 and M Nur1,3

1 Physics Department, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia
2 Biology Department, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia
3 Center for Plasma Research, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia

*Corresponding author: dimastirtoyoso@gmail.com

Abstract. Research on the application of corona glow discharge plasma to increase the nitrogen content on shallot seeds has been done. This study aims to determine the relationship between the irradiation parameters to the amount of nitrogen contained in treated shallot. Corona glow discharge plasma was generated using a plasma reactor with multiple points to the plane configuration, with the number of point electrode is 837 points. The characteristics of current-voltage of reactor circuit were carried out; by varying the distance between electrodes from 1 to 4 cm; to determine the value of ion mobility. Shallot seeds were irradiated at an optimum radiation distance of 3 cm, a voltage of 14 kV, current of 500 μA, and varying irradiation time of 0, 15, and 30 minutes. The characteristic result without sample at the distance of 3 cm yielded the highest mobility of 1.94x10^-7 cm/v.s, while with sample yielded of 9.98x10^-4 cm/v.s. The proximate test results at shallot seeds irradiated for 15 minutes showed the highest nitrogen content of 2.31%, higher than that of a control sample of 2.27%. Furthermore, the water content in irradiated samples decreased with increasing radiation time, with the lowest water content achieved in the 30 minutes irradiated sample of 86% compared to 86.8% in the control samples.

1. Introduction
Plasma is the fourth form of material from the solid, liquid, gas sequence [1]. Plasma in nature is produced by lightning and aurora borealis. The aurora borealis effect on plants has been associated with ion generation on the earth surface by the electric atmosphere [2]. Plasma treatment can affect the growth and physiology of plant, increases seed resistance from stress and disease, modify structure and seed layers, and stimulate seed germination [3]. Plasma technology can be used as a decontaminator for plant and food from bacteria, growth accelerator, and preservation for plant [4]–[5]. The function of nitrogen in a plant such as: stimulating the growth of roots, stems, and leaves; makes the leaves more green because the nitrogen can increase the chlorophyll, reproduce saplings, improve the quality and quantity of product [6].

On the plant growth acceleration that is using a corona glow discharge plasma reactor with multipoint to plan configuration electrode, nitrogen will be directly irradiated toward the shallot seed roots
Corona plasma glow discharge will be ionizing nitrogen gases between two electrodes at atmospheric pressure, and the nitrogen gases will penetrate to the shallot seeds [7].

2. Methods

2.1 Characteristic of electric current - voltage

Characteristics of current as a function of voltage are performed first with the purpose to obtain the optimal current and voltage values for irradiating shallot seed with an optimum distance between electrodes. Characteristics of current as a function of voltage are performed in two-phase which is with and without the sample. So the difference between current and voltage when irradiating with and without sample can be known.

![Figure 1. Scheme of multi-point to plate electrodes configuration](image)

The point electrodes will be given a positive pole and the plane electrode will be given a negative pole, so it can be called positive plasma glow discharge [1]. This circuit is using high voltage direct current which is connected to HV probe so the voltage can be read on the voltmeter and the current will be read on the amperemeter. In this research, the measured parameter is voltage, the distance between electrodes, and irradiation time. The irradiation time is 15 minutes, 30 minutes and 0 minutes as the control.

2.2 Shallot Seeds Irradiation

After current characterization as a voltage function with and without sample has been done, shallot seeds will be irradiated at the optimal distance. With time irradiation 15 minutes, 30 minutes, and 0 minutes as the control. Shallot seeds will be placed under the plane electrode upside down and the shallot seed roots will be placed on each hole of the plane electrode, so the plasma corona can enter directly through the root. Corona plasma will be formed at the point electrode.
2.3 Ion mobility

When the power source is turned on, the electrons will be flowing from cathode to anode. The electrons will be ionizing gases molecule at electrodes point, because of electric field on the electrodes, the ions will flow to the cathode through the drift region. The ions will move with average velocity, this can be called drift velocity, the unipolar saturated current will be formed according to Eq. 1

\[ I_s = \frac{2\mu \varepsilon_0 V^2}{d} \]  

with \( I_s \) is an unipolar saturated current (Ampere), \( V \) is voltage (Volt), \( \mu \) is unipolar ion mobility (m/Vs), \( \varepsilon_0 \) permittivity of vacuum (F/m) and \( d \) is space between electrode (m) [8]. With the data obtained from the experiment are voltage (Volt), unipolar saturated current (Ampere), \( \varepsilon_0 \) permittivity of vacuum (F/m), and the distance between electrodes. So, the value of ion mobility can be declared using Eq. 2:

\[ \mu = \frac{I_s d}{2\varepsilon_0 V^2} \]  

In this case, the research is using multi-points to plane electrodes configuration so the number of point electrodes will be declared as \( N \). And the permittivity will be declared as \( \varepsilon_e \) since using shallot seed. So, the Equation will become:

\[ \mu = \frac{I_s d}{2\varepsilon_e V^2 N} \]  

The mobility value can be calculated based on the linear gradient from the characteristic graph, so the Equation will become:

\[ \mu = \frac{\partial^2 d}{2\varepsilon_e N} \]  

with \( \partial^2 = \sqrt{\frac{I_s}{V^2}} \), while the total dielectric constant were calculated for a series configuration by assuming that the air and sample were installed in series.

2.4 Physical and chemical properties assessment

The physical changes of the shallot seeds can be observed after a few weeks after shallot seeds are planted. The parameter of shallot seeds growth can be represented by the growth of shallot seed leaf after a few weeks.

The chemical properties were observed using proximate test. With nitrogen and water content percentage inside of shallot seed as the tested variable.
3. Result and Discussion

3.1 Characteristic of electric current – voltage

The current characterization as a function of voltage is performed first with the purpose to obtain the optimal current and voltage values for irradiating shallot seed with an optimum distance between electrodes. Furthermore, the characterization of electric current-voltage used to obtain the ion mobility value. By using characteristic of the electric current-voltage graph the value of linear gradient will obtain, and that will be used on one of the variables for determining ion mobility value. The characterization of electric current-voltage started at 0 kV until the arc is appearing.

![Characteristic of electric current as a function of voltage](image)

**Figure 2.** Characteristic of electric current as a function of voltage (a) without the sample, (b) with sample

From Figure 2 and Figure 3 above can be concluded that the current increases in proportion to the voltage increment at each variation of the distance between the electrodes. That matches with the equation of unipolar saturated current (Eq. 1) with current value reversed with the distance between the electrodes but proportional with the square of voltage. So the farther distance between electrodes, the higher the voltage [1].

3.2 Ion mobility

When the voltage increase continuously, there will be an ionization chain and will create an ion wind between electrodes [1]. The calculation of ion mobility will use Eq.4, with reference to the characteristic current-voltage graph as $\hat{\mu}^2$. As we can see in figure 4 and figure 5 that shows ion mobility as a function of the distance between electrodes in the corona discharge region.
From the graphic above can be concluded the ion mobility increased on the 1 cm, 2 cm, 3 cm distance between electrodes and will decrease on the 4 cm distance between electrodes. The values of ion mobility are different from the reference that mobility ion values are approximately $\pm 2$ cm$^2$/Vs for atmospheric pressure [9].

### 3.3 Morphological growth

Plasma treatment can affect the growth and physiology of plants [3]. The morphological growth of shallot seeds can be observed after a few weeks of planting. The parameter growth of shallot seeds is the length of the leaves. The sample of shallot seeds has been irradiated on three different time variable, that is 0 minute (control), 15 minutes, 30 minutes.

| Week 1 (cm) | Week 3 (cm) | Week 6 (cm) |
|-------------|-------------|-------------|
| 0           | 23.15       | 35.19       |
| 15          | 23.63       | 36.00       |
| 30          | 23.80       | 35.47       |

In Table 1 above as we can see, the optimal growth of shallot seeds occurs in the 15th minute, with growth value reach 2.58 cm taller than control variable on the 6th week. And at the 30-minute irradiation decreased growth at 6 weeks rather than 15-minute irradiation, but still higher than control variable.

### 3.4 Chemical changes

The chemical changes of shallot seed can be known through the proximate test by testing the water and nitrogen content at each time variable. The changes of water and nitrogen content of the irradiated shallot seeds can be seen in figure 4 and figure 5.
The proximate test results at shallot seeds irradiated for 15 minutes showed the highest nitrogen content of 2.31%, higher than that of a control sample of 2.27%. Furthermore, the water content in irradiated samples decreased with increasing radiation time, with the lowest water content achieved in the 30 minutes irradiated sample of 86% compared to 86.8% in the control samples.

4. Conclusion
The current increases in proportion to the increase of voltage at each variation of the distance between the electrodes. With the current value is inversely proportional to the distance between the electrodes but proportional with the square of voltage. The optimum distance between electrodes for irradiating shallot seeds is 3 cm. Ion mobility value increases in the proportion of increment of the distance between the electrodes and reached the optimum mobility at the 3rd cm distance between electrodes. Irradiated shallot seeds grow faster than non-irradiated shallot seeds after a few weeks shallot seeds planted. A constant growth occurred in the 15th minute of irradiation. The growth of shallot seed occurs due to the addition of nitrogen structure in the shallot seed. Irradiated shallot seed caused increment nitrogen content of shallot seed, with the highest increment at 15-minute irradiation. The water content of shallot seeds irradiated will decrease during irradiation. On the 30-minute irradiation, water content decreases down to 0.6% from control variable.

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