

Introduction of a new atmospheric pressure plasma device and application on tomato seeds*

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ABSTRACT

We designed new atmospheric pressure plasma device, to explore appropriate voltage of plasma treatment that promote traits and yield of tomato, tomato seeds were treated by plasma at 4760 to 6800 V, and traits and yield of tomato were observed. The results showed that the effects of different voltage plasma treatments on seed germination were not the same. The bloom times, the height, the caulis, the extent of the plants and the average weight, length, diameter of each fruit in the seven treatment groups from 4760 to 6800 V were increased distinctly. The tomato yields of seven different plasma voltage treated groups were increased than the untreated (CK). In most indexes of our tests, effects of (5440 ~ 6120 V) plasma voltage treatments were better than of other voltages, the best was 6120 V plasma voltage treatment. So the tomato yield increase and the most the botany properties of the tomato are improved. The discharges were not uniform and the powers were lower in low voltages (4760 ~ 5100V), and the discharge powers were higher in high voltages (6460 ~ 6800V). There was a step unaltered violet blue light from 5440V to 6120V, it was nearly uniform discharges, it maybe due to the energy of the electron and the active air particles in the plasma increasing with atmospheric plasma voltage adding, more electric charges are produced per unit time and cannot be neutralized at once, which can strengthen the reaction between the active air particles and seeds. The active air particles and ultraviolet

radiation can penetrate into the capsule of the seeds, accelerate to decompose the inner nutrient of the seeds, reduce relative penetrability of cell velum, improve the activities of the root of the tomato seedling. Test data of fruit yield of the tomato are consistent with the statistical regressive line.

Keywords: Atmospheric Pressure Plasma; Treat Voltage; Tomato Seed; Yield

1. INTRODUCTION

Applications of physical technology in agriculture are more and more popular, but most of them are radiations and irradiations with γ -ray, ⁶⁰Co-ray, laser, electric and magnetic field,[1-13] cells of plant seeds are damaged by radiations.

Plasma has been used in industry for applications; few experimental studies have been carried out for seed mutation induced by atmospheric plasma. We used a atmospheric plasma discharge equipment [14,15] to study the mutations of plant seeds. The device is atmospheric dielectric barrier discharge (DBD) with two parallel high voltage electrodes. A mass of electrons bomb plant seeds and bring much ozone, because seeds were put under atmospherical pressure plasma, the plasma would bring a mass electron, ion and ozone, the mass electron were faster and bomb seeds, the ozone can kill bacterium and virus, and also plant seeds are radiated by ultraviolet-ray, plant seeds are mutated by the many factors. We tested with tomato seeds (No.10 Hongza), to study the effects of atmospheric pressure plasma on the seeds germination, seedling growth, fruit yield and quality of tomato, in order to find the methods of improving the plant growth and increasing fruit yield of tomato.

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2. EXPERIMENT

The test device is shown in **Figure 1**, it is two parallel containers made of quartz, the thickness of quartz is 1mm, the length is 15 cm, the width is 5cm, the space of dielectrics is 10mm. there are some liquid of potassium chloride in two containers, two inner copper rings dipped in the liquid are two electrodes connected to AC high voltage power supply 30 kV with frequency 8 ~ 30 kHz. Different plant seeds were treated with different plasma voltages, for example, tomato seed for 4760 ~ 6800V, eggplant seed for 4420 ~ 6800V [16], cucumber seed for 5610 ~ 7310V [15].

As compact joined between the liquid of potassium chloride and dielectrics, both cool quartz dielectrics and uniform plasma were discharged. In our experiment, the tomato seeds were uniformly put on a transmission belt at constant speed, turned on high voltage power supply to discharge, the seeds passed through the plasma, treatment time were controlled by the speed of the belt. There were seven different voltage (4760, 5100, 5440, 5780, 6120, 6460 and 6800 V) treatments with the same treatment time 6 seconds, the different voltages were produced between two parallel high voltage electrodes and the plasma charges occurred in atmospheric pressure environment, therefore the experiment is called atmospheric dielectric barrier discharge (DBD). The process of treating the seeds by plasma device is shown in **Figure 2**.

3. RESULTS AND DISCUSSION

We designed an atmospheric pressure plasma device. The tomato seeds were treated by different voltage from 4760 to 6800 V. The results showed that the effects of different voltages plasma treatments on seed germination and growth were not the same. The height (90 ~ 100cm), the caulis (> 14cm), the extent (> 55×60cm) of the plant and the single fruit weight (> 80g), the length (≥ 5.2cm), the diameter (≥ 5.5cm) of the tomato of seven treatments from 4760 to 6800 V were increased distinctly in **Table**

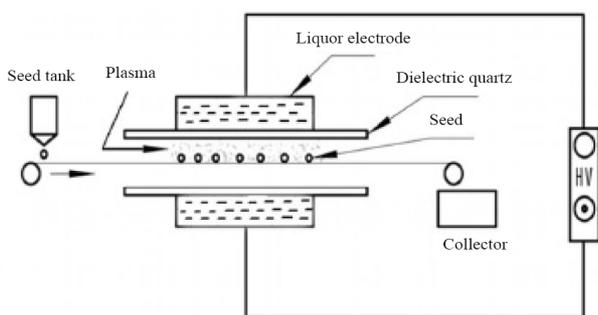


Figure 1. Schematic diagram of the atmospheric plasma dielectric barrier discharge (DBD).



Figure 2. Process of treating seeds by plasma device.

1. In addition, anti-virus of seven treatments (incidence 2.08%) were better than the untreated except sixth and seventh treatment (incidence were as same as the untreated 4.17%). The bloom times of all the treated seeds were longer and earlier than the untreated (CK), as well as the maturity time (**Figure 3**). The tomato yields of seven different voltage plasma treatments were increased, the fifth, the fourth and the third treatments were better than the untreated (CK), the yields of the three treatments increased 26.56%, 20.31%, 16.55% than CK. In **Figure 4** there were obviously increasing yields of the tomato under the proper plasma treatment voltages ranges (5440 ~ 6800V), the figure showed that some experimental data compared with Gaussian distribution curve of the fruit yields of the tomato by using a regression line estimate statistical method, the Gaussian distribution curve was regression equation:

$$y = a \exp[-b(x-c)^2] + d,$$

here $a = 0.743$, $b = 1.500$, $c = 6.120$, $d = 2.797$. The Gaussian distribution curve was comparatively convinced since the F -value was calculated: $F = 5675 > F_{0.05}(1, 5) = 6.61$, remain standard error: $s = 0.02$, it showed that the error was very small between real fruit yields and estimated. In 5440 ~ 6120 V voltage ranges, the fruit yields were better than other voltages. In most indexes of our tests, the effects of 5440 ~ 6120 V plasma treatments were better than of other voltages, the best was 6120 V plasma treatment, real test data of the fruit yields were consistent with the regressive line (estimated yield of forecasting).

Different voltage(4760 ~ 6800 V) plasma treating the tomato seeds were all better than the untreated (CK) in our experiments, the reasons might be that the treated seeds had been in different physical conditions, the atmospheric pressure plasma device was a dielectric barrier discharge (DBD), it created a typical glow discharge free from filament and arc plasma,[17] the macro-temperature of the plasma was nearly at room tempera-

Table 1. Change of botany properties of the Tomato treated by different plasma voltage.

treat group	Treat voltage (V)	Plant height (cm)	Extent (cm×cm)	Caulis height (cm)	Root length (cm)	Incidence of virus (cm)	Bloom time (day)	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Fruit yield (kg/667m ²)	Increased yield (%)
CK	0	90-100	55×60	14	17.3	4.17	16	5.0	5.5	80	2797	
1	4760	95-105	60×65	15	19.3	2.08	17	5.2	5.5	85	2921	4.43
2	5100	100-110	58×63	15	18.7	2.08	17	5.1	5.6	85	2997	7.15
3	5440	100-110	57×60	17	19.4	2.08	17	5.0	5.7	90	3260	16.55
4	5780	105-115	55×68	17	18.9	2.08	17	5.3	5.7	100	3365	20.31
5	6120	105-115	60×70	17	19.4	2.08	17	5.2	5.8	95	3540	26.56
6	6460	100-110	53×64	16	20.2	4.17	17	5.0	5.6	85	3142	12.33
7	6800	95-100	56×62	16	19.9	4.17	17	5.1	5.6	90	3172	13.41

**Figure 3.** Growth of the tomato plants in the test farmland. The tomato seeds treated by plasma had more fruits than CK, and the treated were premature.

ture, and plasma discharge gas pressure was atmospheric pressure. Because the seeds were passed through the plasma on the transmission belt, the seeds were treated with uniform plasma discharge and were not burned.

In **Figure 5** there were seven different discharge processes with seven different voltages, intensity of violet blue light (350nm ~ 500nm) gradually increased with voltage adding (see **Figure 6**), x axis denoted voltage, and y axis denoted the intensity of violet blue light on **Figure 6**. The discharges were not uniform using the lower powers in low voltages (4760 ~ 5100V), and the higher powers in high voltages (6460 ~ 6800V). There was a step unaltered violet blue light from 5440V to

6120V, it was nearly uniform discharges, it due to the energy of the electron and the active air particles in the plasma increasing with atmospheric plasma voltage adding, more electric charges are produced per unit time and cannot be neutralized at once, which can strengthen the reaction between the active air particles and seeds. The active air particles and ultraviolet radiation can penetrate into the capsule of the seeds, accelerate to decompose the inner nutriment of the seeds, reduce relative penetrability of cell velum, improve the activities of the root of the tomato seedling. Lower voltages (< 5440V) cannot penetrate into the seeds capsule and higher voltages (> 6120 V) can burnt the inner cells of the seeds.

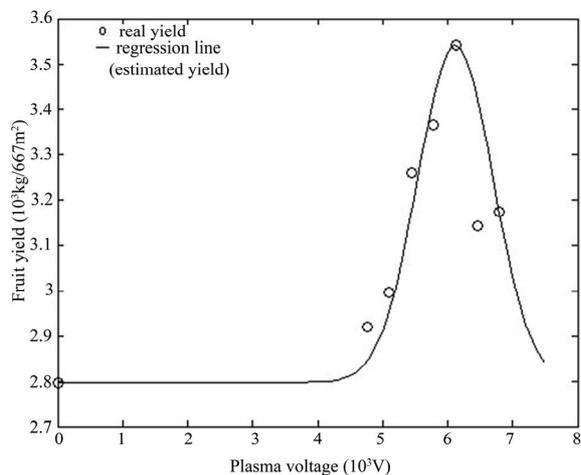


Figure 4. Regression line analysis of fruit yields of tomato. 'o' represents real yield, '—' represents regression line (estimated yield of forecasting).

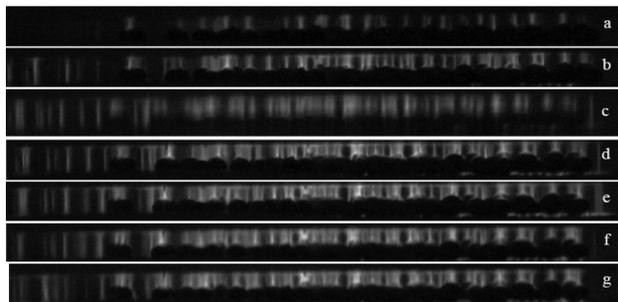


Figure 5. Seven different discharge processes with seven different voltages, intensity of violet blue light gradually increased with adding voltage. In figures a ~ b the discharges were not uniform and the powers were lower with low voltages 4760~5100V, and the discharge powers were higher with high voltages 6460V~6800V in figure f ~ g. There were uniform discharges under the middle plasma voltages 5440, 5780, and 6120V in figures c, d, e.

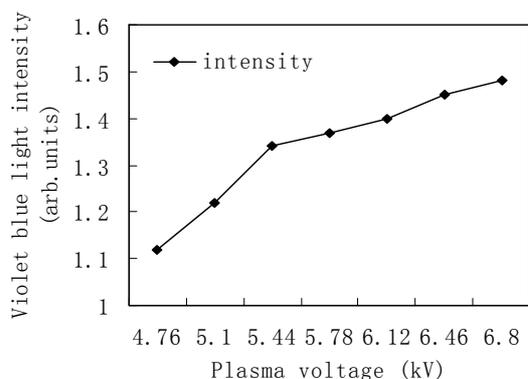


Figure 6. The violet blue light intensity versus different plasma voltage.

For the reasons, the tomato yield increased and the most

of the tomato botany properties were improved.

4. CONCLUSION

The tomato yields of seven different plasma voltage treated groups were increased than the untreated (CK). In most indexes of our tests, effects of (5440 ~ 6120 V) plasma voltage treatments were better than of other voltages, the best was 6120 V plasma voltage treatment. There was a step unaltered violet blue light from 5440V to 6120V, it was nearly uniform discharges, So the tomato yields increased and the most of the botany properties of the tomato were improved, it due to the energy of the electron and the active air particles in the plasma increasing with atmospheric plasma voltage adding, more electric charges are produced per unit time and cannot be neutralized at once, which can strengthen the reaction between the active air particles and seeds. The active air particles and ultraviolet radiation can penetrate into the capsule of the seeds, accelerate to decompose the inner nutriment of the seeds, reduce relative penetrability of cell velum, improve the activities of the root of the tomato seedling. Test data of fruit yield of the tomato were consistent with the statistical regressive line. In recent research, eggplant seeds were treated by the same method, there were the same conclusion in some aspects.[16, 18,19]

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