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The effect of plasma treatment on growth and yield of berseem (Egyptian clover) crop

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Abstract

Non-thermal plasma technology was used to evaluate the effect of exposure on growth and yield of berseem crop (Egyptian clover). The exposure system that was used to generate plasma radiations is the atmospheric pressure plasma jet (APPJ). This system produces a high flux stream of reactive chemical species at atmospheric pressure and low temperature. The clover seeds were divided equally (100 gram weight) into several groups: one unexposed control group and other tested groups (six groups) which were exposed to different number of pulses i.e. different doses of radiations. Among the treatments, all tested groups (1, 3, 5, 7 pulses) except for other two tested groups (9 and 11 pulses) have positive effect of an increased growth of clover crop relative to control group. The field experiments were conducted at Egyptian Atomic Energy Authority (EAEA) farm.

Key Words

Plasma technology, Berseem crop, Field experiments, Clover seeds.

INTRODUCTION

Non-thermal discharge plasma in atmospheric air produces reactive radicals (O, OH, etc.) that promote chemical reactions[1,2]. Cold plasma jets generated in atmospheric pressure discharges represent a rapidly developing technology of great application promise.

Berseem is the most important winter season legume cultivated in a large area in Egypt. It is one of the most important winters forage legumes in Egypt, India, Pakistan, Turkey, and countries of Mediterranean region. The former proved to be highly adaptable and productive as a fodder crop for wide scale cultivation. Madan et al[3] and Studier[4] are continued to improve Berseem yield and quality. Non-thermal plasmas have been successfully applied in agriculture and biomedicine for seed quality improvement and pathogenic micro-organisms inactivation[5].

Filatova et al[6] was used various species of grain crops (rye, wheat and barley), and for investigating its seed germination in response to plasma radiation. Seed germination test for processed and untreated (control) seeds were performed to estimate their germination energy and germination ability. It was concluded that low-pressure air plasma of the treatment of plant seeds stimulates strength and branching of their sprouts and roots within several minutes of plasma treatment. Berseem is important winter forage as it is nutritive and succulent. It contains more than twenty per cent crude protein and has seventy per cent dry matter digestibility[7]. Berseem is the most important winter season legume cultivated in a large area in Egypt. The significance of this forage species lies in the development of milk industry.

Plasma-based technologies are already applied, to some extent, in the agricultural and food industry in the following processes: (1) pasteurization and disinfections of pathogenic microorganisms in food, (2) removal or reduction of pesticides in fruits and vegetables, and (3) in corn steeping processes[8,9]. The use of non-thermal plasma borne species and radicals (like ozone O3, nitric oxide NO, and UV radiation) in the above specified processes is advantageous, as sensory quality, nutritional value, and storage life of the agricultural products is improved.

The main purpose of this study was to check the suitability and controllability of the pulsed atmospheric pressure plasma discharges produced as a source of an active environment for berseem.

EXPERIMENTAL SET-UP

The plasma generator is consisting a negative DC source, Blumlein-type pulse-forming network (E-PFN) and a dynamic spark gap switch. A triggered spark gap switch was used as a closing switch of E-PFN. The APPJ is consists of 4 inductor, each inductor equal 5μH and 5 capacitor each capacitor equal 5nF. A charging resistance value of 100k &! is chosen in the present case which corresponds to a charging RC time constant of 1.0ms. A schematic of the pulsed atmospheric-pressure plasma jet (APPJ) discharge and of the experimental set-up is shown in Figure 1. The gas is fed through an annular region between the two metal electrodes 15 cm in length. The inner electrode is 5 mm in diameter and is powered with a pulsed high voltage power supply, while the grounded outer electrode is separated from the inner electrode by a gap of a few millimeters. The APPJ device operates using 5-20 kV power supply with a gap between two electrodes of 2-3 mm under atmospheric pressure. The spark gap between rotating grounded electrode and fixed high voltage electrode is adjusted at required breakdown voltage. Hence the gap gets triggered in each rotation, which gives the repetition frequency of order 25 Hz (pulses/s). As the voltage on the capacitors reached the spark-over voltage of the spark gap electrode, the capacitors discharged, producing a high voltage pulse.

A Lecroy 200 MS/s 4-channel digital storage oscilloscope model (9304c) was used to recorded

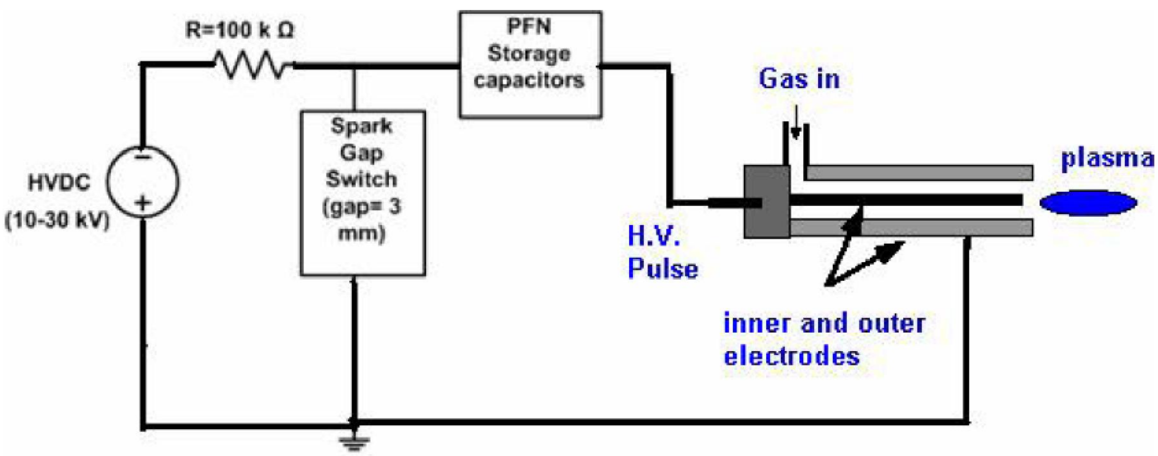

Figure 1 : A schematic of the APPJ discharge

voltage and current waveforms, via a high voltage probe and a pulse current transformer, respectively. A typical oscillograph of discharge current and voltage pulse using was shown in Figure 2.

The seeds were treated with plasma radiations before sowing (figure 3) and were grown in soil under natural conditions. For the measurement of growth characters, berseem plants were harvested at 45, 65 and 85 days after exposure to plasma radiations. Ten plants from each chamber were harvested at each stage for analysis of plant growth. The leaves and stem portion were separated and the number of branches and leaves per plant were counted. All the plant parts were dried at 80 °C for determining dry weight.

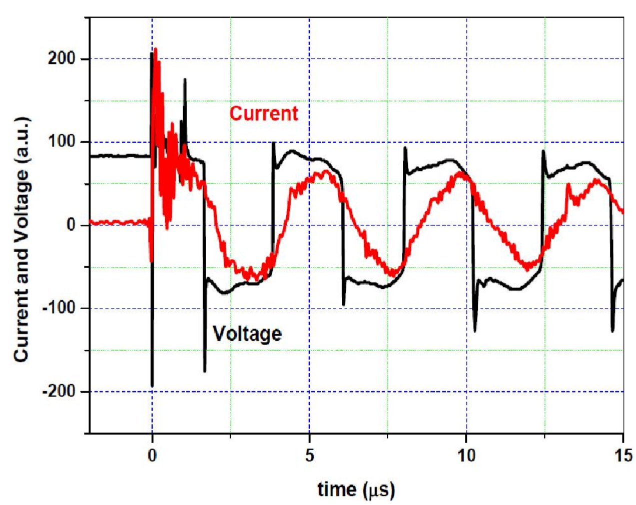

Figure 2 : Current-voltage characteristics of pulsed plasma jet

Figure 3 : Seed samples treatment system before exposure (left) and during exposure (right)

The plasma jet was injected directly through the clover seeds positioned in the treatment holes as shown in Figure 3. There are many holes inside a rectangular sheet designed for exposure seed samples, a 100 gm of seeds distributed uniformly through it. The seed samples filled the inner holes of 25 mm diameter with depth about 3 mm. For this purpose, plasma radiation can be easily penetrate into seed samples. It was injected into the seed samples at different varying durations (number of pulses). Berseem seeds (treated and untreated) were planted in the soil and their growth was observed.

The application of plasma species (UV radiations, ozone, electrons, excited atoms, free radicals and nitrogen oxides) in the agricultural industry has advantages. From these advantages; ozone has a very short decay time and the treated seeds with ozone will not result in the build-up of any environmentally persistent and minimal toxic effects. Therefore, gas plasma-assisted methods of agricultural materials sterilization can provide reasonable alternatives to traditional thermal or chemical ones[10,11]. At the beginning the system was checked using about eleven seed samples of berseem type Gemmiza1 (100 seeds) and treated at different number of pulses with another untreated

MATERIALS AND METHODS

The experiment was allocated for multi-cut Egyptian clover Gemmiza1 (Gm). Seeds of each clover type were subjected to six treatments of non-thermal plasma pulse, in addition to non-treated control. The electrical discharge inside the reactor of APPJ was induced by a pulsed high voltage power supply. The plasma radiation was injected directly through the clover seeds positioned in the treatment holes. The seed samples filled the inner holes of 25 mm diameter with depth about 3 mm. For this purpose, ozone and UV easily penetrate into the subjected seeds. The plasma radiation (consist of ozone, free radicals, charged particles and photons) was injected into the seed samples at different varying durations or number of pulses. The used treatments were 1, 3, 5, 7, 9, and 11 pulses and non-treated control. Clover treated seeds of multi-cut Gemmiza1 (Gm) was planted in randomized complete block design (RCBD) in three replicates with an experimental plot area of 6.0 m^2, all other agronomic practices were done as recommended. The experiment with Gm cultivar, three consecutive cuts were obtained to estimate fresh and dry yield t/fed. Sample of ten plants were harvested at cutting time to measure plant height (cm) and number of leaves.

RESULTS AND DISCUSSION

The effect of application of non-thermal plasma technique on berseem clover morphological characters as well as fresh and dry yield was very noticed in multi-cut Gm cultivars. The first field experiment (Gemmiza1 cultivar's) the fresh (FY) and dry yield (DY) of Gm clover cultivar's (multi-cut) in response to plasma radiation treatments is presented in TABLE (1). It seems that both fresh and dry yields were increased as the cut order increased (from the 1st to the 2nd to the 3rd cut). The mean fresh yield of the 1st cut was 11.5 t/fed increased significantly to 17.9 and 24.7 t/fed in the 2^{nd} and 3rd cuts respectively. The total fresh yield was affected by plasma radiation treatments (pulse numbers) compared to non-treated control. The higher FY of 63.0 t/fed was found for 9-pulse plasma radiation (PR) treatment over the other treatments. The DY was

TABLE 1 : Non – thermal plasma radiation treatments effects on Gm clover fresh and dry yield (t /fed) over three cuts

	Fresh	yield	(t/fed)		Dry	yield	(t/fed)	
Treat	1st cut	2nd cut	3rd cut	Total	1st cut	2nd cut	3rd cut	Total
Control	14.3	18.8	23.8	57.0	1.8	2.6	4.3	8.7
1 p	5.0	12.0	19.2	36.2	1.1	2.1	3.7	6.9
3 p	10.3	17.5	28.7	56.5	1.5	2.6	5.4	9.6
5 p	10.3	19.2	29.2	58.7	1.6	2.5	4.6	8.7
7 p	12.5	19.3	25.5	57.3	1.9	2.4	4.3	8.6
9 p	14.7	20.3	28.0	63.0	2.1	2.7	5.1	10.0
11 p	13.5	18.3	18.7	50.5	1.4	2.6	3.8	7.8
Mean	**11.5**	**17.9**	**24.7**		**1.63**	**2.50**	**4.46**	

increased from the early cut to the later cuts. The mean DY was 1.63 t/fed in the 1st cut, and then increased significantly ($p>0.32$) to 2.5 and 4.46 t/fed in the 2nd and 3rd cuts respect. The highest total DY (10.0 t/fed) in response to plasma radiation was recorded under 9-pulse PR treatment. It represented about 14.9 % significant ($p>0.49$) increase over the total DY of non-treated control.

Non-thermal plasma radiation treatment effects on Gm clover plant height (PH) as well as L/S ratio were shown in TABLE (2). The highest PH of 92.0 cm was recorded for plants at 5 pulse treatment at the 3rd cut, whereas the lowest PH was recorded under 7 pulse (43.6 cm) at the 1st cut. The mean PH was 59.2 cm for control that increased by 12.5 % fewer than 5 pulse plasma radiation treatments to be 66.6 cm (the tallest mean plants).

L/S ratios were (cut mean) found to be decreased from the 1st cut to 2nd and 3rd one. Mean L/S ratios for plasma treatments were higher under 7 and 11 pulses with the same value of 0.7. There were no significant differences in the treatment mean of L/S ratios under non treated or 1, 3 and 5 pulses.

Number of leaves (NL) of Gm clover plants was expressed in TABLE (3) as affected by non-thermal plasma radiation. The mean NL was higher in the 2nd

TABLE 2 : Non- thermal plasma radiation treatments effects on Gm clover plant height (cm) and L/S ratio over three cuts

	Plant	height(cm)			Leave to Stem	(L/S)		
Treat	1st cut	2nd cut	3rd cut	Mean	1st cut	2nd cut	3rd cut	Mean
Control	45.9	62.8	69.0	59.2	0.8	0.6	0.5	0.6
1 p	49.2	70.1	63.9	61.1	0.7	0.6	0.5	0.6
3 p	48.1	66.7	68.0	60.9	0.8	0.6	0.5	0.6
5 p	49.1	58.6	92.0	66.6	0.8	0.5	0.5	0.6
7 p	43.6	59.8	77.9	60.4	0.8	.07	0.5	0.7
9 p	55.4	67.7	71.4	64.8	0.6	0.5	0.5	0.5
11 p	47.0	67.0	71.5	61.8	0.8	0.6	0.6	0.7
Mean	**48.3**	**64.7**	**73.4**		**0.8**	**0.6**	**0.5**	

TABLE 3 : Non – thermal plasma radiation treatments effects on Gm clover number of leaves over three cuts

	Number of	Leaves		
Treat	1st cut	2nd cut	3rd cut	Mean
Control	3.0	12.5	10.1	8.53
1 p	5.3	12.5	10.7	9.50
3 p	2.5	10.1	11.9	8.17
5 p	3.0	10.1	12.3	8.47
7 p	2.0	10.7	9.1	7.27
9 p	3.8	11.8	10.0	8.53
11 p	2.1	11.3	10.0	7.80
Mean	**3.10**	**11.29**	**10.59**	

cut followed by 3rd cut, while the lowest was recorded for the 1st cut. The mean treatments NL was higher (9.50) under 1 pulse treatment followed by the value of 8.53 for the control and 9 pulse treatments.

CONCLUSION

Non-thermal plasma radiation of clover seeds led to important results. It increase total DY for Gm clover cultivar to 10.0 t/fed in response to 9 pulse PR treatment. It represented about 14.9 % significant (p>0.49) increase over the total DY of non treated control.

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