Effect of Low-Temperature Plasma on Forage Maize (*Zea mays Linn.*) Seeds Germination and Characters of the Seedlings

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Abstract. Low-temperature plasma is a high-energy state of the material gathered. Plasma seed processing technology is the use of high energy aggregation on treating crop seeds within 20 seconds. Previous research elucidated that this technology could improve germination and seedling growth of welsh onion seeds. In this paper, the effects of different intensities of low-temperature plasma on forage maize seeds have been investigated. The vigor and rate of germination, length of root and shoot of seedlings, the green and dry weight, and the fiber root number of seedlings of the treated sample seeds were compared with those of untreated seeds. The results showed substantial changes in the vigor and rate of germination just like what we found in welsh onion seeds. Thus, the characters of seedlings change regularly with the intensity of low-temperature plasma, and the analysis indicated that 120W was the optimum treatment. Results showed that low-temperature plasma was effective in improving seedling growth, we believe it will be also effective in earlier flowering and maturity and higher yield. There is a great value of using and spreading on production.

Keywords: Low-temperature plasma, forage maize seeds, characters of seedlings.

1 Introduction

Besides the 'traditionally' known solid state, liquid and gas phase and the more recently found low-temperature states (BOSE-EINSTEIN condensate), high-temperature states, such as plasmas existing. Although the generation of a plasma from the gas phase

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(Figure 1) isn't strictly spoken to be a real phase transition, plasma was recognized as the 4th state of matter due to its distinct properties, which substantially discriminated it from the gas phase[1] .

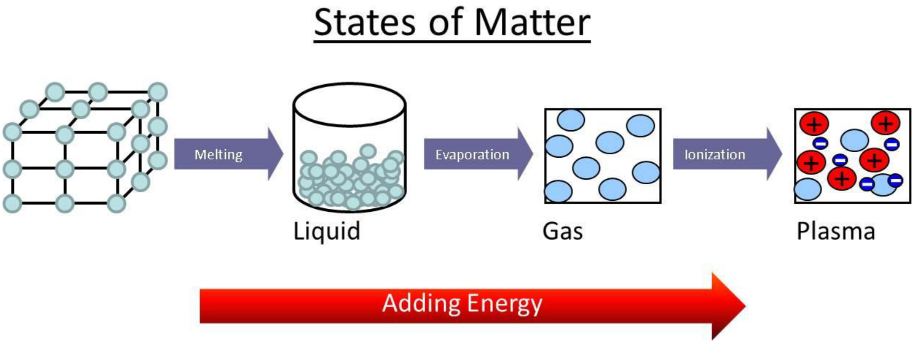

Fig. 1. Four states of matter. Plasma is characterized by a collective behavior of its free charge carriers. (Franziska Grzegorzewski, 2010)

Physical agriculture is the application of physical methods in agriculture and has been studied since the 1970s[2]. Low-temperature plasma (LTP) is an application of physical agriculture. Yin (2006) reported that LTP was utilized in biological applications in Russia[3]. There has been some research in LTP seed processor comprising a plasma generator was used to treat seeds in Russia and CIS countries (Li, 2010). Similar reports exist in America and Canada[4]. Stimulation of plants with a plasma field to promote seed germination and increase yield quantities and quality has attracted interest worldwide, with remarkable achievements reported in Japan[5]. At present, abroad study shows that both ionizing radiations, and even mass loading effect and exchange of charge are existing in LTP field. This field activated endogenous substances in the seeds, leading to improvements in the rate of seed germination, crop resistance and crop yield and an earlier maturity date[6-11].

Zea mays Linn., maize or corn, is one of the major cereals of the world and is the third largest field crop. Various kinds of technology have been used on maize seeds processing to promote germination and increase yield, such as magnetization and plasma[12-13].Our study focuses on the influence of LTP treatment on maize seeds in terms of the seed germination and biological characters of seedlings.

2 Materials and Methods

2.1 Experimental Set-Up

The equipment used in this study was provided by ChangZhou ZhongKe ChangTai Plasma Technology Co. and the device worked under the vacuum state. This machine can be carried out with large capacity in a continuous or batch process.

2.2 Sample Seeds

Tests were carried out both in laboratory and field conditions with LUZHONG 99118 maize seeds (selected by Shandong Province Seeds Group Co., LTD). This variety is food and fodder dual-purpose maize. There still have 12 to 13 green leaves when maturing, suit to be used as silage.

2.3 Experimental Design

2.3.1 Test Media

Laboratory plasmas can be generated by supplying energy to a kind of neutral gas. Electrical discharges are the most common for generating non-thermal plasmas. Neon is colorless and odorless inert gases. Neon conducts electricity 75 times better than air. The test result indicates a uniform stable glow discharge has been obtained between two planar electrodes when using neon as test media. Therefore, neon was used as media in our experiment.

2.3.2 LTP Treatment

Healthy and uniform maize seeds were treated with various plasma strengths (0, 60, 80, 100, 120, 140, 160, 180, 200W). 1 kilogram of maize seeds was used in each treatment.

2.3.3 Germination Tests and Analysis of the Germination Rate, Vigor

The germination tests were started on the 16th, 30th, 45th, 60th, 75th, 90th, 120th, 150th days after seeds treated by LTP. Each treatment was repeated four times to confirm the repeatability of the results, with 100 seeds for every repetition.

After treatment, the seeds were allowed to germinate in sand bed under laboratory. During the experiments, water was added to the sand bed to guarantee sufficient moisture for germination. The incubation temperature was 25°C.

A seed was considered germinated if both the radicle and coleoptile length were ≥2 mm. Seedlings were counted at 24-h intervals up to 7 days. The germination vigor is used to assess the quality of field emergence and is defined as the percentage of seeds that germinate within a short time (4 days after lined for maize according to GB/T 3543.4-1995, Rules for Agricultural Seed Testing-germination test). The germination rate is defined as the percentage of seeds that germinate in a specified time (7 days after lined for maize according to GB/T 3543.4-1995). These are calculated as follows:

Vigor of germination (%) = (Number of seeds germinated in 4 days/total number of seeds) × 100

Rate of germination (%) = (Number of seeds germinated in 10 days/total number of seeds) × 100

2.3.4 Investigation on Biological Characters of Maize Seedlings in Laboratory

On the 7th day of germination experiment, ten seedlings of each repetition were randomly selected and the length of shoot & root, green & dry weight of these seedlings were investigated. Length of shoot is defined as the length between the mesocotyl and tip of seedlings. Length of root is defined as the length between the mesocotyl and the root tip.

Samples used in this experiment were kept in a cool dry place for 90 days after treated by LTP. Also, both the green and dry weight of seedlings were measured.

2.3.5 Investigation on Biological Characters of Maize Seedlings in Field

In 90 days after treated by LTP, seeds were sowed in field. Ten days later. Ten seedlings of each repetition were randomly selected and the length of shoot & root, fiber root number were investigated.

3 Results and Discussion

This experiment was conducted to assess the influence of different intensities of LTP on seed germination and early growth, also the aging effect of this influence was investigated. The data of germination vigor for maize seeds are listed in Table 1, and the data of germination rate are listed in Table 2.

The optimum intensity of samples in different times after LTP treated is fugitive. But for each samples, we can both have the maximal vigor and rate in one certain intensity.

The effect of LTP on vigor and rate of maize seeds germination changed with time. LTP played an active role in seed germination within 16 days. And it dropped the seed germination rate and vigor during 30-120 days, 150 days after treated, and this inhibition had been weak.

Table 3 showed the shoot and root length of seedlings under lab condition, and the shoot & root length and fiber root number of seedlings in field were lined in table 4. The green and dry weight of seedlings in field were listed in table 5.

Table 1. Vigor of germination of forge maize seeds stimulated by low-temperature plasma (%)

Intensity of LTP (W) / Days after treatment	0 (ck)	60	80	100	120	140	160	180	200	
16	81b	88a	89a	91a	91a	91a	88a	88a	87a	87.83ab
30	82d	86bcd	86bc	87bc	90abc	90abc	92a	86cd	91ab	88.06ab
45	81b	91a	89a	86a	89a	88a	92a	90a	87a	88.17a
60	81b	91a	89a	89a	86a	86a	87a	89a	87a	87.22ab
75	81d	88abc	91ab	92a	86bc	86c	85cd	84cd	87bc	86.44b
90	80c	89a	86ab	86ab	91a	88a	88a	83bc	88a	86.44b
120	75d	80cd	81bc	84ab	86a	80bc	86a	81bc	78cd	80.33c
150	74cd	76abc	75bcd	79a	81a	80a	79ab	81a	71d	77.11d
	78.94e	85.5bcd	85.75abcd	87ab	87.38a	86.13abc	87.06ab	84.81cd	84.25d	/

Note: Columns with different lowercase letters: Low-temperature plasma treatment on Alexander Summer Squash bud potential, germination rate, significant differences in germination index ($P \leq 0.05$)

Table 2. Rate of germination of forge maize seeds stimulated by low-temperature plasma (%)

Intensity of LTP (W) / Days after treatment	0(ck)	60	80	100	120	140	160	180	200	
16	93c	94bc	94bc	96ab	96a	94bc	95ab	96a	93c	94.22a
30	93ab	92b	93ab	92b	94ab	92b	95a	94ab	92b	92.72bc
45	93bcd	93bcd	94abc	91d	95a	93bcd	94ab	92cd	92cd	92.79b
60	93ab	93ab	92abc	91bc	90c	93ab	93ab	94a	91bc	92.18cd
75	93ab	94a	94a	91b	93a	94a	93ab	92ab	92ab	92.83b
90	93abc	92bc	92abc	93ab	93abc	91c	92bc	93ab	93a	92.33bc
120	94a	92abc	93a	93ab	9a1bc	91abc	92ab	92abc	90bc	92.11cd
150	92abc	94ab	92abc	92bc	91c	91c	94ab	94a	91c	92.06cd
	92.56ab	92.68ab	92.87ab	92.75ab	92.69ab	92.13bc	93.25a	93.25a	91.63c	/

Note: Columns with different lowercase letters: Low-temperature plasma treatment on Alexander Summer Squash bud potential, germination rate, significant differences in germination index ($P \leq 0.05$)

Table 3. Length of shoot and root of seedlings under laboratory condition stimulated by low-temperature plasma (%)

Intensity of LTP (W)	0(CK)	60	80	100	120	140	160	180	200
Length of shoot (cm)	10.99cd	11.52bc	12.04ab	12.13ab	12.3a	11.50bc	11.65bc	11.36cd	10.74d
Length of root (cm)	19.11bc	19.55abc	20.82a	20.14ab	19.33bc	19.12bc	19.40bc	18.98bc	18.19c

Note: Columns with different lowercase letters: Low-temperature plasma treatment on Alexander Summer Squash bud potential, germination rate, significant differences in germination index ($P \leq 0.05$)

Table 4. Length of shoot and root and fiber root number of seedlings under field condition stimulated by low-temperature plasma （%）

Intensity of LTP (W)	0(CK)	60	80	100	120	140	160	180	200
Length of shoot (cm)	10.21cd	10.14d	10.33cd	11.42abc	12.04a	11.95ab	11.62abc	10.75bcd	11.03abcd
Length of root (cm)	31.04a	36.55a	35.53a	34.57a	33.05a	33.04a	36.07a	36.9a	35.01a
Fiber root number	4.4ab	4b	4.6ab	4.75ab	5ab	5.2a	4.6ab	4.6ab	4.5ab

Note: Columns with different lowercase letters: Low-temperature plasma treatment on Alexander Summer Squash bud potential, germination rate, significant differences in germination index ($P \leq 0.05$)

Table 5. Green and dry weight of seedlings stimulated by low-temperature plasma （%）

Intensity of LTP (W)	0	60	80	100	120	140	160	180	200
Green weight (g)	83.04cd	81.83d	85.77cd	91.62ab	95.10a	95.70a	87.96bc	83.47cd	83.46cd
Dry weight (g)	12.52bc	12.44bc	12.21cd	12.69bc	13.00a	12.75ab	12.55bc	12.76ab	12.45bc

Note: Columns with different lowercase letters: Low-temperature plasma treatment on Alexander Summer Squash bud potential, germination rate, significant differences in germination index ($P \leq 0.05$)

90 days after seeds treated by LTP, almost all the intensities (60 -200W) could increase the shoot & root length, green & dry weight and the fiber root number also increased.

It is clear that in the case of an ordinary plant leaf area will increase as growth proceeding, and with increasing leaf area the rate of production of material by assimilation will also increase, this will also lead to higher yield. LTP treatment has a great value of using and spreading on crop production, and the optimal treatment intensity for forage maize seeds was 120W.

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References

1. Hao, X., Qin, J.: Preliminary study on low temperature plasma treatment of seed. Journal of Shanxi Agricultural Sciences 26(2), 39–41 (1998) (in Chinese)
2. Li, R.: Plasma machine seed treatment technology. North Rice 4(4), 52–53 (2010) (in Chinese)
3. Yin, M.: Research of magnetized arc plasma on seeds biological effects. Dalian University of Technology, Dalian (2006) (in Chinese)
4. Zhang, Y., Zhang, J., Wang, Q.: The application of physical methods in sugar beet seed treatment. China Beet and Sugar (2), 20–22 (2005) (in Chinese)
5. Xu, Z., Chen, B., Wei, Z.: Various seed treatments on corn yield. Agricultural science & technology and Equipment (4), 15–16 (2011) (in Chinese)
6. Liu, S., Ouyang, X., Nie, R.: Application status and development trend of the physical methods in the crop seed treatment. Crop Research 5(2), 520–524 (2007) (in Chinese)
7. Shao, C., Wang, D., Tang, X., et al.: Arc plasma system and its application & development treads on pre-sowing seeds treatment. China Seed Industry (8), 1–3 (2012) (in Chinese)
8. Lianglong, H., Lijia, T., Zhichao, H., et al.: Application of physical agriculture techniques in cleaned seeds treatments. Journal of Anhui agricultural science 35(13), 3778- 3779 (2007) (in Chinese)
9. Yin, M., Huang, M.: Stimulatnig Effects of Seed Treament by Magnetized Plasma on Tomato Growth and Yield. Plasma Science & Technology 7(6), 3143–3147 (2005)
10. Filatova, I., Azharonok, V., Kadyrov, M.: Rf and Microvawe Plasma Application for Pre-Sowing Caryopsis Treatments. Publ. Astron. Obs. Belgrade (89), 289–292 (2010)
11. Shao, C., Fang, X., Tang, X., et al.: Stimulating effects of low-temperature plasma on seed germination characteristics of green Chinese onion. Transaction of the Chinese Society for Agriculture Machinery 06 (2013)
12. Fu, S., Zhang, F., Li, J., et al.: Several physical techniques in agriculture and Prospects. Agricultural Mechanization Research (1), 36–38 (2006) (in Chinese)
13. Shi, Y., Fang, X., Xu, D., et al. Effect of plasma treatment of soybean seed with different radiation intensity on biological traits, yield and economic output. Journal of Jilin Agricultural Sciences 35(6), 6-7 (2010) (in Chinese)
14. Luo, H., Ran, J., Wang, X., et al.: Comparision Study of Dielectric Barrier Discharge in Inert Gases at Atmospheric Pressure. High Voltage Engineering 38(5), 1070–1077 (2012)

15. Zeng, Q., Liang, C., Shen, D., et al.: Effects of Acid Rain on Seed Germination of Various Acid Fastness Plants. Journal of Agro-Environment Science 23(1), 39–42 (2004)
16. Niu, D., Sun, Z., Yu, F., et al.: Primary report on effects of plasma on maize. Journal of Farm and Cuiture 1, 43–44 (2011)
17. Yu, F., Zhang, R., Zhang, P., et al.: Effects of plasma on maize. Agricultural Technology &Equipment 148(4), 29–31 (2008)
18. Chai, S., Fang, X., Fu, X., et al.: Effects of plasma on maize. Modern agricultural science (23), 138–138 (2007)
19. Fa, X., Bian, S., Xu, K., et al.: Study on Maize Seeds Treated with Plasma to Influence Biological Properties and Yield of Maize. Journal of Maize Sciences 12(4), 60–61 (2004)
20. Du, H., Liu, S., Zhao, W., et al.: Effects of plasma on old maize. China Seed Industry (supplement), 22–23 (2011)