

## **Phenotypic changes induced by the application of low-temperature plasma treatments in various crop species**

Hiroshi Ehara<sup>1,2</sup>, Mana Kano-Nakata<sup>2</sup>, Mitsutaka Taniguchi<sup>1</sup>, Xinwei Jiang<sup>1</sup>, Fumito Sugiura<sup>1</sup>,  
Adisak Kaewkam<sup>1,3</sup>, Ibuki Kurosawa<sup>1</sup>, Destieka Ahyuni<sup>1,4</sup>, Marina Fukazawa<sup>1</sup>,  
Mayuko Nakagawa<sup>1</sup>, Hiroo Takaragawa<sup>5</sup>, Hiroshi Matsuda<sup>5</sup>, Kenji Ishikawa<sup>6</sup>, Hiromasa Tanaka<sup>6</sup>,  
Hiroshi Hashizume<sup>6</sup>, Kenichi Inoue<sup>6</sup>, Yushi Ishibashi<sup>7</sup>, Akiko Fujita<sup>2,8</sup>,  
Sotaro Chiba<sup>1</sup>, Takahiro Shibata<sup>1</sup>, Fumie Nakashima<sup>1</sup>, Aidil Azhar<sup>9</sup>

<sup>1</sup> Graduate School of Bioagricultural Sciences, Nagoya University, <sup>2</sup> International Center for Research and Education in Agriculture, Nagoya University, <sup>3</sup> Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, <sup>4</sup> Politeknik Negeri Lampung, <sup>5</sup> Tropical Agriculture Research Front, Japan International Research Center for Agricultural Sciences, <sup>6</sup> Center for Low-temperature Plasma Sciences, Nagoya University, <sup>7</sup> Faculty of Agriculture, Kyushu University, <sup>8</sup> Satake Corporation, <sup>9</sup> IPB University  
e-mail (speaker): ehara.hiroshi.h9@f.mail.nagoya-u.ac.jp

The effects of exposing dry seeds of various food and industrial crops to low-temperature plasma were investigated. In mung bean seeds (JP229241: Afghan local variety), helium atmospheric pressure plasma jet irradiation for 3 to 5 minutes modified the germination preparation process compared to the control. Under non-stress conditions, early growth parameters of mung bean seedlings germinated from plasma-treated seeds (1–5 minutes irradiation) were almost the same as those of the control. In contrast, when the seedlings were grown under submerged conditions, the 3-minute plasma treatment increased leaf dry matter weight, top/root (T/R) ratio, leaf weight ratio (LWR), and leaf area ratio (LAR). The 5-minute treatment tended to enhance root dry matter weight, root weight ratio (RWR), and net assimilation rate (NAR). In the 3-minute treatment, the relative growth rate (RGR) increased with the rise in LAR, whereas in the 5-minute treatment, RGR was mainly attributed to a comparatively high NAR.

In rice seedlings (cv. Nipponbare) germinated from seeds treated with an air plasma device (on for 10 seconds / off for 50 seconds × 18 cycles; total 180 seconds), seedling emergence, plant height, and stem number were significantly greater in the treated plants compared to the control for approximately two months after germination. Cumulative water consumption by the booting stage was also significantly higher in the treated plants. The percentage of filled grains increased in the plasma-treated

plants, which was supported by an enhanced photosynthetic rate after heading, attributed to increased stomatal conductance. Investigations into the factors contributing to increased plant height suggested that cell elongation in the leaf blade may have led to increased leaf and plant length.

During the early growth stage, the phenotypes of rice seedlings, especially in the root system, were improved by longer irradiation durations (1 to 10 minutes) with the helium plasma jet. The differences in phenotypes between seedlings from treated and untreated seeds were especially pronounced under water-deficient condition. Plasma treatment also reduced the accumulation of reactive oxygen species (ROS) in the seedlings, thereby alleviating oxidative stress.

In sago palm seeds harvested from a spiny-type mother palm, low-temperature plasma treatments using either a helium jet or air plasma accelerated the germination process.

Plasma exposure was also considered to affect vegetative propagation. In sugarcane (cv. NiF8), helium plasma jet irradiation of the root primordia around the stem cutting for 1 minute, followed by 2 minutes of irradiation to the lateral bud (1-minute irradiation, 1-minute interval, and another 1-minute irradiation), promoted an increase in the number of sett roots.