Agri Articles

(e-Magazine for Agricultural Articles)

Volume: 05, Issue: 06 (NOV-DEC, 2025)

Available online at http://www.agriarticles.com

©Agri Articles, ISSN: 2582-9882

Plasma Activated Water and Its Utilization in Agriculture

*Priyanka Devi

Ph. D. Scholar, Department of Agronomy, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India

*Corresponding Author's email: priyankadevi_1998@yahoo.com

Plasma-activated water (PAW) represents a promising intervention for improving agricultural productivity amid accelerating population growth, escalating global food requirements, and worsening environmental pressures. The presence of reactive oxygen and nitrogen species (RONS) enhances seed germination, checks pest and disease infestation, improves quality of fresh produce and thereby boost overall plant growth. Thus, PAW reduces reliance on agrochemicals and reduces the cost of cultivation, although its adoption may necessitate an initial capital investment.

Introduction

The rise in food demand associated with burgeoning population is tremendously increasing. The traditional agricultural practices of extensive utilization of fertilizers and pesticides in order to ensure high agricultural production have severely exhausted soil and water, resulting in stagnant crop yields and high ecological risks. Hence, to tackle the dual problem of increasing food products along with achieving environmental sustainability has been the prime objective of the researchers. Scientist and researchers have designed severely technologies for achieving the mentioned goal, of which the development of novel technology, plasma activated water have garnered much attention lately. Plasma, that is the aggregation of excited substances such as ions, electrons, high energy atoms and molecules, free radicals, etc. is considered as the fourth state of matter (Guo *et al.*,2021). It has been reported that plasma activated water bears the potential of efficiently improving the yields of crop by enhancing germination, improving tolerance to biotic and abiotic stresses and exhibit overall significant plant growth without any residual effect on the environment (Iqbal *et al.*,2019).

Generation of Plasma Activated Water

The genesis of plasma activated water involves exposing water to cold atmospheric plasma discharge generated by devices such as plasma jest, barrier discharges or transient spark into water (Chuea-uan *et al.*, 2023). It is laden with reactive species on treatment of water by a stream of ionized gas (plasma) (Zhao *et al.*, 2020). The active and primary ingredients of PAW are reactive oxygen species (ROS) and reactive nitrogen species (RNS) (Liu *et al.*, 2016). The main constituents of ROS are hydrogen peroxide, hydroxyl radicals, superoxide anions, singlet oxygen and ozone; nitrate, nitrite, peroxynitrite, nitric oxide radical, ammonia and nitrogen are the component of RNS (Thirumdas *et al.*, 2018). Among all, hydrogen peroxide, nitrite and nitrate are long -lived particles. Fig. 1 shows the generation of plasma activated water using plasma jest and nitrogen as feeding gas.

Application of PAW in agriculture

1. *Reduce pest and disease attack* – ROS present in plasma activated water such as hydrogen peroxide, hydroxyl radical and ozone induce oxidative stress on the membranes of microbial cell. They also disintegrate peptidoglycan structure of most bacteria

subsequently leading to cell wall destruction, halting metabolic activities and ultimately death (Li *et al.*, 2017). It was reported that when grapes treated with PAW reduced the surface yeast contamination and minimized the mycelial growth of *Fusarium graminearun* when treated for 24 – 36 hours (Guo, 2016).)

2. *Enhances seed germination* – reports suggest that RONS induced by PAW cause several biochemical processes within the seed *viz.*, seed coat breaking, thinning the seed coat and promoting water and nutrient uptake, nitrate assimilation to ammonia by the catalysing action of nitrate and nitrite reductase (Duermeyer *et al.*, 2018). Additionally, RONS checks the activity of ABA and jasmonic acid enabling seed germination and improving germination and vigour index (Panngom *et al.*, 2018).
3. *Promotes plant growth* – the presence of nitrate nitrogen and its assimilation catalysing action of nitrate and nitrite reductase promotes plant growth. Moreover, ROS such as hydrogen peroxide reduce oxidative damage, maintain osmotic regulation, enhance ascorbate peroxide (APX) and proline accumulation thereby enabling the plants to cope biotic and abiotic stresses (İşeri, *et al.*,2013).
4. *Improving quality of fresh produce* – several research showed that PAW treated strawberries, mushrooms, berries and other fruits exhibited higher firmness, better colour index, reduced browning and higher total soluble solids (Thirumdas *et al.*, R. 2018).

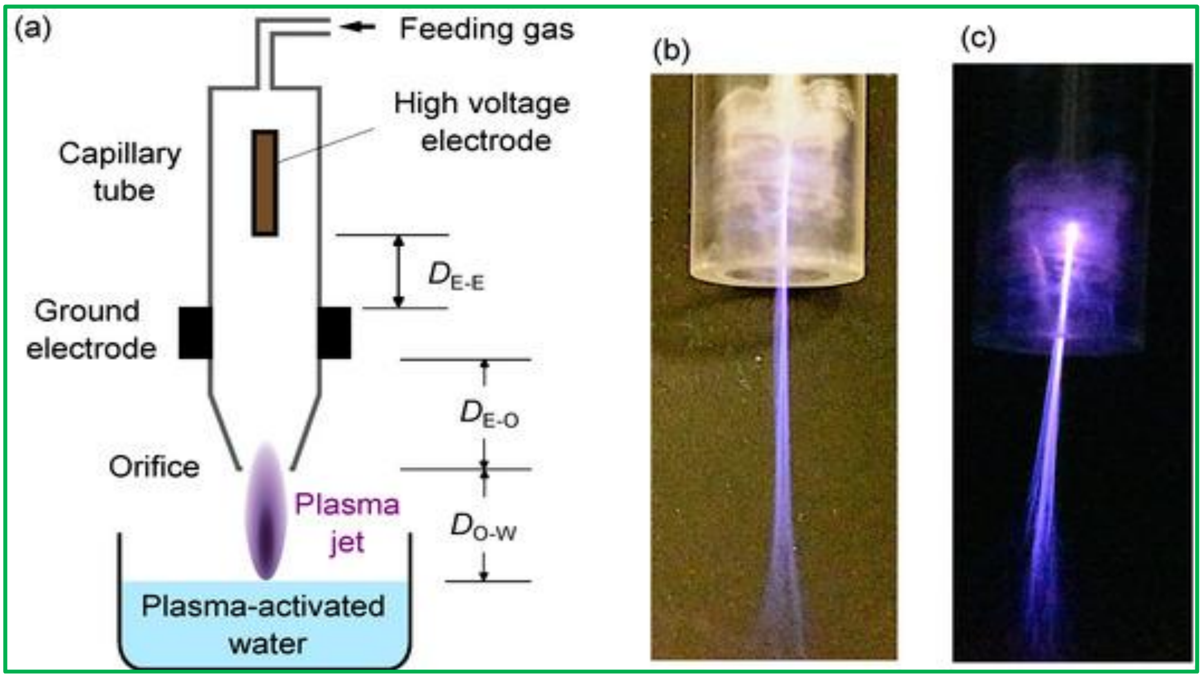

Fig. 1: (a) Illustration of generation of plasma activated water using plasma jet. The gas fed into the plasma jest breaks down into excited particles when subjected to high voltage passed through the electrodes present in the capillary tube (b) and (c) shows plasma jet using nitrogen as feeding gas (Source: Wong *et al.*, 2023)

Problems associated with plasma activated water

Atmospheric-pressure plasma systems vary widely in design and operation, producing different reactive species through complex and difficult-to-control chemistries. A key limitation for plasma-activated water is the extremely short lifetime of reactive species such hydrogen peroxide and single oxygen radical. Plasma activated water generated above versus below the water surface exhibits distinct physicochemical properties and biological effects, which remain insufficiently understood. Accurate assessment of antimicrobial activity of plasma activated water requires detailed plasma and aqueous-phase diagnostics, yet isolating the physical and chemical factors responsible for microbial inactivation is challenging. The specific oxidants formed, their roles, and the mechanisms of microbial killing remain unclear, and the final reaction products depend strongly on the carrier gas—raising costs when inert gases are used. Furthermore, the source of plasma activated water acidification and its contribution to antimicrobial efficacy are not well established, and many studies fail to link plasma parameters with the molecular species formed in plasma activated water.

Conclusion

A conclusion can be derived that the plasma activated water is a viable alternative of agrochemicals to improve crop quality and yield with minimum environmental hazards. It can help widen industrial opportunity and achieve sustainable development goals. However, this cutting-edge technology for improving agricultural production demands extensive research on generation of long-lived reactive species, reduced their phytotoxicity and generation of novel strategies for popularizing among the youth.

References

1. Chuea-uan, S., Boonyawan, D., Sawangrat, C., & Thanapornpoonpong, S. N. (2023). Using plasma-activated water generated by an air gliding arc as a nitrogen source for rice seed germination. Agronomy, 14(1), 15.
2. Duermeyer, L., Khodapanahi, E., Yan, D., Krapp, A., Rothstein, S. J. and Nambara, E. (2018). Regulation of seed dormancy and germination by nitrate. Seed Science Research, 28(3): 150-157
3. Guo, J. Study on the sterilization Mechanism of low-temperature plasma and the Bactericidal action of active water [D]: Zhejiang University (2016)
4. Guo, D., Liu, H., Zhou, L., Xie, J. and He, C. (2021). Plasma-activated water production and its application in agriculture. Journal of the Science of Food and Agriculture, 101(12): 4891-4899
5. Iqbal, T., Farooq, M., Afsheen, S., Abrar, M., Yousaf, M. and Ijaz, M. (2019). Cold plasma treatment and laser irradiation of Triticum spp. seeds for sterilization and germination. Journal of Laser Applications, 31(4): 042013-7
6. İşeri, Ö. D., Körpe, D. A., Sahin, F. I. and Haberal, M. (2013). Hydrogen peroxide pretreatment of roots enhanced oxidative stress response of tomato under cold stress. Acta Physiologiae Plantarum, 35(6): 1905-1913
7. Li, Y., Pan, J., Ye, G., Zhang, Q., Wang, J., Zhang, J. and Fang, J. (2017). In vitro studies of the antimicrobial effect of non-thermal plasma-activated water as a novel mouthwash. European Journal of Oral Sciences, 125(6): 463-470
8. Liu, D. X., Liu, Z. C., Chen, C., Yang, A. J., Li, D., Rong, M. Z., Chen, H.L. and Kong, M. G. (2016). Aqueous reactive species induced by a surface air discharge: Heterogeneous mass transfer and liquid chemistry pathways. Scientific reports, 6(1): 23737
9. Panngom, K., Chuesaard, T., Tamchan, N., Jiwchan, T., Srikongsritong, K. and Park, G. (2018). Comparative assessment for the effects of reactive species on seed germination, growth and metabolisms of vegetables. Scientia Horticulturae, 227: 85-91
10. Thirumdas, R., Kothakota, A., Annapure, U., Siliveru, K., Blundell, R., Gatt, R. and Valdramidis, V. P. (2018). Plasma activated water (PAW): Chemistry, physico-chemical properties, applications in food and agriculture. Trends in Food Science & Technology, 77: 21-31
11. Wong, K. S., Chew, N. S., Low, M. and Tan, M. K. (2023). Plasma-activated water: Physicochemical properties, generation techniques, and applications. Processes, **11**(7): 2213.
12. Zhao, Y. M., Patange, A., Sun, D. W. and Tiwari, B. (2020). Plasma-activated water: Physicochemical properties, microbial inactivation mechanisms, factors influencing antimicrobial effectiveness, and applications in the food industry. Comprehensive Reviews in Food Science and Food Safety, 19(6): 3951-3979