Acceleration of propagule mangrove growth using plasma pijar corona radiation

Erma Prihastanti*, Endah Dwi Hastuti, Sapto Purnomo Putro, and Riche Haryati

Department of Biology, Diponegoro University, Semarang, Central Java, Indonesia

Abstract

The purpose of this study was to determine the interaction of plasma radiation on the growth rate and the number of leaves in several species of mangrove. A factorial complete randomized design was used with 12 treatments and 3 replications. The first factor was the duration of plasma radiation, with values of 0 minutes, 30 minutes, and 60 minutes. The second factor was the species of mangrove, which included *Rhizopora stylosa*, *Rhizopora mucronata*, *Creriops tagal*, and *Bruguera* sp. The parameters observed and recorded were growth rate and the number of leaves. The results showed that plasma radiation was able to increase the growth rate in *R. mucronata* species while not affecting the number of leaves. Plasma radiation for 60 minutes met the nitrogen requirements of the plants. This study concluded that corona incandescent plasma radiation can increase the mangrove growth rate, especially in *R. mucronata* species.

Keywords: growth rate, mangrove, number of leaves, plasma radiation, woody plants

Prihastanti, E., E. Dwi Hastuti, S. Purnomo Putro, and R. Haryati. 2023. 'Acceleration of propagule mangrove growth using plasma pijar corona radiation'. *Iranian Journal of Plant Physiology 13*(4), 4701-4707.

Introduction

Mangroves are woody plants that grow between the land and the sea in tropical and sub-tropical climates. Mangroves require high salinity, high waves, strong winds, high temperatures, and mud (Kathiresan and Bingham, 2001; Castro et al., 2014; Alongi, 2018). These plants supply a variety of ecosystem and socioeconomic requirements such as nutrient cycles, soil composition, ecotourism, carbon (C) storage, and wood production (Mardiyarso et al., 2015).

Biologically, mangroves are the most productive ecosystems and serve many ecological functions, such as a place for feeding (feeding ground), spawning ground, or breeding ground (nursery for various types of shrimp, fish, and other marine biota. In addition, mangroves also play a role in maintaining water quality because they have an excellent ability to absorb pollutants (Srikanth et al., 2016). Mangrove plants develop a distinctive and sturdy root system as a form of adaptation to their environment (Basyuni et al., 2018), to prevent erosion in coastal areas and rising seawater (Polidoro et al., 2010; Wahyudi et al., 2012; Basyuni et al., 2018). Mangroves play a role in ecosystem conservation by repairing the damage caused by land conversion activities as an aquaculture area (Vo et al., 2013; Salampessy et al., 2014; Roziqin, 2017).

Indonesia has the largest mangrove forest in the world, which comprises 23% of the global mangrove ecosystem (Arif et al., 2017). However, the forest is decreasing due to urbanization,

* *Corresponding Author*
E-mail Address: *eprihast@yahoo.co.id*
Received: July, 2021
Accepted: June, 2023

pollution, and overexploitation (Leung, 2015). Mangroves in Indonesia have been exploited since 1800, and as a result, more than 70% of Indonesia's original mangrove areas have been lost due to overdevelopment activities in the coastal area (Ilman et al., 2016; Rizal et al., 2018). Conservation has been used to solve this issue and is often performed by local people, governments, or international agreements (Romanach et al., 2018). Mangrove land restoration is one of the conservation activities carried out by the government (Fereira and Lacerda, 2016). A new conservation issue is that propagules can be carried away by waves and require more time to grow and that propagules can be harmed by disease (Islam and Gnauck, 2009; Tonne et al., 2016).

Mangrove growth and production are limited by the availability of macro and micronutrients, such as nitrogen (Alongi, 2011). The nitrogen must be concentrated and available in large quantities for the growth process and should not be too little or excessive (Bown et al., 2010; Fageria and Moreira, 2011; De Giorgio and Fornaro, 2012). The requirements of the growth process must be considered (Lewis et al., 2019). The largest source of nitrogen is free air. As much as 80% of the composition of air consists of nitrogen (Jain and Singh, 2008).

Corona incandescent radiation technology is often applied to increase the nitrogen ions in mangrove propagules. The use of plasma radiation technology has been reported to increase propagule germination and plant growth (Ito et al., 2018). Corona incandescent discharges occur due to the presence of field electrons, which shoot nitrogen ions into the propagules so that they affect the stroke. Corona glow discharge is self-sustained, which is the process of generating a current in a neutral fluid between two high-voltage electrodes, so that a plasma is formed around one of the electrodes and the ions produced in the process are used as charge carriers to the other electrode (Susan et al., 2016). Hence, the present study was aimed to determine the interaction effect of plasma radiation on the growth rate and the number of leaves in several species of mangrove.

Materials and Methods

Sampling location and collection

This research was carried out in June and July 2019, and sampling was carried out in the mangrove forest area of Karimunjawa Island, Jepara, Central Java, Indonesia. The coordination of the sampling location was 5°49'36.4"S, 110°28'03.9" E. Mangroves belonging to the species *Rhizophora stylosa*, *Rhizophora mucronata*, *Creriops tagal*, and *Bruguiera* sp. were collected. Sampling was performed by taking a mature propagule from the environment. The ripened propagules were collected using a cutting tool and placed in water to keep them fresh.

Research design

The research design was a factorial completely randomized design (FCRD) with 20 treatments and three replications. The completely randomized design was chosen due to the flexibility of treatment and replication number with simple statistical analysis. There were two factors: the first factor was corona incandescent plasma radiation duration and the second was mangrove species. Each type had 15 propagules, which were grouped into three groups. The groups consisted of the control group (A), 30 minutes radiation (B), and 60 minutes radiation (C). Plasma technology for growth stimulation was used to irradiate four samples with different species of Mangrove plants, namely *Rhizophora stylosa* (RS), *Rhizophora mucronata* (RM), *Creriops tagal* (CT), and *Bruguera* sp. (B).

Fifteen mangrove propagules were selected for each species based on the measurement of their weight and height. Propagules were sorted by their morphological appearance and uniformity. According to Mustofa (2018), good propagules are mature, healthy, fresh, and free from pests and disease.

Plasma radiation

The propagules were irradiated by plasma light for 0, 15, or 30 minutes. For each radiation treatment, there were 5 propagules per species. Samples

Table 1
Mangrove growth rate

Species	Plasma Radiation			Mean (cm/day)
	A	B	C	
RM	1.28[abc]	1.33[a]	1.21[abcd]	1.27[a]
RS	1.17[bcd]	1.076[d]	1.31[ab]	1.18[b]
CT	0.82[e]	1.18[abcd]	1.22[abcd]	1.06[c]
B	1.07[d]	1.18[abcd]	1.21[abcd]	1.18[b]
Mean	1.10[b]	1.19[a]	1.24[a]	(+)

Numbers followed by the same letter show the effect that is not significantly different between treatments based on DMRT test at 95% confidence level. The sign "–"indicates no interaction between factors.

Table 2
The effect of plasma radiation and mangrove species on the number of mangrove leaves

Treatment		Number of Leaves
Radiation	A	2.995 [b]
	B	3.165 [a]
	C	2.747 [c]
Mangrove Species	RM	2.000 [d]
	RS	2.663 [b]
	CT	2.330 [c]
	Br	4.883 [a]

Numbers followed by the same letter show the effect that is not significantly different between treatments based on DMRT test at 95% confidence level. The sign "–" indicates no interaction between factors.

were placed near field electrodes with a transverse propagule position. The distance from the growing point to the plasma reactor was 5 cm. According to the research by Ariyanti et al. (2020), the plasma technology reactor system for growth stimulation uses a DC high-voltage generator system and a field point configuration electrode system. The distance between the point electrode and the field electrode where the propagule was positioned was 3 cm.

Planting and observation

The corona glow treatment was done in Plasma Laboratory, Department of Physic, Diponegoro University, Semarang. The observation of mangrove propagules development was conducted in Greenhouse of Department of Biology, Diponegoro University, Semarang. All the mangrove propagules were planted in planting media in pots with 100% peat soil. Seven days later, the observation began. The parameters observed were the growth rate in the form of plant height per day for 35 days and the number of leaves on each plant. The number of leaves was calculated at the final observation day. The growth rate was calculated using the following equation:

$$Gr = \frac{h2 - h1}{t2 - t1}$$

Gr = growth rate

h1 = plant height at first observation

h2 = plant height at final observation

t1 = first observation (day)

t2 = final observation (day)

Data analysis

The data were processed using Microsoft Excel. The percentage of growth and the number of leaves obtained were processed using Microsoft Excel. The other results were analyzed using SPSS (95% significance level). The types of analyses used were a one-way ANOVA and the univariate general linear model.

Result

The interaction between corona incandescent plasma radiation and mangrove species showed an effect on the growth rate (Table 1). The interaction that produced the most rapid growth

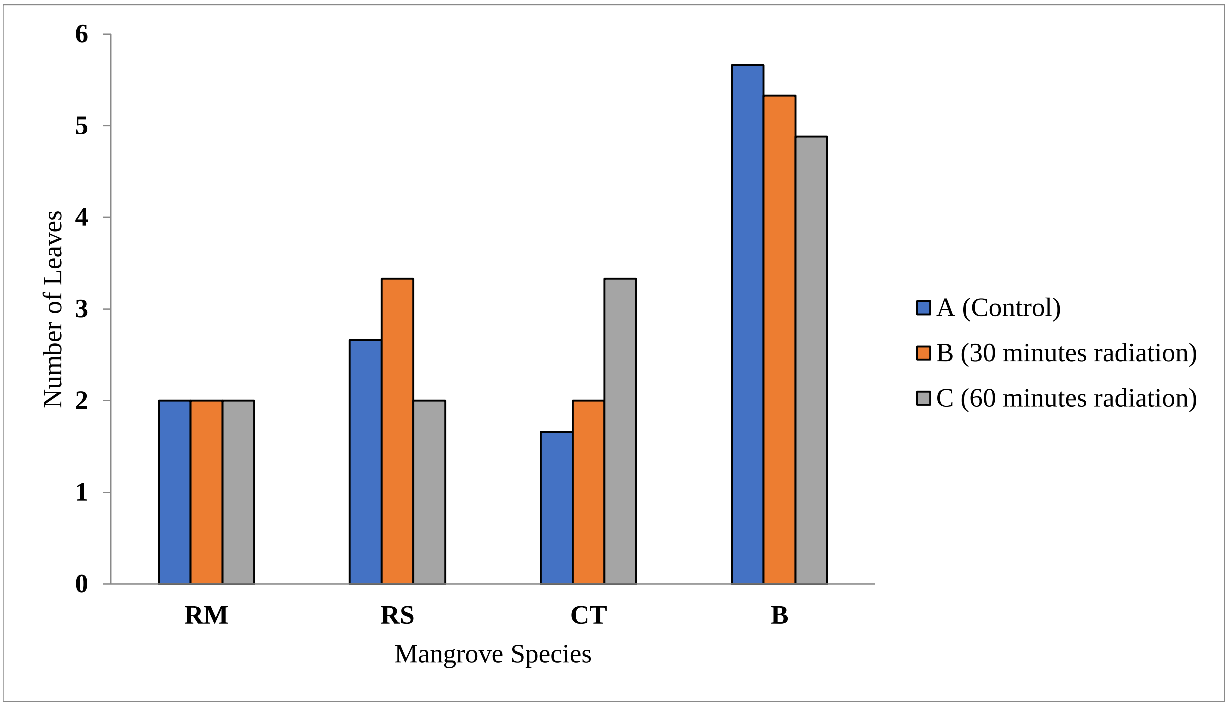

Fig. I. Number of mangroves leaves after plasma radiation in different time

(1.33 cm/day), was the RMB treatment (30 minutes of radiation, *R. mucronata* species).

There was no statistical effect of the interaction between corona incandescent plasma radiation and mangrove species on the number of mangrove leaves (Table 2). The mangrove species factor showed a significantly different effect. The species that had the highest number of leaves was *Burguiera* sp and the lowest number was *Ceriops tagal* (Fig. I).

Discussion

Plasma radiation can supply the nitrogen requirements for the growth process of mangrove plants. This is indicated by the acceleration of growth rates in mangrove propagules. Nitrogen is a determining nutrient for plant growth and productivity (Razaq et al., 2017). It increases the growth of hypocotyl biomass so that it will accelerate the emergence of buds (Cui et al., 2017; Shiau et al., 2017). In addition, the availability of nitrogen increases maximal stem growth (Alongi, 2011). Increasing stem growth increases the rate of plant growth every day. *R. mucronata* experienced an increase in the growth rate of 1.33 cm/day or an increase of 62.19% compared with the growth rate of *C. tagal*. According to Robert et al. (2016), the roots of *R. mucronata* show faster growth than those of *C. tagal*.

R. sylosa and *Bruguera* sp. did not show any significant difference in growth rate for the 15-minute and 30-minute radiation treatments. Observations for the 30 minutes of radiation showed an increase in the growth rate of each species compared with the control treatment. According to Fridman (2008), nitrogen ions produced by corona incandescent discharge are in the form of N_2^+, N^+, and N* ions. These positively charged nitrogen ions are attracted by negative fields/negative electrodes (field electrodes), so nitrogen ions are deposited on samples placed on negative electrodes, and they increase the nitrogen content of the sample. According to Nucifera et al. (2016), the influence of plasma administration on the growth of black soybean in the 30-minute radiation treatment was higher than the control requirements.

Corona's incandescent radiation technology is capable of fulfilling the nitrogen requirements of mangroves. Nitrogen in the original habitat of mangrove plants is low due to the high salinity (Kao et al., 2001; Rodriguez et al., 2015). Nutrient limitations may be due to competition between mangroves and the high bacteria levels in the soil

(Alongi, 2010). The addition of nitrogen through plasma technology can balance nitrogen absorption and nitrogen depletion due to several factors. According to Shiau et al. (2017), an increase in nitrogen will balance the absorption of nitrogen. Thus, the expenditure of nitrogen efficiently results from a decrease in nitrogen in the estuary region.

Plasma radiation is quite effective in supplying the requirements of mangrove seed nutrients while accelerating the growth of propagules. During plasma radiation, gas or nitrogen ion diffusion occurs in the mangrove propagule substrate. Statistical analysis showed no interaction between plasma radiation factors, but there was an effect on the single factor of mangrove species. The single factor of plasma radiation did not show an effect on the number of leaves. The results showed that mangroves with *Bruguiera* sp. had the highest number of leaves compared with the other mangrove species. Leaf formation occurs because of cell division in the apical meristem of the terminal and lateral buds that periodically produce reserves of new cells that form leaves. The number of leaves affects the quantity of light absorption and the rate of photosynthesis.

Nitrogen stimulates leaf formation and gives a dark green color to plants (Jahan, 2016). The addition of nitrogen encourages the formation of active photosynthetic pigments by increasing the amount of stromal and thylakoid proteins and increasing the formation of chloroplasts during leaf growth (Teixeira et al., 2011). Plasma radiation may only play a role during the initial growth of mangroves in the formation of roots and the growth of mangrove stems. Nitrogen is required for the initial process of mangrove growth because mangrove carbohydrate reserves for the growth process are relatively low during the propagule phase. According to Lea and Miflin (2018), nitrogen is diverted from asparagine glutamine as long as plants lack carbohydrates and have nitrogen content. The process carried out is the metabolic process of asparagine synthase in anabolic reactions and asparaginase in catabolic reactions.

The sustainability of mangroves in a forest area depends on seedlings, and seedling growth is influenced by environmental factors. Lack of water in the environment during the dry season causes plants to lack water during the nursery process. *Bruguiera* sp. mangrove seedlings are mangrove fruits that have separated hypocotyl parts so they have leafy plumules, and include mangrove species that grow on land with a salinity level close to that of freshwater (Lechthaler et al., 2016).

Conclusion

Corona incandescent plasma radiation can increase the mangrove growth rate, especially in *R. mucronata* species. However, plasma radiation had no statistically significant effect on the number of leaves. Plasma radiation for 60 minutes produced the best yield, indicating fulfillment of the nitrogen requirements, especially during the hypocotyl formation process and stem growth.

Acknowledgement

The author would like to thank Diponegoro University for financial support from the Riset Publikasi internasional (RPI), Diponegoro University 2023 research scheme with contract number 569-141/UN7.D2/PP/IV/2023.

References

Alongi, D. M, 2010. ‘Dissolved iron supply limits early growth of estuarine mangroves’. *Ecology,* 10 (11): 1890-2142.

Alongi, D. M, 2011. ‘Early growth responses of mangroves to different rates of nitrogen and phosphorus supply’. *Journal of Experimental Marine Biology and Ecology,* 397 (2): 85-93.

Alongi, D. M. 2018. ‘Impact of global change on nutrient dynamics in mangrove forest’. *Forest,* 9 (10): 1-13.

Arif, A. M., G. Guntur, A. Ricky, P. Novianti, and **I. Andik,** 2017. ‘Mangrove ecosystem c-stocks of

Lamongan, Indonesia and its correlations with forest age'. *Research Journal of Chemistry and Environment,* 21 (8): 1-9.

Ariyanti, A., E. Prihastanti, and **M. Azam**, 2020. 'Radiasi plasma pijar korona terhadap pertumbuhan dan kandungan nitrogen total bawang merah dan bawang bombay [Korona incandescent plasma radiation to growth and total nitrogen content of shallots and onions]'. *Jurnal Biologi Lingkungan Industri Kesehatan,* 6 (2): 126-137.

Basyuni, M., D. A. Keliat, M. U. Lubis, N. B. Manalu, R. Wati, and **Yunasfi,** 2018. 'Growth and root development of four mangrove seedlings under varying salinity'. *Earth and Environmental Science,* 130 (1): 1-7.

Bown, H. E., M. S. Watt, P. W. Clinton, and **E. G. Mason**, 2010. 'Influence of ammonium and nitrate supply on growth, dry matter partitioning, N uptake and photosynthetic capacity of pinusradiata seedlings'. *Trees,* 24 (6): 1097-1107.

Castro, R. A., M. N. Dourado, J. R. Almeida, P. T. Lacava, I. S. Melo, and **J. L. de Azevedo. L,** 2014. 'Mangrove endophyte promotes reforestation tree (*Acacia polyphylla*) growth'. *Brazil Journal Microbiology,* 49: 59-661.

Cui, X., W. Song, J. Feng, D. Jia, J. Guo, and **Z. Wang,** 2017. 'Increased nitrogen input enhances *Kandelia obovota* seedling growth in the presence of invasive *Spartina alterniflora* in subtropical region of China'. *Conservation Biology,* 13 (1): 1-5.

De Giorgio, D. and **F. Fornaro,** 2011. 'Nitrogen fertilization and root growth dynamics in durum wheat'. *Italian Journal of Agronomy,* 7 (3): 207-213.

Fageria, N. K., and **A. Moreira.** (2011). 'The role of mineral nutrition on root growth of crop plants'. *Advances in Agronomy,* 110: 251-331.

Fereira, A. C. and **L. D. Lacerda, L. D,** 2016. 'Degradation and conservation of Brazilian mangroves, status and perspectives'. *Ocean Coastal Management,* 125: 38-46.

Fridman. 2008. *Plasma Chemistry*. New York: Cambridge University Press.

Ilman, M., P. Dargush, P. Dart, and **A. Onrizal,** 2016. 'Historical of the drivers of loss and degradation of indonesia's mangroves'. *Land Use Policy,* 54: 448-459.

Islam, M. S. and **A. Gnauck.,** 2009. 'Threats to the sundarbans mangroves wetland ecosystems from transboundary water allocation in the ganges basin: A preliminary problem analysis'. *International Journal of Ecological Economics and Statistics,* 13 (W09): 64-78.

Ito, M., J. S. Oh, T. Ohta, M. Shiratani, and **M. Hori,** 2018. 'Current status and future prospects of agricultural applications using atmospheric-pressure plasma technologies'. *Plasma Processes and Polymers,* 15 (2): 1700073.

Jahan, S. L, 2016. 'Role of nitrogen for plant growth and development: a review. advances in environmental biology'. *AENSI Journals,* 10 (9): 209-218.

Jain, S. K. And **V. P. Singh,** 2008. 'Acquisition and processing of water resources data'. *In Developments in Water Science,* 51: 47-121.

Kao, W., H. Tsai, and **T. Tsai,** 2001. 'Effect of NaCl and nitrogen availability on growth and photosynthesis of seedlings of a mangrove species *Kandelua candel* (L.) Druce'. *Journal of Plants Physiology,* 154 (7): 841-846.

Kathiresan, K. and **B. L. Bingham,** 2001. 'Biology of mangroves and mangrove ecosystems'. *Advances in Marine Biology,* 40: 81-251.

Lea, P. J. and **B. J. Miflin,** 2018. 'Nitrogen assimilation and its relevance to crop improvement'. *Annual Plant Reviews Book Series,* 42: 1-40.

Lechthaler, S., E. M. Robert, N. Tonné, A. Prusova, E. Gerkema, and **H. V. As,** 2016. 'Rhizophoraceae mangrove saplings use hypocotyl and leaf water storage capacity to cope with soil water salinity changes'. *Frontiers in Plant Science,* 7: 895.

Leung, J. Y. S, 2015. 'Habitat heterogeneity affects ecological functions of macrobenthic communities in a mangrove: Implication for the impact of restoration and afforestation'. *Elsevier,* 4: 423-433.

Lewis, R. R., B. M. Brown, and **L. L. Flynn,** 2019. 'Methods and criteria for successful mangroves forest rehabilitation'. *Coastal Wetlands,* 2: 863-887.

Mardiyarso, D., J. Purbipuspito, J. B. Kauffman, M. W. Warren, S. D. Sasmito, and **D. C.**

Donato, 2015. 'The potential of Indonesia mangrove forest for global climate change mitigation'. *Nature Climate Change,* 5: 1089-1092.

Mustofa, A, 2018. 'Praktik pembibitan dan revitalisasi hutan mangrove pesisir Jepara [Jepara coastal mangrove forest nursery and revitalization practices]'. *Journal of Dedicators Community,* 2: 8-17.

Nucifera, N., M. A. Kanie, S. H. Pratiwi, R. Pratiwi, S. P. Putro, and **M. Nur,** 2016. 'Korona discharge plasma technology to accelerate the growth of black soybean plants'. *Journal of Natural Sciences Research,* 6 (14): 35-40.

Polidoro, B. A., K. E. Carpenter, L. Collins, N. C. Duke, M. Ellison, and **J. C. Ellison,** 2010. 'The loss of species: mangrove extinction risk and geographic areas of global concern'. *Plos One,* 5 (4): e10095.

Razaq, M., P. Zhang, H. Shen, and **Salahuddin,** 2017. 'Influence of nitrogen and phosphorous on the growth and root morphology of Acer mono'. *Plos One,* 7 (2): e0171321.

Rizal, A., A. Sahidin, and **H. Herawati,** 2018. 'Economic value estimation of mangrove ecosystems in Indonesia'. *Biodiversity International Journal,* 2 (3): 51-54.

Robert, E. M. R., J. Oste, T. V. Stocken, D. J. R. Ryck, K. Quisthoutdt, and **J. G. Kairo,** 2016. 'Viviparous mangrove propagules of *Ceriops tagal* and *Rhizopora mucronata*, where both rhizoporaceae show different dispersal and establishment strategies'. *Journal of Experimental Marine and Technology,* 468: 45-54.

Rodriguez, J. A. R., J. E. M. Pineda, L. M. Melgarejo, and **J. H. M. Calderon,** 2015. 'Functional traits of leaves and forest structure of neotropical mangroves under different salinity and nitrogen regimes'. *Flora,* 239 (2018): 52-61.

Romanach, S. S., D. L., DeAngelis, H. L. Koh, Y. Li, S. Y. Teh, and **R. S. R. Barizan,** 2018. 'Conservation and restoration of mangroves: Global status, perspectives and prognosis'. *Ocean and Coastal Management,* 154: 72-82.

Roziqin, A, 2017. 'Environmental policy of mangroves management in Rembang regency'. *International Conference on Energy, Environment, Epidemiology, and Information System,* 31, pp: 1-6.

Salampessy, M. L., I. G. Febryano, Martin, M. E. Siahaya, and **Papilaya, R,** 2014. 'Cultural capital of the communities in the mangrove conservation in the coastal areas of Ambon dalam Bau, Moluccas, Indonesia'. *Procedia Environmental Sciences,* 23 (2015): 222-229.

Shiau, Y., S. Lee, T. Cheen, G. Tian, and **C. Chiu,** 2017. 'Water salinity effects on growth and nitrogen assimilation rate of mangrove (*Kandelia candel*) seedlings'. *Aquatic Botany,* 3: 50-55.

Srikanth, S., S. K. Y. Lum, and **Z. Chen,** 2016. 'Mangrove root: Adaptations and ecological importance'. *Trees,* 30: 451-465.

Susan A.I., Sjaifudin T.A., Widodo, M., Nur M. 2016. Electrical Study of Corona Glow Discharge Plasma Using Multi Point to Plane electrodes In Textile Treatment. *Arena Tekstil* 31(1): 11-16.

Teixeira, F. M. C. M., S. Buzetti, M. Andeotti, O. Arf, and **M. E. de Sa,** 2011. 'Application times, sources and doses of nitrogen on wheat cultivars under no till in the cerrado region'. *Ciência Rural,* 41 (8): 1375-1382.

Tonne, N., H. Beeckman, E. M. R. Robert, and **N. Koedam,** 2016. 'Towards an unknown fate: The floating behaviour of recently abscised propagules from wide ranging Rhizophoracea mangrove species'. *Aquatic Botany,* 140: 23-33.

Vo, Q. T., N. Oppelt, P. Leinenkugel, and **C. Kuenzer,** 2013. 'Remote sensing in mapping mangroves ecosystems an object bases approach'. *Remote Sens,* 5 (1): 183-201.

Wahyudi, S. I., M. F., Na'iman and **G. L. Bras,** 2012. 'Problems, causes and handling analysis of tidal flood, erosion and sedimentation in northern coast of Central Java: Review and recommendation'. *International Journal of Civil and Environmental Engineering,* 12 (4): 65-70.