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Mahardika Prasetya Aji <mahardika@mail.unnes.ac.id>

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ADVANCES IN NATURAL SCIENCES: NANOSCIENCE AND NANOTECHNOLOGY

Carbon Dots from Dragon Fruit's Peels as Growth-Enhancer on Ipomoea Aquatica Vegetable Cultivation

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Carbon Dots from Dragon Fruit's Peels as Growth-Enhancer on *Ipomoea Aquatica* Vegetable Cultivation

Mahardika Prasetya Aji[1,*], Lathifatus Sholikhah[1], Fina Idhamatus Silmi[1], Hestining Ajeng Permatasari[1], Ita Rahmawati[1], Aan Priyanto[2], Bebeh Wahid Nuryadin[3]

[1]Department of Physics, Universitas Negeri Semarang, Jalan Taman Siswa, Sekaran, Gunungpati Semarang, Central Java 50229, Indonesia.

[2]Department of Physics, Institut Teknologi Bandung, Jalan Ganesha No.10, Bandung, West Java 40132, Indonesia.

[3]Department of Physics, Universitas Islam Negeri Sunan Gunung Djati, Jalan A. H. Nasution No. 105, Cibiru Bandung, West Java 40614, Indonesia.

Email: mahardika@mail.unnes.ac.id

Abstract. Nanoparticles C-Dots have been successfully synthesized from the extract of dragon fruit peels. In this study, C-Dots were used to promote the growth of *Imopea Aquatica* vegetable. C-Dots were obtained from the extract of dragon fruit irradiated by microwave for 5 to 30 minutes. The optimum C-Dots have been obtained from the extracts of dragon fruit peels irradiated by microwave for 20 minutes. C-Dots have emission at wavelength of 450 nm. The obtained C-Dots are also capable to bind Nitrogen—Phosphor—Potassium (NPK) fertilizer and act as nutrients carrier. C-Dots then can be directly supplemented to

Imopea Aquatica cultivation to explore their influence on the plants at different concentrations of 0 ml, 25 ml/L, 50 ml/L, 75 ml/L, 100 ml/L, and 125 ml/L. The effect of C-Dots on plant was analyzed by measuring the growth rate of plant. It was confirmed that with supplementary of 25-50 ml/L C-Dots enhance the growth of *Imopea Aquatica* vegetable. This study indicates that C-Dots synthesized from dragon fruit peels extracts can act as a growth enhancer to increase vegetable yields.

Keywords: Nanoparticle, C-Dots, Dragon fruit peels, Growth enhancer, Imopea Aquatica.

Classification numbers: 1.00, 2.10, 4.02, 5.00

1. Introduction

Nanotechnology is currently being applied in agriculture. Nanomaterials play several fundamental roles in agriculture as plant protection, fertilization and growth promotion [1-4]. Several nanomaterials such as Titanium Dioxide (TiO_2) and Zinc Oxide (ZnO) are able to act as pesticides, fungicide, and antibacterial for plants. Whereas, nanoparticles of Calcium (Ca), Potassium (K), Zinc (Zn), Phosphor (P), Sulfur (S), Iron (Fe), Manganese (Mn) and Magnesium (Mg) could also be used as nutrients to promote the plant growth [7-12]. Another significant application of nanomaterial is as an active material for nutrients deliveries and suppresses nutrients losses in fertilization. Nanomaterials such as ZnO, Gold (Au), Magnetite (Fe_3O_4), Carbon Nanotubes (CNT), Carbon Nanodots (C-Dots) have been successfully used to trigger seed growth, root and stem formation in plants [12-15]. Nanomaterials with their tiny size allow them to be easily absorbed by plants. In addition, nanomaterials are capable to strongly bind the nutrients in the soil using the electrostatic interaction forces.

Despites nanomaterials could minimize nutrients losses in fertilization, but several issues are still to be addressed. The presence of inorganic nanomaterials as plant supplements can potentially accumulated in plants and it is possibly harmful for consumption. Furthermore, toxicity is a crucial problem from the use of inorganic nanoparticles in plants. For further development of nanomaterials for agriculture, organic materials become very promising to produce non-toxic nanomaterials. The use of organic nanomaterials in agricultural is still rarely. Researcher from China has been successfully synthesized nanomaterials C-Dots from pollen. The use of 10-30 mg/L C-Dots from pollen has successfully triggered the growth of *Lactuca sativa L.* C-Dots nanoparticles has a very promising for plant supplements due to their tiny size <10 nm, non-toxic and easily dissolved [16]. Moreover, negative charged ligands on a surface of C-Dots could play as nutrients binder in fertilization.

Nanoparticle C-Dots are easily synthesized from organic materials with prosperous carbon chains such as various pigments in flowers, fruit and fruit's peels. Betalains pigment in the dragon fruit peels has become one of the organic materials for producing C-Dots nanoparticles [17]. With the properties of less cytotoxicity and good biocompatibility, C-Dots are potentially useful for agriculture. In addition, another potential of betalains pigment in dragon fruit's peels is the presence of nitrogen in its functional groups a macro nutrient needed by plants. In present work, we synthesize C-Dots from dragon fruit peels and use it as a growth enhancer for *Imopea Aquatica* vegetable.

2. Experiment

Ripe red dragon fruit is easily obtained from the local market in Semarang, Central Java-Indonesia. The raw material for synthesis is dragon fruit peels. Another ingredient is urea with technical quality obtained from the chemical shop Indrasari, Indonesia. Betalains pigment was extracted by heating process of 20 g dragon fruit peels in 100 ml of distilled water at 70^{o}C for 2 hours. A total of 20 ml of dragon fruit peels extract mixed with 20 g of urea. A total of 20 ml of this homogeneous extract solution then was irradiated by microwave (Panasonic NN-SM322M) for 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes, and 30 minutes. C-Dots from synthesis then were analyzed the absorption and emission spectrum. The absorption spectrum was measured using Vis-Nir Ocean Optics type USB 4000. While the emission spectrum was measured using a photoluminescence device of Cary Eclipse type Spectroflourometer MY14440002. The changes in the functional groups of the dragon fruit peels extracts due to microwave radiation were analyzed by measurement using Fourier Transform Infrared (FTIR) type Perkin Elmer Spectrum Version 10.03.06. C-Dots with optimum absorption and emission spectrum then were used as supplements or growth enhancer for Imopea Aquatica vegetable cultivation. C-Dots were implemented with volume variations of 0 ml, 25 ml, 50 ml, 75 ml, 100 ml, and 125 ml in 1000 ml of distilled water. The growth rate can then be observed in a certain period of time.

3. Result and discussion

The extracts of dragon fruit peels irradiated by microwave changes its color from red to brown as shown in Figure 1. The dominant red color of dragon fruit peels extract shows betalains pigment [18]. Microwave radiation causes polymerization and carbonization process at betalains pigment thus the extract turns brown. This color change denotes an alteration of the optical properties of the extract. Dragon fruit peels extract does not emit when irradiated using ultraviolet (UV) light. Meanwhile, dragon fruit peels extract which has been irradiated by microwave waves emits waves of emission when irradiated by ultraviolet (UV) light. The emission shows that the extract of the dragon fruit peels irradiated by microwave yield C-Dots particles. This luminescence property is also found in C-Dots produced from other fruit peels—mangosteen peels, orange, watermelon, etc—, waste plastics, leaves, sugar, flowers, and pollen seeds [16,19-24].

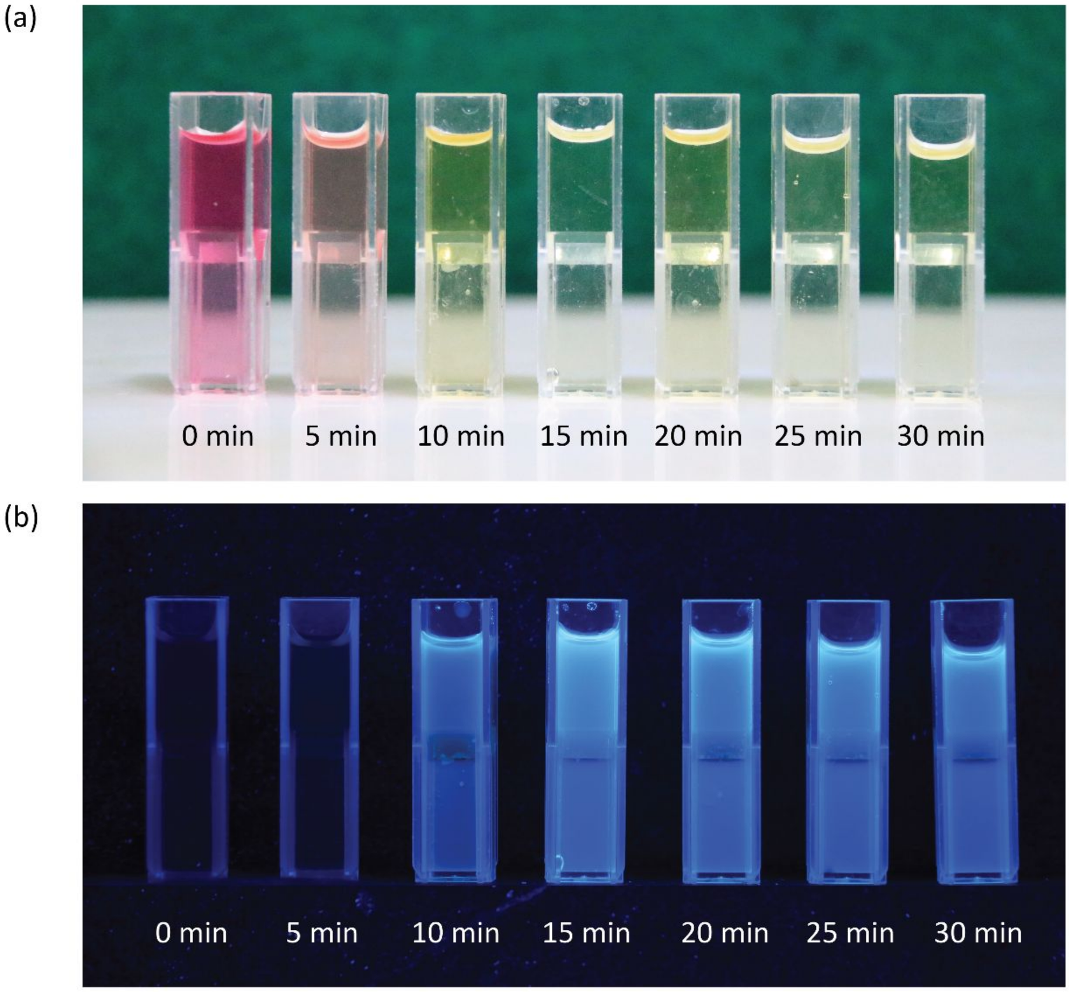

Figure 1. Dragon fruit peels extract irradiated by microwave in: (a). day light, and (b). UV light

Microwave radiation changes the absorbance spectrum of dragon fruit peels extract as shown in Figure 2. The absorption spectrum of dragon fruit peels extract is in the wavelength range of 350-700 nm. Dragon fruit peel extract solution showed two peaks of absorbance at 420 nm and 543 nm wavelengths. Two peaks indicate the typical peak of the betalains pigment in the extract of dragon fruit peels [25]. Two typical peaks of betalains in the absorbance spectrum are still observed in the extract of dragon fruit peels which were given microwave radiation for 5 minutes. The longer the microwave radiation time, the typical peak intensity at 543 nm is decreased and peak intensity at 420 nm is increased. The energy of microwave radiation breaks the conjugate double bonds in the betalains pigment thus the intensity at the wavelength of 543 nm has decreased. Whereas the intensity of the absorption spectrum at wavelength 420 nm goes higher with the longer time of the microwave wave radiation. This is related to the vibrations of the short chain bonds which are increasing due to termination of the other pigment chains.

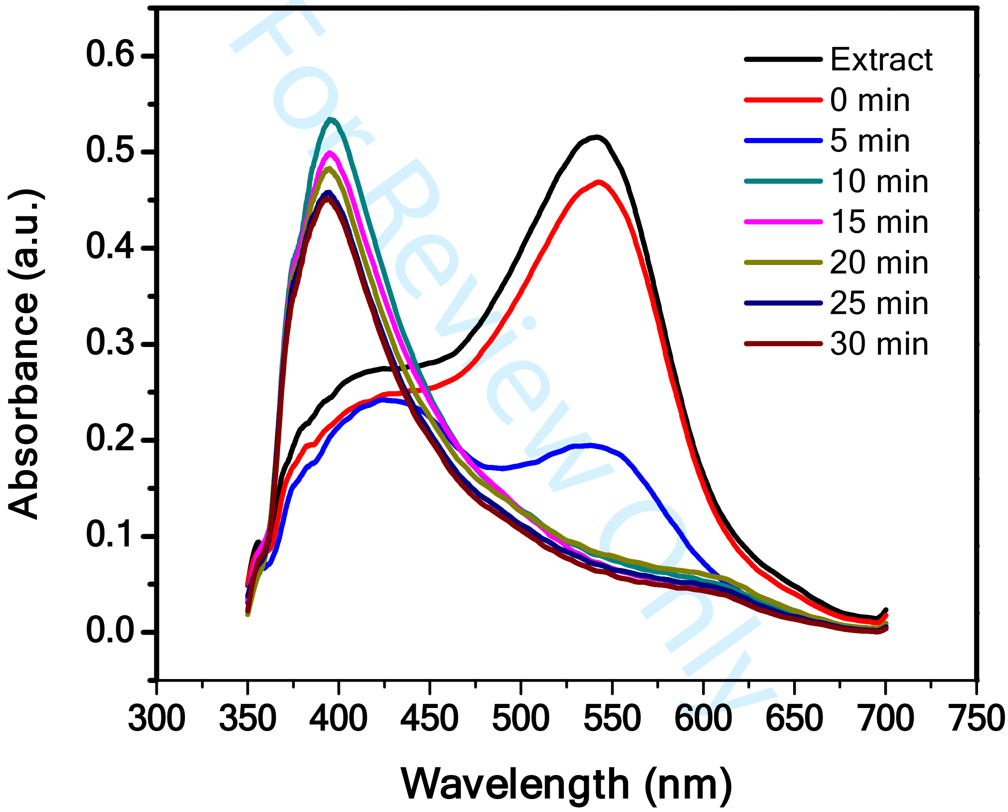

Figure 2. Absorbance spectrum of the obtained dragon fruit peels extract irradiated by microwave.

Reduction of absorption spectrum intensity also occurs in the extract of dragon fruit peels with and without urea due to a chemical interaction between dragon fruit peels extract and urea. The presence of urea in the dragon fruit peel extract is very important as passivation agent to modify the functional groups on the surface of C-Dots. The typical peaks of the betalain pigment denote an electronic transition. The peak at 420 nm shows the electron transition in n → π* and the peak at 543 nm denotes the electron transition in π → π* orbitals. The electron transition to the bonding n → π* orbitals is the electron transition from the C=C bond while the electron transition to the π → π* orbitals shows the transition from sp^2 of the C=O and C=N bonds.

The excited electrons due to C-Dots received UV-ligth experienced recombintaion process—return to ground state by emitting the visible light. The C-Dots photoluminescence spectrum is in the wavelength range of 375-650 nm as shown in Figure 3. The C-Dots photoluminescence peak is at a wavelength of 450 nm (1.92 eV). The enhancement of photoluminescence intensity occurred in the spectrum of the extract before being irradiated with microwave waves to the extract after being irradiated for 20 minutes. The higher the intensity indicates that the number of C-Dots from dragon fruit peels are produced more. Thus, 20 minutes is an effective radiation time in the mechanism of formation of C-Dots from dragon fruit peels extract. C-Dots that produced from 20 minutes radiation then be applied as a supplement growth enhancer of Imopea Aquatica cultivation. The intensity of photoluminescence of dragon fruit peels extract decreases when irradiated for 30 minutes where C-Dots turns into carbon charcoal.

The photoluminescence mechanism of C-Dots from dragon fruit peels is influenced by the electronic transition π. The electrons in the High Occupied Molecular Orbital (HOMO) band are excited to the Low Unoccupied Molecular Orbital (LUMO) band after received UV energy from outside. The electrons in the LUMO band are unstable so they recombine into the HOMO band by emitting visible light.

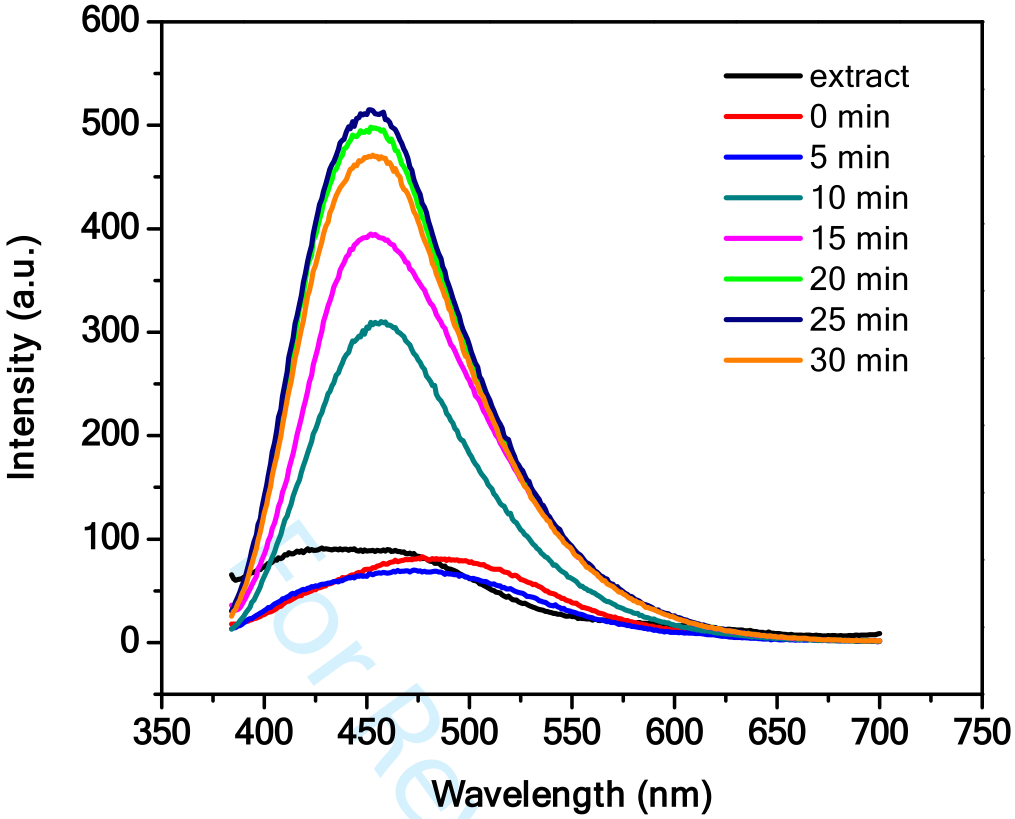

Figure 3. Photoluminescence spectrum of the obtained dragon fruit peels extract irradiated by microwave.

The alteration of functional group of dragon fruit peels extract irradiated by microwave for 20 minutes is shown by the FTIR analysis in Figure 4. The wave number band of 729 cm^{-1} indicates a strong bending of C-H. The band shows changes in spectrum patterns that indicate damaging of the aromatic structures in the pigment caused by microwave radiation. The functional group of OH-streching found in the absorption area of 3478 cm^{-1} which denotes the presence of water (H_2O) as a solvent. The band at wave number of 1639 cm^{-1} shows the bond of C=O. In addition, the bond of C=N appears at wave number of 2123 cm^{-1}. C-H, C=O, and C=N bonds are functional groups formed on the surface of C-Dots. The C=N bond interprets that the addition of urea has successfully modified the surface structure of the C-Dots from the extract of the dragon fruit peels.

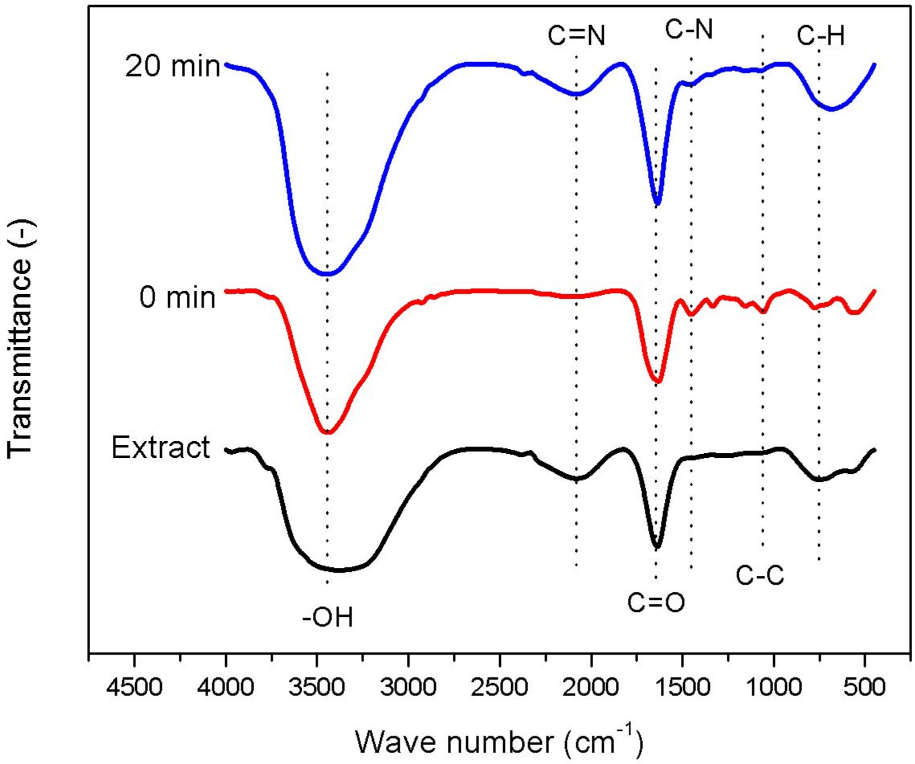

Figure 4. FTIR spectrum of the obtain dragon fruit peels extract and irradiated by microwave irradiation for 0 minute and 20 minutes.

Ipomea Aquatica grows taller with the supplementary C-Dots as shown in Figure 5. Plants with supplementary C-Dots of 50 ml/L grow higher than those given with 25 ml/L and 0 ml/L. This indicates that the more C-Dots are given, the more C-Dots are absorbed into the the plant through plant transport mechanisms.

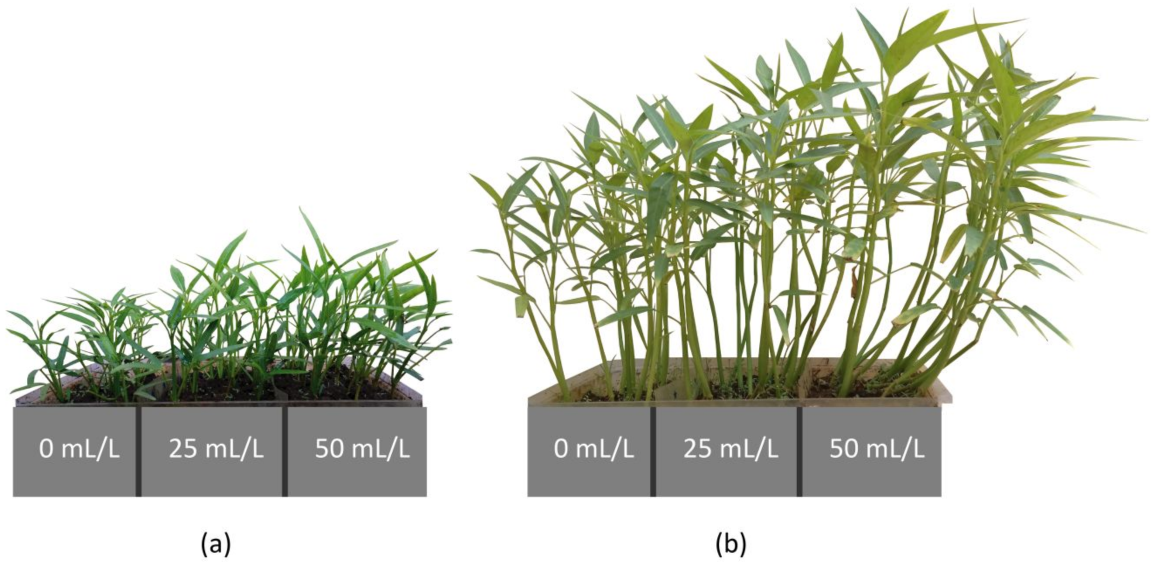

Figure 5. Growth of *Ipomea Aquatica* plants giving various C-Dots (a) 20 days growth (b) 40 days growth.

The effect of supplementary C-Dots on the height of vegetable is shown in Figure 6a. The results showed that *Ipomea Aquatica* with supplementary C-Dots grew taller than without C-Dots, and also taller than vegetable which were only given urea. In addition, the greater the volume of supplementary C-Dots, the vegetable grows taller. The effectiveness of C-Dots as growth enhancer is described by the growth rate as shown in Figure 6b. The Growth rate of *Ipomea Aquatica* goes with a positive trend. However, growth rates did not differ significantly when fertilized with a volume fraction of 100 ml/L. This indicates that the volume fraction of 100 ml/L is the limit of the saturation volume of C-Dots given to the plant.

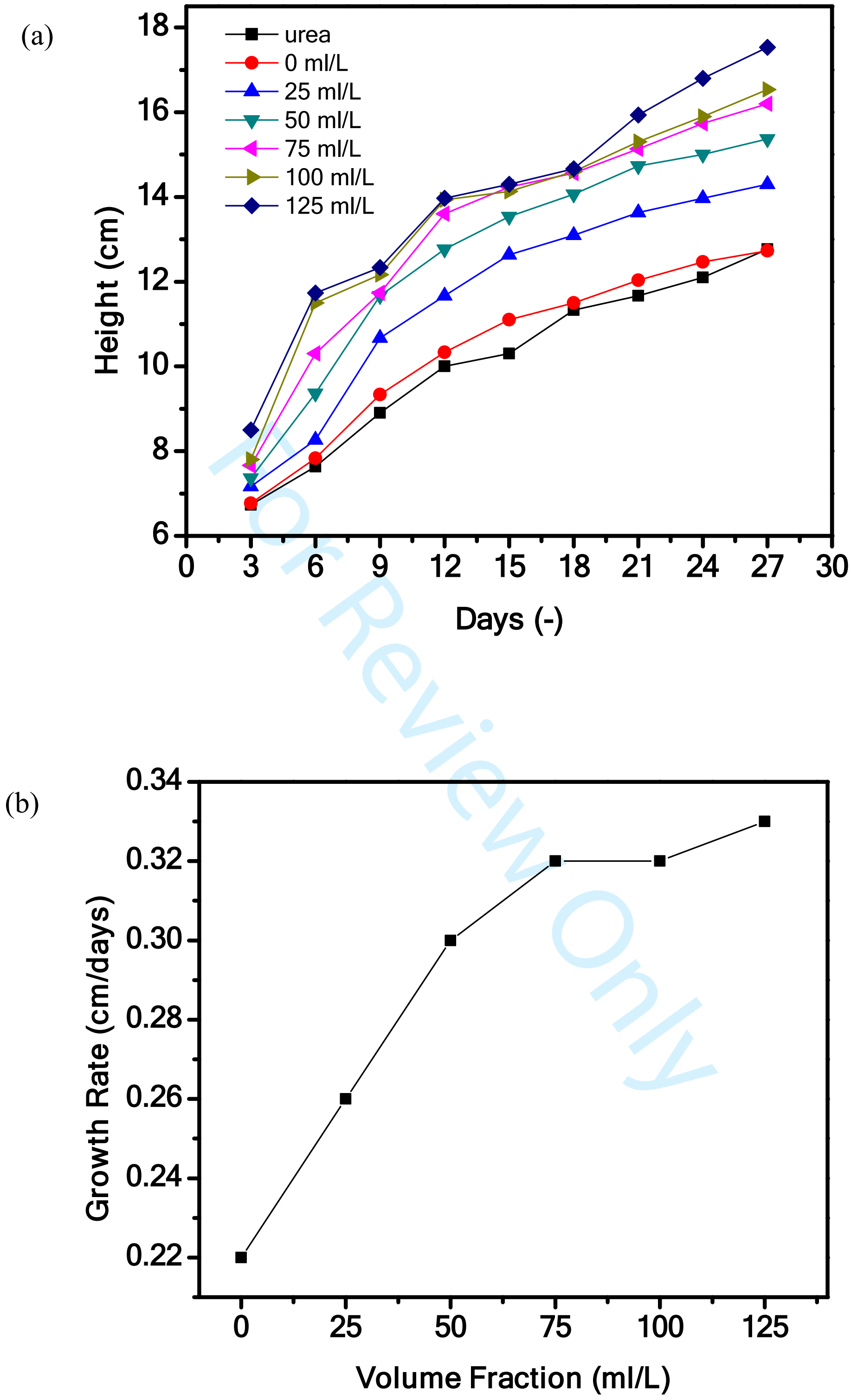

Figure 6. Effect of supplementary C-Dots on *Imopea Aquatica* physiology : (a) plant height (b) plant growth rate.

The yield and physiology of *Ipomea Aquatica* due to the supplementary C-Dots is shown in Figure 7. Higher volume of C-Dots yield vegetable has thicker and longer roots, longer leaves, and taller stems. This indicates that C-Dots from dragon fruit peels can be effectively used as a growth enhancer of *Ipomea Aquatica*.

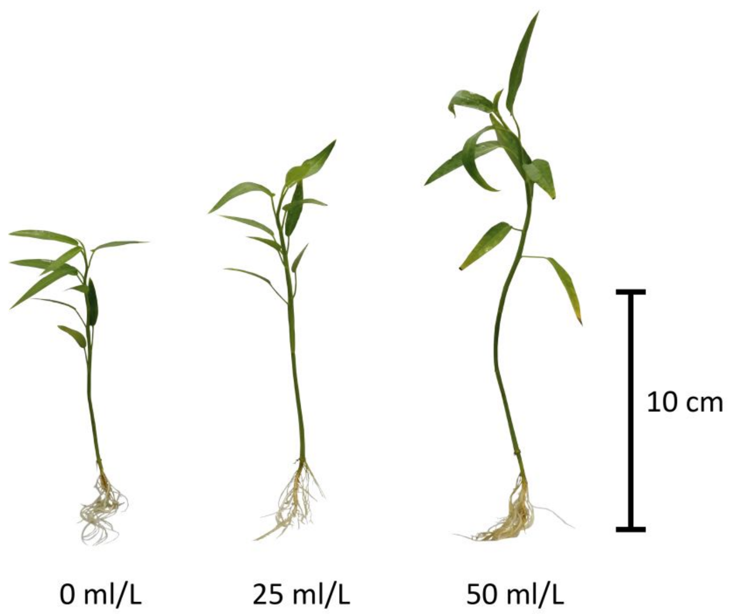

Figure 7. Effect of supplementary C-dots on the physiology of *Imopea Aquatica*.

The interaction of C-Dots with Nitrogen—Phosphor—Potassium (NPK) fertilizer is shown in Figure 8. NPK has a C-N functional group at wave number of 1483 cm^{-1}. Whereas C-Dots from dragon fruit peels have no C-N functional group at these wave numbers. The intensity of the C-N functional group was more observed in the mixing C-Dots with NPK. This indicates that there is an interaction between C-Dots and NPK and proves that C-Dots can interact and bind NPK so that it can potentially useful as a nutrients carrier.

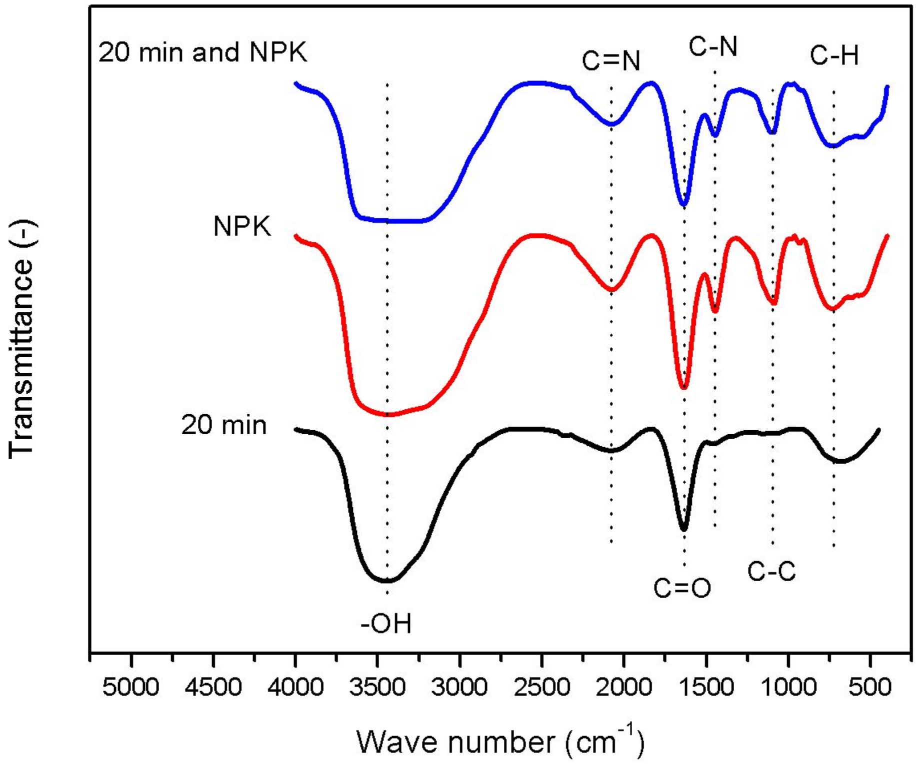

Figure 8. FTIR spectrum of the obtain dragon fruit peels extract with 20 minutes microwave irradiation (C-Dots) with Nitrogen—Phosphor—Potassium (NPK).

4. Conclusion

In the present work, C-Dots have been successfully synthesized an implemented as growth enhancer of *Imopea Aquatica* vegetable. The optimum C-Dots have been obtained from the extracts of dragon fruit peels irradiated by microwave for 20 minutes. The obtained C-Dots are capable to bind Nitrogen—Phosphor—Potassium (NPK) fertilizer and act as nutrients carrier. It was confirmed that with supplementary of 25-50 ml/L C-Dots enhance the growth of *Imopea Aquatica* vegetable. This study indicates that C-Dots synthesized from dragon fruit peels extracts can act as a growth enhancer to increase vegetable yields.

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2. Bukti konfirmasi keputusan dan hasil review manuskrip

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Once again, thank you for submitting your manuscript to the Advances in Natural Sciences: Nanoscience and Nanotechnology and I look forward to receiving your revision.

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Reviewers' Comments to Author:

Reviewer: 1

Comments to the Author
This is an interesting experiment. The ability to use a waste produce (such as dragonfruit peel) and convert an extract from the peel into a plant nutrient carrier is an excellent idea.

The physics part of the experiment is wellexplained, although you do need to include the wattage of the microwave you used - since that can be quite variable between manufacturers (and over time it will decrease).

The plant part of the experiment needs more information to be very useful top researchers - and some of the should be in the methods section - not the discussion.

Did you start with cuttings of the plant? How large were they? How long since they were rooted? Had they received any other supplemental fertilization before the C-dots treatments? How often was the C-dots treatment applied - and how much. What size container is used for each rooted cutting? What are the environmental parameters? What is the lighting source (greenhouse, artificial lighting?) What temperatures were the plants grown under? Did you count the number of leaves or stem nodes at 20 or 40 days.

Is there some other reason possible for stem elongation (that's why the number of nodes is important - to separate growth from elongation).

Why not include photos of all treatments, even those that were not much different. Certainly we would want a photo of plants with C-dots added that did not have the added urea, just to see if there is a mechanical effect. It would not hurt to explain briefly (maybe in the introduction or in the discussion) why you selected water spinach as a test crop - and the proper scientific name is Ipomoea aquatica ... you need to spell it the same way throughout the paper and the "aquatica" starts with a lowercase letter - not uppercase that is correct for "Ipomoea". It should be in italics every time you use it (and I can't write in italics here). If you introduce a common name for the crop, it is also ok to use that after you have introduced the scientific name.

There are number of minor grammar errors and perhaps the editor will make some suggestions. The Fruit's Peel in the title does NOT need to be possessive, so just say Fruit Peel or Dragonfruit Peel if you prefer to make it one word (and that is acceptable for dragonfruit).

Reviewer: 2

Comments to the Author
The paper presents an application of C-Dots for promoting the growth of Imopea Aquatica vegetable. It is a topic of interest to the researchers in the related areas but the paper needs significant improvement before acceptance for publication. My detailed comments are as follows:
1) In the abstract sentence, you mention "Nanoparticles C-Dots have been …..". Which will you use in the following text, "nanoparticle C-Dots" or "C-Dots nanoparticles" or “C-Dots”? All three are found.
2) How much microwave oven power do you use?
3) Page 7, please add references to confirm that the peaks at 420 nm and 543 nm are from the C=C bond and C=O and C=N bonds and attributed to the electron transition in $n \rightarrow \pi^*$ and $\pi \rightarrow \pi^*$ orbitals, respectively.
4) Page 8, please add references to confirm that the peaks at 729 cm-1, 1639 cm-1, 2123 cm-1 and 3478 cm-1 are assigned to the stretching vibration of C-H, C=O, C=N, and -OH, respectively.
5) Please re-word the sentence in lines 39-43, page 9.
6) The authors should provide TEM image to indicate the size of the C-Dots
7) There are a lot of typos.

3. Bukti submit revisi, respon dan revisi manuskrip

(26 Maret 2020)

(File : Authors Respone dan Revision Manuscript)

UNNES
UNIVERSITAS NEGERI SEMARANG

Mahardika Prasetya Aji <mahardika@mail.unnes.ac.id>

[ANSN-2019-0169.R1] - Manuscript Submitted

NVT Secretariat of ANSN <onbehalfof@manuscriptcentral.com> Thu, Mar 26, 2020 at 12:08 PM
Reply-To: journal@ans.vast.vn
To: mahardika@mail.unnes.ac.id

26-Mar-2020

Dear Dr. Aji:

Your manuscript entitled "Carbon Dots from Dragonfruit Peels as Growth-Enhancer on Ipomoea aquatica Vegetable Cultivation" has been successfully submitted online and is presently being given full consideration for publication in the Advances in Natural Sciences: Nanoscience and Nanotechnology (ANSN).

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REPLIES TO REVIEWER'S COMMENTS

No	Comments	Replies
	Reviewer 1	
1	The physics part of the experiment is well-explained, although you do need to include the wattage of the microwave you used -since that can be quite variable between manufacturers (and over time it will decrease).	We used 230 watt microwave. This information has been added to experiment/method section in line 16 page 4
2	The plant part of the experiment needs more information to be very useful top researchers - and some of the should be in the methods section - not the discussion.	The plant part of the experiments with more information have been added to method section in line 1-6 page 5
3	Did you start with cuttings of the plant? How large were they? How long since they were rooted?	*Ipomoea aquatica* plants were grown from seeds. Step process with detail information have been added to experiment section line 1-2 page 5
4	Had they received any other supplemental fertilization before the C-dots treatments?	Plants did not receive any other fertilizers beside C-Dots. This information has been updated at experiment section line 4-5 page 5
5	How often was the C-dots treatment applied - and how much.	Supplementation of C-Dots was given every 5 days as explained in experiment section line 6 page 5
6	What size container is used for each rooted cutting?	We used container with size of 10x19x6 cm. We have added this information to experiment section line 3 page 5
7	What are the environmental parameters?	During the treatment, environmental parameters—light intensity, temperature and humidity—were measured using Lightmeter LT Lutron LX-107HA and Victor VX230A respectively. Measured data is presented in Figure 6 line 10 page 12
8	What is the lighting source (greenhouse, artificial lighting?)	The plants were grown under sunlight as mentioned in line 2 page 5
9	What temperatures were the plants grown under?	The plants were grown under temperature of 28.9^{o}C-30.5^{o}C as mentioned in line 12 page 12
10	Did you count the number of leaves or stem nodes at	We did not count the

	20 or 40 days.	number of leaves or stem nodes due to we decided to figure out the growth from plants dimension change.
11	Is there some other reason possible for stem elongation (that's why the number of nodes is important – to separate growth from elongation).	We considered that dimension change (to higher) shows the growth of plants. Several researchers are also use dimension change to indicate the plants growth such as: 1. Zheng et al. (2017): Growth-Promoting Behavior of Carbon Dots from Pollen on Hydroponically Cultivated Rome Lettuce. 2. Dimkpa et al (2018): Effects of Manganese Nanoparticle Exposure on Nutrient Acquisition in Wheat (Triticum aestivum L.). 3. Al-Juthery et al (2019): Effect of foliar nutrition of nano-fertilizers and amino acids on growth and yield of wheat.
12	Why not include photos of all treatments, even those that were not much different. Certainly we would want a photo of plants with C-dots added that did not have the added urea, just to see if there is a mechanical effect.	Photo of all treatments are shown in Figure 7 line 2 page 13 and Figure 9 line 7 page 15
13	It would not hurt to explain briefly (maybe in the introduction or in the discussion) why you selected water spinach as a test crop -	We have added our reason in line 9-10 page 11
14	- and the proper scientific name is Ipomoea aquatica ... you need to spell it the same way throughout the paper and the "aquatica" starts with a lowercase letter – not uppercase that is correct for "Ipomoea". It should be in italics every time you use it (and I can't write in italics here). If you introduce a common name for the crop, it is also ok to use that after you have introduced the scientific name.	We have revised the way to write *Ipomoea aquatica* in all part of manuscript.
15	There are number of minor grammar errors and perhaps the editor will make some suggestions. The Fruit's Peel in the title does NOT need to be possessive, so just say Fruit Peel or Dragonfruit Peel if you prefer to make it one word (and that is acceptable for dragonfruit).	We have changed “dragon fruit peels” into “dragonfruit peels” as reviewer suggested
	Reviewer 2	

16	In the abstract sentence, you mention "Nanoparticles C-Dots have been …..". Which will you use in the following text, "nanoparticle C-Dots" or "C-Dots nanoparticles" or "C-Dots"? All three are found.	We have decided to use "C-Dots"
17	How much microwave oven power do you use?	We used 230 watt microwave. This information has been added to experiment/method section in line 16 page 4
18	Page 7, please add references to confirm that the peaks at 420 nm and 543 nm are from the C=C bond and C=O and C=N bonds and attributed to the electron transition in n →π* and π →π* orbitals, respectively.	References are mentioned in line 5 Page 8 and labelled as references [26-28].
19	Page 8, please add references to confirm that the peaks at 729 cm-1, 1639 cm-1, 2123 cm-1 and 3478 cm-1 are assigned to the stretching vibration of C-H, C=O, C=N, and -OH, respectively.	Reference is mentioned in line 10 Page 9 and labelled as references [21].
20	Please re-word the sentence in lines 39-43, page 9.	We have revised the sentence in lines 39-43, page 9.
21	The authors should provide TEM image to indicate the size of the C-Dots	▪ TEM images was taken with Hitachi TEM system HT7700 device as mentioned in experiment section line 23-25 page 4 ▪ Distribution of C-Dots particle size based on TEM image is presented in results section line 6-7 page 10 and line 1-6 page 11
22	There are a lot of typos.	We have checked and revised our typos

ADVANCES IN NATURAL SCIENCES: NANOSCIENCE AND NANOTECHNOLOGY

Carbon Dots from Dragonfruit Peels as Growth-Enhancer on Ipomoea aquatica Vegetable Cultivation

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Keywords:	Carbon Dots, Dragon fruit peels, Growth enhancer, Imopea Aquatica
Classification numbers:	1.00, 2.10, 4.02, 5.00

Carbon Dots from Dragonfruit Peels as Growth-Enhancer on *Ipomoea aquatica* Vegetable Cultivation

Mahardika Prasetya Aji[1,*], Lathifatus Sholikhah[1], Fina Idhamatus Silmi[1], Hestining Ajeng Permatasari[1], Ita Rahmawati[1], Aan Priyanto[2], Bebeh Wahid Nuryadin[3]

[1]*Department of Physics, Universitas Negeri Semarang*

Jalan Taman Siswa, Sekaran, Gunungpati Semarang

Central Java 50229, Indonesia

[2]*Department of Physics, Institut Teknologi Bandung*

Jalan Ganesha No.10, Bandung

West Java 40132, Indonesia

[3]*Department of Physics, Universitas Islam Negeri Sunan Gunung Djati,*

Jalan A. H. Nasution No. 105, Cibiru Bandung

West Java 40614, Indonesia

*email : mahardika@mail.unnes.ac.id

Abstract

C-Dots have been successfully synthesized from the dragonfruit peels and were applied as growth-enhancer for *Ipomoea aquatica* vegetable cultivation. C-Dots were obtained from the extract of dragonfruit peels via microwave radiation for 5 to 30 minutes. Two typical peaks of betalains in the dragonfruit peels extract experienced alteration. The longer the microwave radiation time, the typical peak intensity at 543 nm is decreased and peak intensity at 393 nm is increased. C-Dots from dragonfruit peels have particle size of 8-25 nm. The optimum C-Dots have been produced from 20 minutes microwave radiation with power of 230 watt. The emission of C-Dots appeared at wavelength of 450 nm. The obtained C-Dots are capable to bind Nitrogen—Phosphor—Potassium (NPK) fertilizer and act as nutrients carrier. C-Dots were then be directly supplemented to *Ipomoea aquatica* vegetable to figure out their influence on plants growth. The supplementation of C-Dots was varied by their volume fraction. The effect of C-Dots was analyzed by measuring the growth rate of plant. This study confirmed that with supplementary of C-Dots could enhance the growth of *Ipomoea aquatica* vegetable. This study denoted that C-Dots from dragonfruit peels extracts were successfully act as a growth enhancer to increase vegetable yields.

Keywords: C-Dots, Dragonfruit peels, Growth enhancer, *Ipomoea aquatica*.

1. Introduction

Nanotechnology is currently being applied in agriculture. Nanomaterials play several fundamental roles in agriculture as plant protection, fertilization and growth promotion [1-4]. Several nanomaterials such as Titanium Dioxide (TiO_2) and Zinc Oxide (ZnO) are able to act as pesticides, fungicide, and antibacterial for plants. Whereas, nanoparticles of Calcium (Ca), Potassium (K), Zinc (Zn), Phosphor (P), Sulfur (S), Iron (Fe), Manganese (Mn) and Magnesium (Mg) could also be used as nutrients to promote the plant growth [7-12]. Another significant application of nanomaterial is as an active material for nutrients deliveries and suppresses nutrients losses in fertilization. Nanomaterials such as ZnO, Gold (Au), Magnetite (Fe_3O_4), Carbon Nanotubes (CNT), Carbon Nanodots (C-Dots) have been successfully used to trigger seed growth, root and stem formation in plants [12-15]. Nanomaterials with their tiny size allow them to be easily absorbed by plants. In addition, they are capable to strongly bind the nutrients in the soil using the electrostatic interaction forces.

Despites nanomaterials could minimize nutrients losses in fertilization, but several issues are still to be addressed. The presence of inorganic nanomaterials as plant supplements can potentially accumulated in plants and possibly harmful for consumption. Furthermore, toxicity is a crucial problem from the use of inorganic nanoparticles in fertilization. For further development of nanomaterials for agriculture, organic materials become very promising to produce non-toxic nanomaterials. The use of organic nanomaterials in agricultural is still rarely. Researcher from China has been successfully synthesized nanomaterials C-Dots from pollen. The use of 10-30 mg/L C-Dots from pollen has successfully triggered the growth of *Lactuca sativa L.* C-Dots are very promising for plant supplements due to their tiny size <10 nm, non-toxic and easily dissolved [16]. Moreover, negative charged ligands on a surface of C-Dots could play as nutrients binder for delivery process in fertilization.

C-Dots are easily synthesized from organic materials with prosperous carbon chains such as various pigments in flowers, fruit and fruit peels. Betalains pigment in the dragonfruit peels has become one of the organic materials for producing C-Dots [17]. With the properties of less cytotoxicity and good biocompatibility, C-Dots are potentially useful for agriculture. In addition, another potential of betalains pigment in dragonfruit peels is the presence of nitrogen in its functional groups as a macro nutrient needed by plants. In present work, we synthesize C-Dots from dragonfruit peels and use it as a growth enhancer for *Ipomoea aquatica* vegetable.

2. Experiment

Ripe red dragonfruit is easily obtained from the local market in Semarang, Central Java-Indonesia. The raw material for synthesis is dragonfruit peels. Another ingredient is urea with technical quality obtained from the chemical shop Indrasari, Indonesia. Betalains pigment was extracted by heating process of 20 g dragonfruit peels in 100 mL of distilled water at 70^{o}C for 2 hours. A total of 20 ml of dragonfruit peels extract mixed with 2 g of urea. A total of 20 ml of this homogeneous extract solution then was irradiated by 230 watt microwave (Panasonic NN-SM322M) for 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes, and 30 minutes. C-Dots from synthesis then were analyzed the absorption and emission spectrum. The absorption spectrum was measured using Vis-Nir Ocean Optics type USB 4000. While the emission spectrum was measured using a photoluminescence device of Cary Eclipse type Spectroflourometer MY14440002. The changes in the functional groups of the dragonfruit peels extracts due to microwave radiation were analyzed by measurement using Fourier Transform Infrared (FTIR) type Perkin Elmer Spectrum Version 10.03.06. C-dots particle size were analyzed by Transmission Electron Microscopy (TEM) (Hitachi TEM system HT7700). C-Dots with optimum absorption and emission spectrum then were used as growth enhancer for *Ipomoea aquatica* vegetable cultivation. The plant was grown from seeds on soil medium and under sunlight. After 5 days growth, we selected plants with similar height and conditions for treatment at 10x19x6 cm container. Plant only receive C-Dots supplementation with volume variations of 0 mL, 25 mL, 50 mL, 75 mL, 100 mL, and 125 mL in 1000 mL of distilled water without any other fertilizer. This supplementation was given every 5 days. The growth rate can then be observed in a certain period of time. During the treatment, environmental parameters—light intensity, temperature and humidity—were measured using Lightmeter LT Lutron LX-107HA and Victor VX230A respectively.

3. Result and discussion

The extracts of dragonfruit peels irradiated by microwave changes its color from red to brown as shown in Figure 1. The dominant red color of dragonfruit peels extract shows betalains pigment [18]. Microwave radiation causes polymerization and carbonization process at betalains pigment thus the extract turns into brown. This color change denotes an alteration of the optical properties of the extract. Dragonfruit peels extract does not emit when irradiated using ultraviolet (UV) light. Meanwhile, dragonfruit peels extract which has been irradiated by microwave waves emits waves of emission when irradiated by ultraviolet (UV) light. The emission shows that the extract of the dragonfruit peels irradiated by microwave yield C-Dots particles. This luminescence property is also found in C-Dots produced from other fruit peels—mangosteen peels, orange, watermelon, etc—, waste plastics, leaves, sugar, flowers, and pollen seeds [16,19-24].

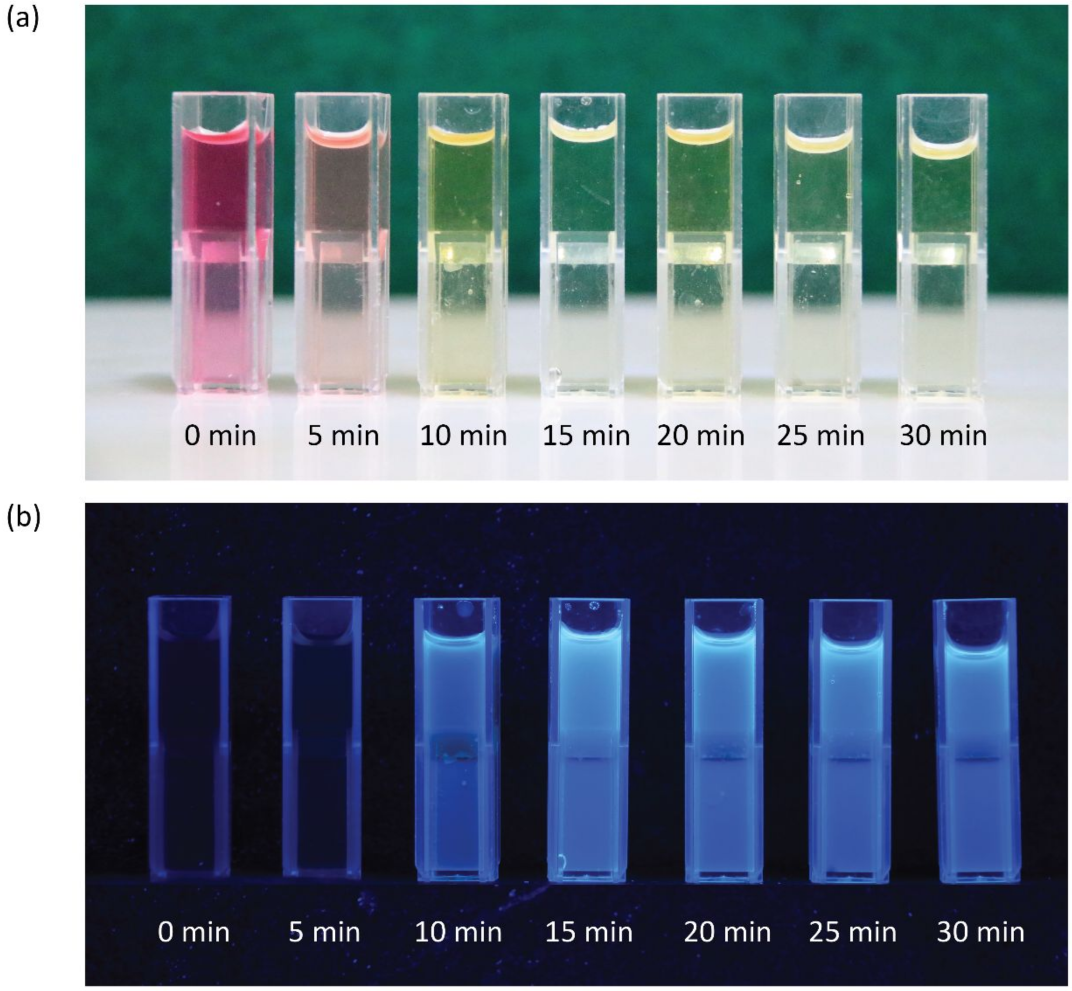


Figure 1. Dragonfruit peels extract irradiated by microwave in: (a). day light, and (b). UV light

Microwave radiation changes the absorbance spectrum of dragonfruit peels extract as shown in Figure 2. The absorption spectrum of dragonfruit peels extract is in the wavelength range of 350-700 nm. Dragonfruit peel extract solution showed two peaks of absorbance at 393 nm and 543 nm wavelengths. Two peaks indicate the typical peak of the betalains pigment in the extract of dragonfruit peels [25]. Two typical peaks of betalains in the absorbance spectrum are still observed in the extract of dragonfruit peels which were given microwave radiation for 5 minutes. The longer the microwave radiation time, the typical peak intensity at 543 nm is decreased and peak intensity at 393 nm is increased. The energy of microwave radiation breaks the conjugate double bonds in the betalains pigment thus the intensity at the wavelength of 543 nm has decreased. Whereas the intensity of the absorption spectrum at wavelength 393 nm goes higher with the longer time of the microwave wave radiation. This is related to the vibrations of the short chain bonds which are increasing due to termination of the other pigment chains.

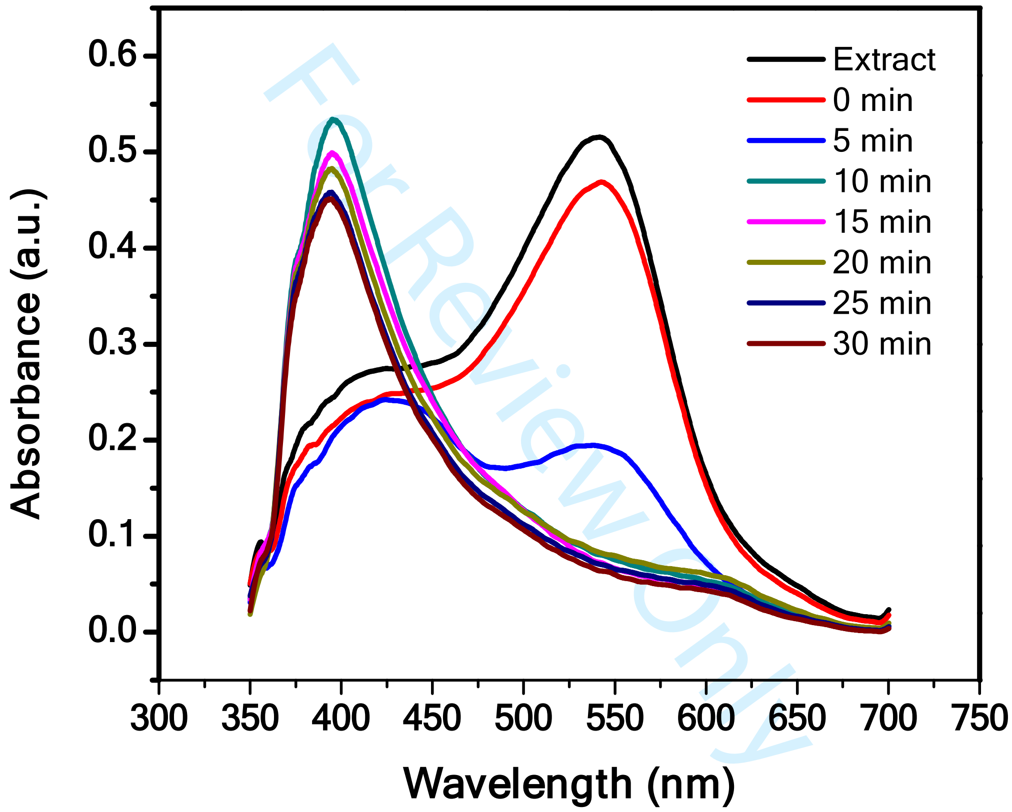


Figure 2. Absorbance spectrum of the obtained dragonfruit peels extract irradiated by microwave.

Reduction of absorption spectrum intensity also occurs in the extract of dragonfruit peels with and without urea due to a chemical interaction between dragonfruit peels extract and urea. The presence of urea in the dragonfruit peels extract is very important as passivation agent to modify the functional groups on the surface of C-Dots. The typical peaks of the betalains pigment denote an electronic transition. The peak at 393 nm shows the electron transition in n → π* and the peak at 543 nm denotes the electron transition in π → π* orbitals. The electron transition to the bonding n → π* orbitals is the electron transition from the C=C bond while the electron transition to the π → π* orbitals shows the transition from sp^2 of the C=O and C=N bonds [26-28].

The excited electrons due to C-Dots received UV-ligth experienced recombintaion process—return to ground state by emitting the visible light. The C-Dots photoluminescence spectrum is in the wavelength range of 375-650 nm as shown in Figure 3. The C-Dots photoluminescence peak is at a wavelength of 450 nm (1.92 eV). The enhancement of photoluminescence intensity occurred in the spectrum of the extract before being irradiated with microwave waves to the extract after being irradiated for 20 minutes. The higher the intensity indicates that the number of C-Dots from dragonfruit peels are produced more. Thus, 20 minutes is an effective radiation time in the mechanism of formation of C-Dots from dragonfruit peels extract. C-Dots that produced from 20 minutes radiation then be applied as a supplement growth enhancer of *Ipomoea aquatica* cultivation. The intensity of photoluminescence of dragonfruit peels extract decreases when irradiated for 30 minutes where C-Dots turns into carbon charcoal.

The photoluminescence mechanism of C-Dots from dragonfruit peels is influenced by the electronic transition π. The electrons in the High Occupied Molecular Orbital (HOMO) band are excited to the Low Unoccupied Molecular Orbital (LUMO) band after received UV energy from outside. The electrons in the LUMO band are unstable so they recombine into the HOMO band by emitting visible light.

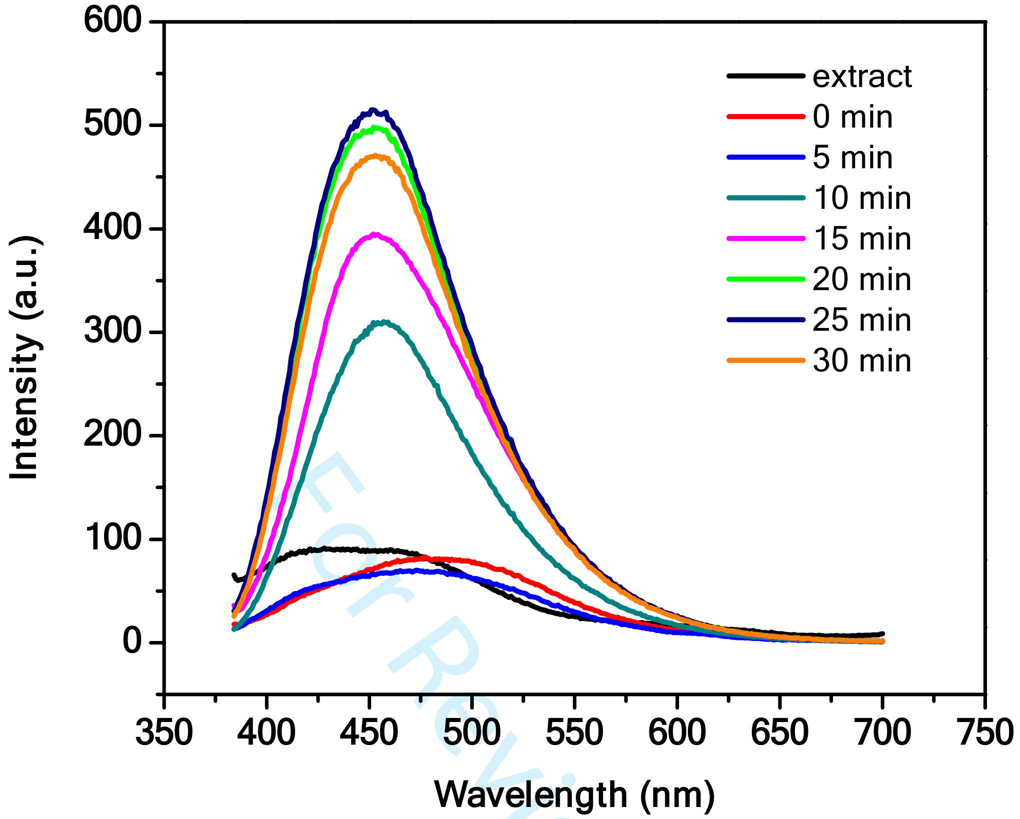


Figure 3. Photoluminescence spectrum of the obtained dragonfruit peels extract irradiated by microwave.

The alteration of functional group of dragonfruit peels extract irradiated by microwave for 20 minutes is shown by the FTIR analysis in Figure 4. The wave number band of 729 cm^{-1} indicates a strong bending of C-H. The band shows changes in spectrum patterns that indicate damaging of the aromatic structures in the pigment caused by microwave radiation. The functional group of OH-streching found in the absorption area of 3478 cm^{-1} which denotes the presence of water (H_2O) as a solvent. The band at wave number of 1639 cm^{-1} shows the bond of C=O. In addition, the bond of C=N appears at wave number of 2123 cm^{-1} [21]. C-H, C=O, and C=N bonds are functional groups formed on the surface of C-Dots. The C=N bond interprets that the addition of urea has successfully modified the surface structure of the C-Dots from the extract of the dragonfruit peels.

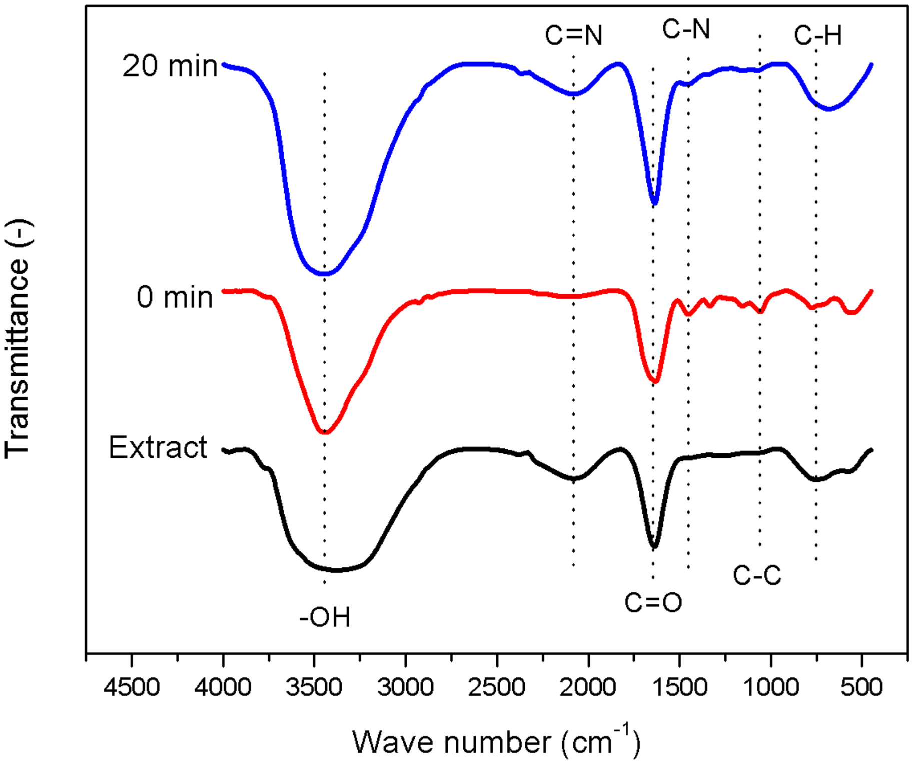
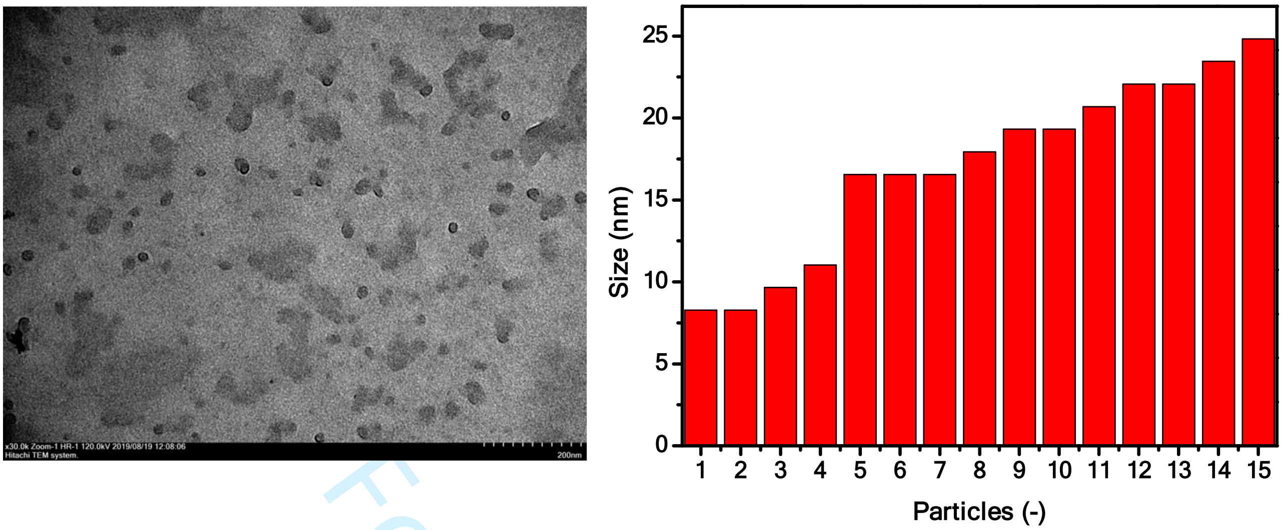


Figure 4. FTIR spectrum of the obtain dragonfruit peels extract, and irradiated by microwave irradiation for 0 minute and 20 minutes.

TEM images of 20 minutes synthesized C-Dots is shown in Figure 5. C-Dots particles have size distribution in range of 8-25 nm. Generally, C-Dots based organic materials—such as from pollen, water melon, sugar, rose flower, etc—have size distribution at <10 nm [16,21,23,24]. TEM image in Figure 5 shows that C-Dots were experienced agglomeration which due to surface interaction between C-Dots particle [29].



(a) (b)

Figure 5. (a). TEM image of 20 minutes synthesized C-Dots (b). distribution of 20 minutes synthesized C-Dots particle size.

The obtained C-Dots have size in nanometers which very promising for absorption process in fertilization. *Ipomoea aquatica* was chosen for C-Dots performance as growth-enhancer since they are easily to grow in both soil as well as water medium. Furthermore, *Ipomoea aquatica* vegetable has short period of growth and immune to several insects. *Ipomoea aquatica* that has been grown from seeds is then given a solution containing C-Dots with various volume fractions. During the growth process of *Ipomoea aquatica*, environmental parameters of humidity, temperature and light intensity were measured as shown in Figure 6.

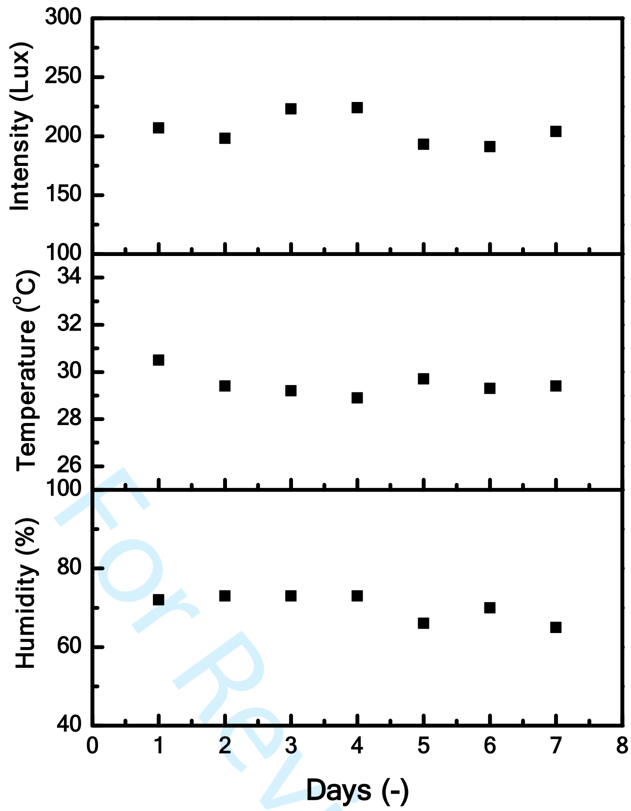


Figure 6. Measured environmental parameters during treatment.

Treatment was conducted under relative stable environmental parameters. The plants were grown under temperature of 28.9°C-30.5°C, 65%-73% humidity and light intensity at 191 lux-224 lux.

Ipomoea aquatica grows taller with the supplementary C-Dots as shown in Figure 7. Generally supplementation C-Dots with 125 mL/L yields higher plant than below. High volume of supplementation leads to high absorption of C-Dots by plant through plant transport mechanisms.

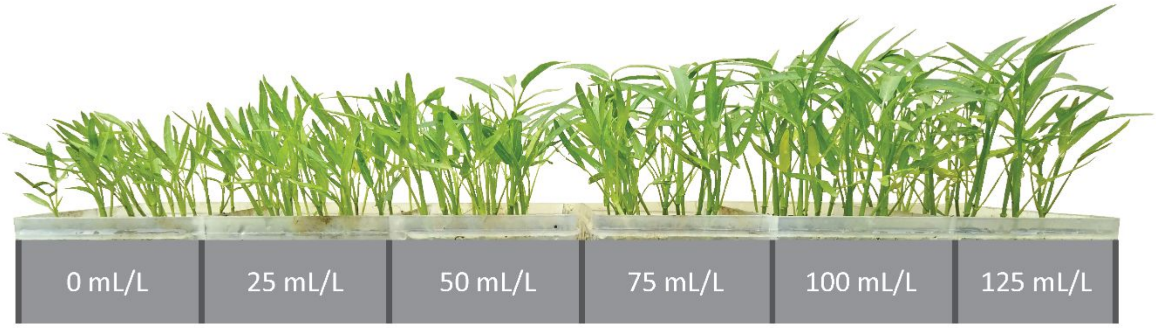


Figure 7. Growth of *Ipomoea aquatica* plants giving various C-Dots after 20 days.

The effect of supplementary C-Dots on the height of vegetable is shown in Figure 8a. The results showed that *Ipomoea aquatica* with supplementary C-Dots grew taller than without C-Dots, and also taller than vegetable which were only given urea. In addition, the greater the volume of supplementary C-Dots, the vegetable grows taller. The effectiveness of C-Dots as growth enhancer is described by the growth rate as shown in Figure 8b. The Growth rate of *Ipomoea aquatica* goes with a positive trend. However, growth rates did not differ significantly when fertilized with a volume fraction of 100 mL/L. This indicates that the volume fraction of 100 mL/L is the limit of the saturation volume of C-Dots given to the plant.

(a)

(b)

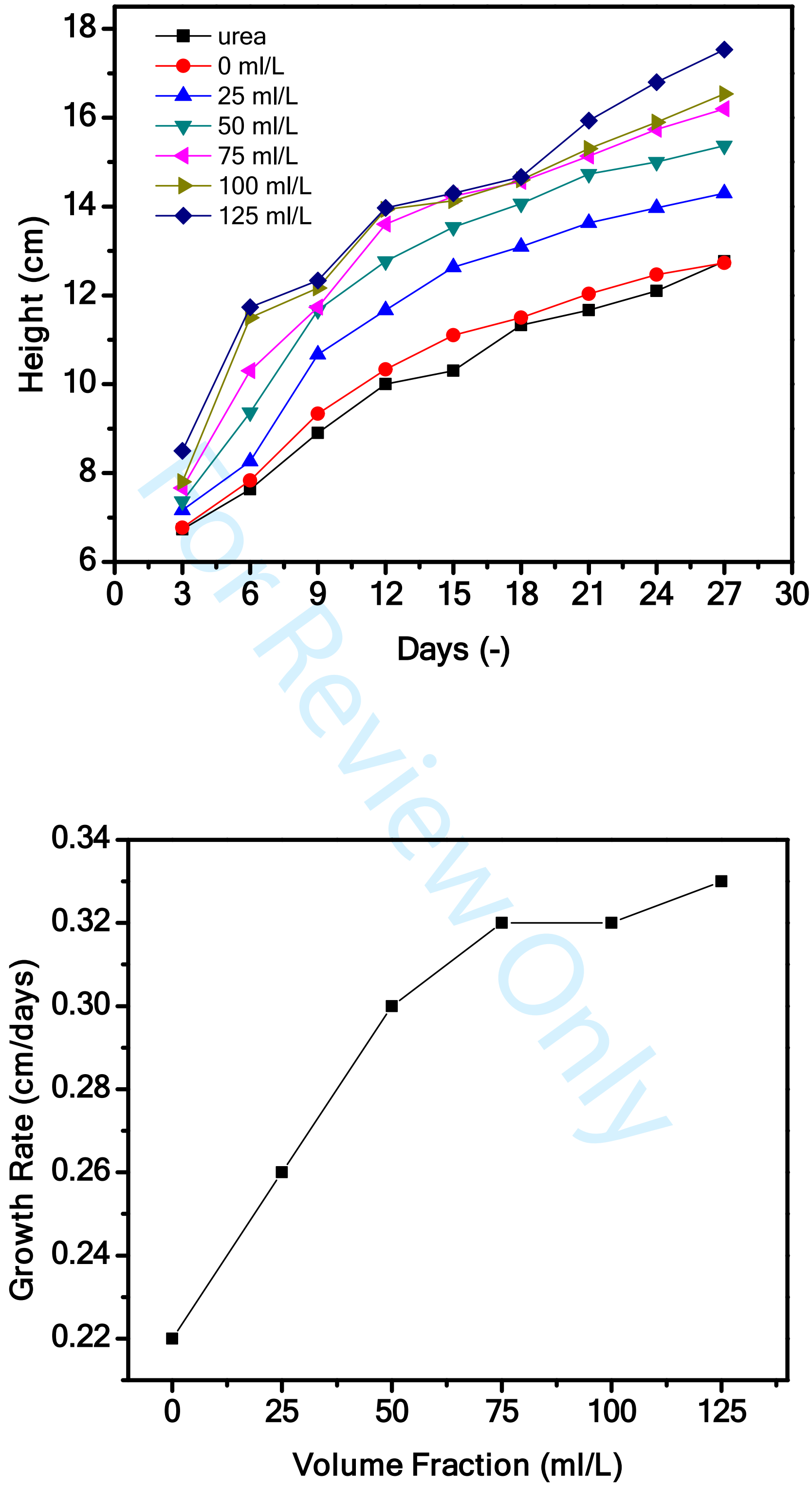


Figure 8. Effect of supplementary C-Dots on *Ipomoea aquatica* physiology : (a) plant height (b) plant growth rate.

The yield and physiology of *Ipomoea aquatica* due to the supplementary C-Dots is shown in Figure 9. Higher volume of C-Dots yield vegetable has thicker and longer roots, longer leaves, and taller stems. This indicates that C-Dots from dragonfruit peels can be effectively used as a growth enhancer of *Ipomoea aquatica*.

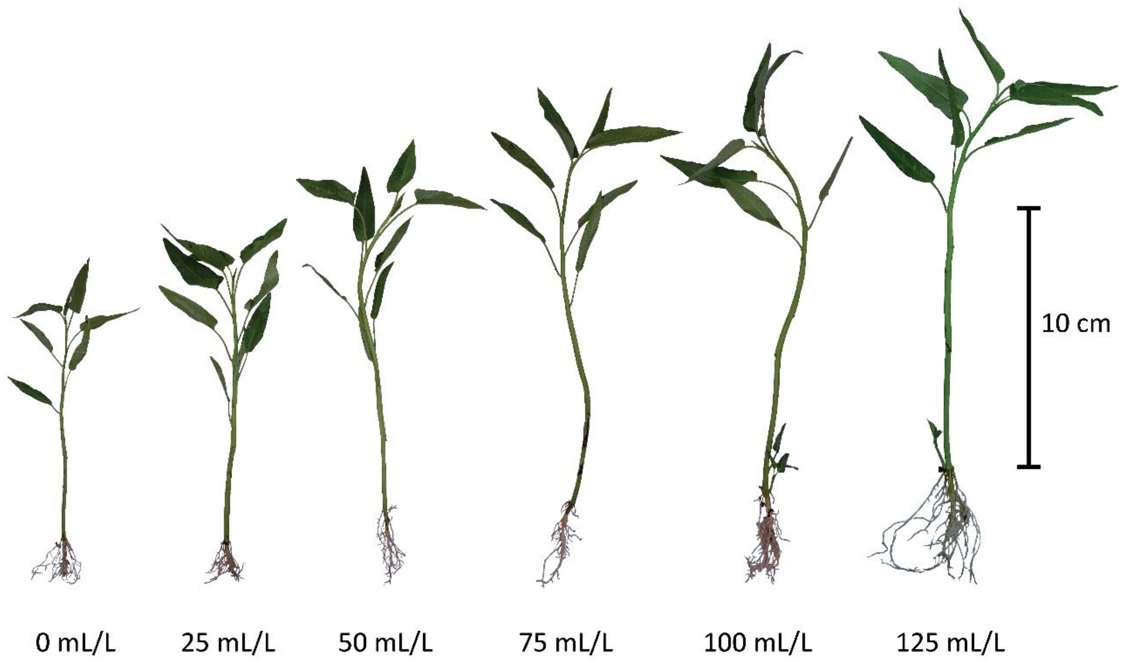


Figure 9. Effect of supplementary C-dots on the physiology of *Ipomoea aquatica* after 30 days growth.

The interaction of C-Dots with Nitrogen—Phosphor—Potassium (NPK) fertilizer is shown in Figure 10. NPK has a C-N functional group at wave number of 1483 cm^{-1}. Whereas C-Dots from dragonfruit peels have no C-N functional group at these wave numbers. The intensity of the C-N functional group was more observed in the mixing C-Dots with NPK. This indicates that there is an interaction between C-Dots and NPK and proves that C-Dots can interact and bind NPK so that it can potentially useful as a nutrients carrier.

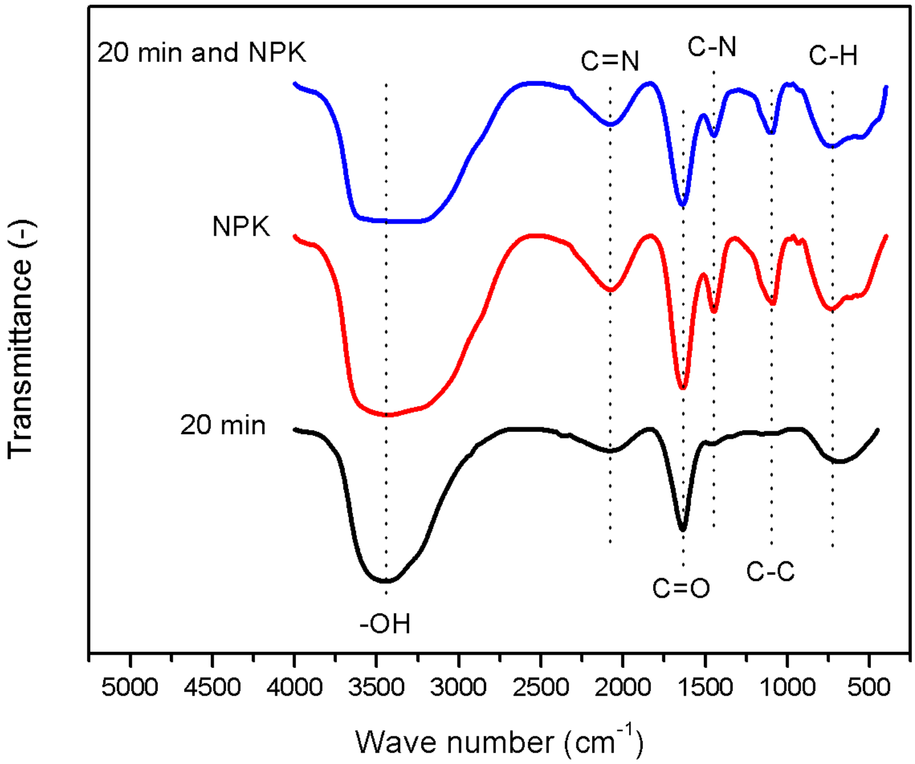


Figure 10. FTIR spectrum of the obtain dragonfruit peels extract with 20 minutes microwave irradiation (C-Dots) with Nitrogen—Phosphor—Potassium (NPK).

4. Conclusion

In this work, C-Dots have been successfully synthesized and implemented as growth enhancer for *Ipomoea aquatica* vegetable cultivation. The optimum C-Dots have been obtained from the extracts of dragonfruit peels irradiated by microwave for 20 minutes. The obtained C-Dots are capable to bind Nitrogen—Phosphor—Potassium (NPK) fertilizer and act as nutrients carrier. It was confirmed that with supplementary of C-Dots enhance the growth of *Ipomoea aquatica* vegetable. This study denoted that C-Dots from dragonfruit peels extracts were successfully act as a growth enhancer to increase vegetable yields.

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Carbon Dots from Dragonfruit Peels as Growth-Enhancer on *Ipomoea aquatica* Vegetable Cultivation

Mahardika Prasetya Aji[1,*], Lathifatus Sholikhah[1], Fina Idhamatus Silmi[1], Hestining Ajeng Permatasari[1], Ita Rahmawati[1], Aan Priyanto[2], Bebeh Wahid Nuryadin[3]

[1]*Department of Physics, Universitas Negeri Semarang*
Jalan Taman Siswa, Sekaran, Gunungpati Semarang
Central Java 50229, Indonesia

[2]*Department of Physics, Institut Teknologi Bandung*
Jalan Ganesha No.10, Bandung
West Java 40132, Indonesia

[3]*Department of Physics, Universitas Islam Negeri Sunan Gunung Djati,*
Jalan A. H. Nasution No. 105, Cibiru Bandung
West Java 40614, Indonesia

*email : mahardika@mail.unnes.ac.id

Abstract

C-Dots have been successfully synthesized from the dragonfruit peels and were applied as growth-enhancer for *Ipomoea aquatica* vegetable cultivation. C-Dots were obtained from the extract of dragonfruit peels via microwave radiation for 5 to 30 minutes. Two typical peaks of betalains in the dragonfruit peels extract experienced alteration. The longer the microwave radiation time, the typical peak intensity at 543 nm is decreased and peak intensity at 393 nm is increased. C-Dots from dragonfruit peels have particle size of 8-25 nm. The optimum C-Dots have been produced from 20 minutes microwave radiation with power of 230 watt. The emission of C-Dots appeared at wavelength of 450 nm. The obtained C-Dots are capable to bind Nitrogen—Phosphor—Potassium (NPK) fertilizer and act as nutrients carrier. C-Dots were then be directly supplemented to *Ipomoea aquatica* vegetable to figure out their influence on plants growth. The supplementation of C-Dots was varied by their volume fraction. The effect of C-Dots was analyzed by measuring the growth rate of plant. This study confirmed that with supplementary of C-Dots could enhance the growth of *Ipomoea aquatica* vegetable. This study denoted that C-Dots from dragonfruit peels extracts were successfully act as a growth enhancer to increase vegetable yields.

Keywords: C-Dots, Dragonfruit peels, Growth enhancer, *Ipomoea aquatica*.

1. Introduction

Nanotechnology is currently being applied in agriculture. Nanomaterials play several fundamental roles in agriculture as plant protection, fertilization and growth promotion [1-4]. Several nanomaterials such as Titanium Dioxide (TiO_2) and Zinc Oxide (ZnO) are able to act as pesticides, fungicide, and antibacterial for plants. Whereas, nanoparticles of Calcium (Ca), Potassium (K), Zinc (Zn), Phosphor (P), Sulfur (S), Iron (Fe), Manganese (Mn) and Magnesium (Mg) could also be used as nutrients to promote the plant growth [7-12]. Another significant application of nanomaterial is as an active material for nutrients deliveries and suppresses nutrients losses in fertilization. Nanomaterials such as ZnO, Gold (Au), Magnetite (Fe_3O_4), Carbon Nanotubes (CNT), Carbon Nanodots (C-Dots) have been successfully used to trigger seed growth, root and stem formation in plants [12-15]. Nanomaterials with their tiny size allow them to be easily absorbed by plants. In addition, they are capable to strongly bind the nutrients in the soil using the electrostatic interaction forces.

Despites nanomaterials could minimize nutrients losses in fertilization, but several issues are still to be addressed. The presence of inorganic nanomaterials as plant supplements can potentially accumulated in plants and possibly harmful for consumption. Furthermore, toxicity is a crucial problem from the use of inorganic nanoparticles in fertilization. For further development of nanomaterials for agriculture, organic materials become very promising to produce non-toxic nanomaterials. The use of organic nanomaterials in agricultural is still rarely. Researcher from China has been successfully synthesized nanomaterials C-Dots from pollen. The use of 10-30 mg/L C-Dots from pollen has successfully triggered the growth of *Lactuca sativa L.* C-Dots are very promising for plant supplements due to their tiny size <10 nm, non-toxic and easily dissolved [16]. Moreover, negative charged ligands on a surface of C-Dots could play as nutrients binder for delivery process in fertilization.

C-Dots are easily synthesized from organic materials with prosperous carbon chains such as various pigments in flowers, fruit and fruit peels. Betalains pigment in the dragonfruit peels has become one of the organic materials for producing C-Dots [17]. With the properties of less cytotoxicity and good biocompatibility, C-Dots are potentially useful for agriculture. In addition, another potential of betalains pigment in dragonfruit peels is the presence of nitrogen in its functional groups as a macro nutrient needed by plants. In present work, we synthesize C-Dots from dragonfruit peels and use it as a growth enhancer for *Ipomoea aquatica* vegetable.

2. Experiment

Ripe red dragonfruit is easily obtained from the local market in Semarang, Central Java-Indonesia. The raw material for synthesis is dragonfruit peels. Another ingredient is urea with technical quality obtained from the chemical shop Indrasari, Indonesia. Betalains pigment was extracted by heating process of 20 g dragonfruit peels in 100 mL of distilled water at 70^{o}C for 2 hours. A total of 20 ml of dragonfruit peels extract mixed with 2 g of urea. A total of 20 ml of this homogeneous extract solution then was irradiated by 230 watt microwave (Panasonic NN-SM322M) for 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes, and 30 minutes. C-Dots from synthesis then were analyzed the absorption and emission spectrum. The absorption spectrum was measured using Vis-Nir Ocean Optics type USB 4000. While the emission spectrum was measured using a photoluminescence device of Cary Eclipse type Spectroflourometer MY14440002. The changes in the functional groups of the dragonfruit peels extracts due to microwave radiation were analyzed by measurement using Fourier Transform Infrared (FTIR) type Perkin Elmer Spectrum Version 10.03.06. C-dots particle size were analyzed by Transmission Electron Microscopy (TEM) (Hitachi TEM system HT7700). C-Dots with optimum absorption and emission spectrum then were used as growth enhancer for *Ipomoea aquatica* vegetable cultivation. The plant was grown from seeds on soil medium and under sunlight. After 5 days growth, we selected plants with similar height and conditions for treatment at 10x19x6 cm container. Plant only receive C-Dots supplementation with volume variations of 0 mL, 25 mL, 50 mL, 75 mL, 100 mL, and 125 mL in 1000 mL of distilled water without any other fertilizer. This supplementation was given every 5 days. The growth rate can then be observed in a certain period of time. During the treatment, environmental parameters—light intensity, temperature and humidity—were measured using Lightmeter LT Lutron LX-107HA and Victor VX230A respectively.

3. Result and discussion

The extracts of dragonfruit peels irradiated by microwave changes its color from red to brown as shown in Figure 1. The dominant red color of dragonfruit peels extract shows betalains pigment [18]. Microwave radiation causes polymerization and carbonization process at betalains pigment thus the extract turns into brown. This color change denotes an alteration of the optical properties of the extract. Dragonfruit peels extract does not emit when irradiated using ultraviolet (UV) light. Meanwhile, dragonfruit peels extract which has been irradiated by microwave waves emits waves of emission when irradiated by ultraviolet (UV) light. The emission shows that the extract of the dragonfruit peels irradiated by microwave yield C-Dots particles. This luminescence property is also found in C-Dots produced from other fruit peels—mangosteen peels, orange, watermelon, etc—, waste plastics, leaves, sugar, flowers, and pollen seeds [16,19-24].

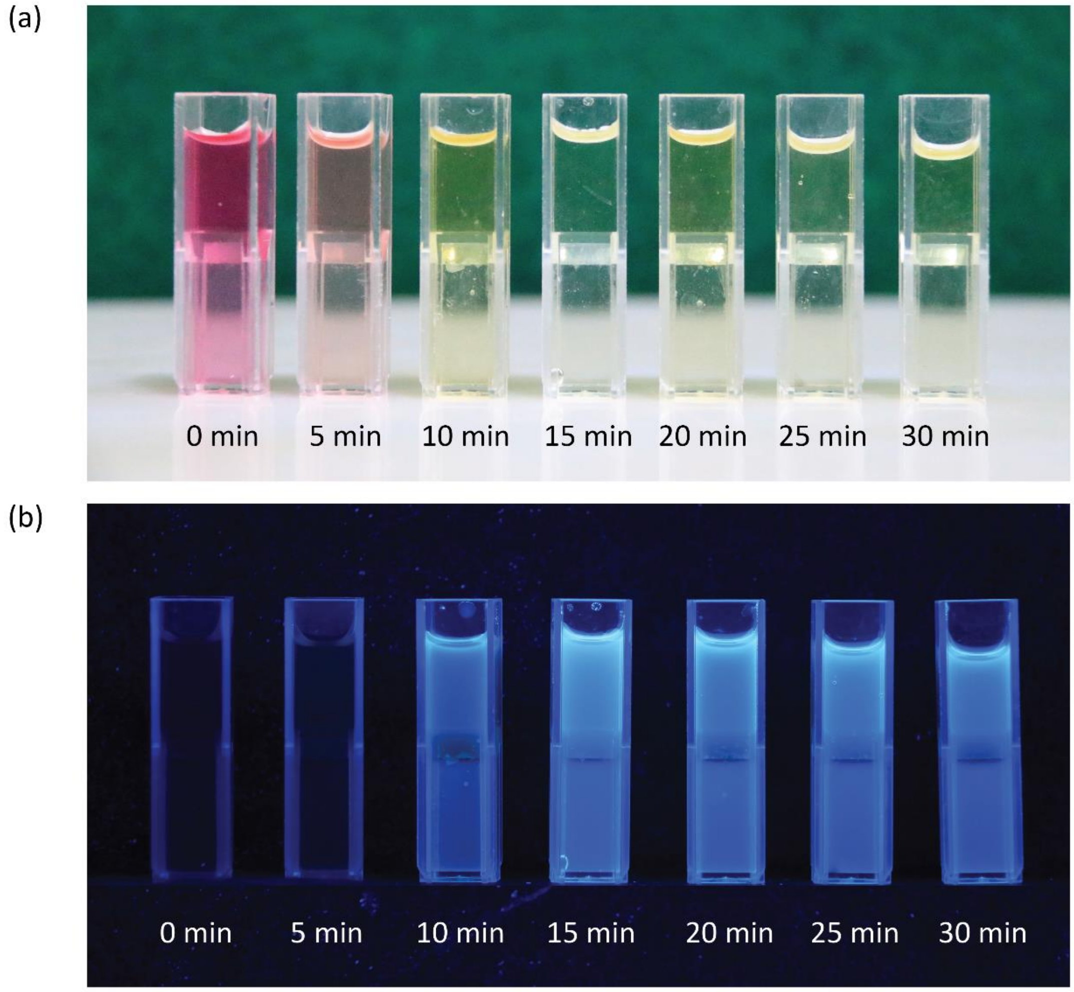


Figure 1. Dragonfruit peels extract irradiated by microwave in: (a). day light, and (b). UV light

Microwave radiation changes the absorbance spectrum of dragonfruit peels extract as shown in Figure 2. The absorption spectrum of dragonfruit peels extract is in the wavelength range of 350-700 nm. Dragonfruit peel extract solution showed two peaks of absorbance at 393 nm and 543 nm wavelengths. Two peaks indicate the typical peak of the betalains pigment in the extract of dragonfruit peels [25]. Two typical peaks of betalains in the absorbance spectrum are still observed in the extract of dragonfruit peels which were given microwave radiation for 5 minutes. The longer the microwave radiation time, the typical peak intensity at 543 nm is decreased and peak intensity at 393 nm is increased. The energy of microwave radiation breaks the conjugate double bonds in the betalains pigment thus the intensity at the wavelength of 543 nm has decreased. Whereas the intensity of the absorption spectrum at wavelength 393 nm goes higher with the longer time of the microwave wave radiation. This is related to the vibrations of the short chain bonds which are increasing due to termination of the other pigment chains.

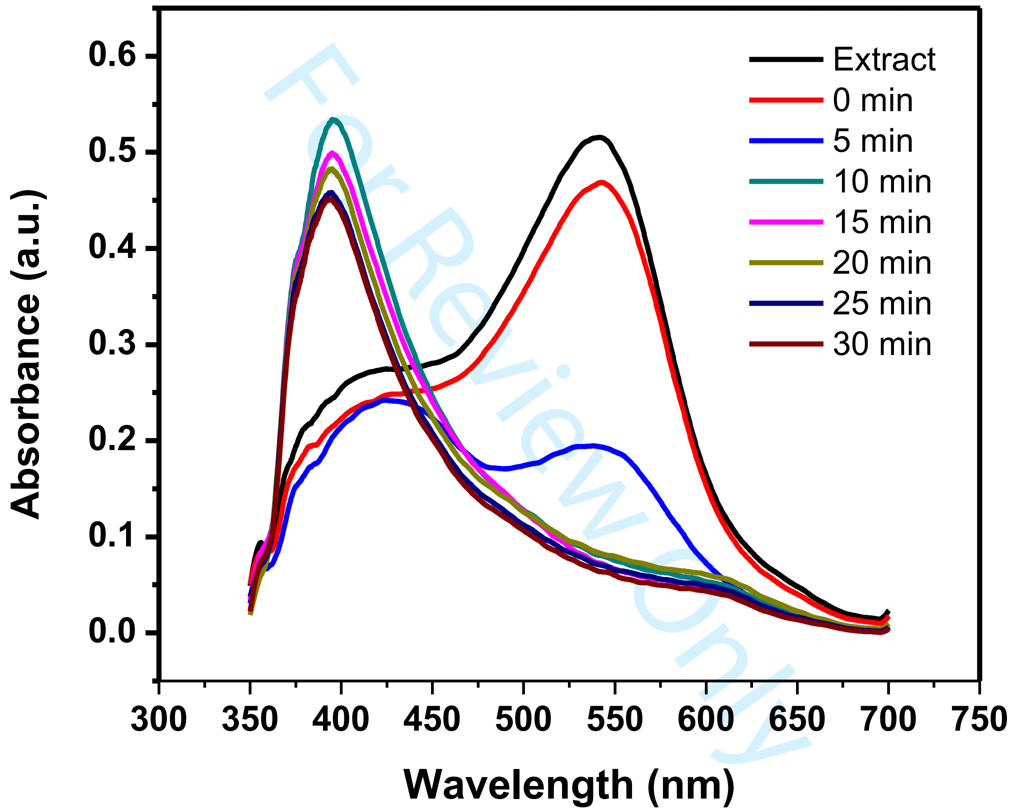


Figure 2. Absorbance spectrum of the obtained dragonfruit peels extract irradiated by microwave.

Reduction of absorption spectrum intensity also occurs in the extract of dragonfruit peels with and without urea due to a chemical interaction between dragonfruit peels extract and urea. The presence of urea in the dragonfruit peels extract is very important as passivation agent to modify the functional groups on the surface of C-Dots. The typical peaks of the betalains pigment denote an electronic transition. The peak at 393 nm shows the electron transition in n → π* and the peak at 543 nm denotes the electron transition in π → π* orbitals. The electron transition to the bonding n → π* orbitals is the electron transition from the C=C bond while the electron transition to the π → π* orbitals shows the transition from sp^2 of the C=O and C=N bonds [26-28].

The excited electrons due to C-Dots received UV-ligth experienced recombintaion process—return to ground state by emitting the visible light. The C-Dots photoluminescence spectrum is in the wavelength range of 375-650 nm as shown in Figure 3. The C-Dots photoluminescence peak is at a wavelength of 450 nm (1.92 eV). The enhancement of photoluminescence intensity occurred in the spectrum of the extract before being irradiated with microwave waves to the extract after being irradiated for 20 minutes. The higher the intensity indicates that the number of C-Dots from dragonfruit peels are produced more. Thus, 20 minutes is an effective radiation time in the mechanism of formation of C-Dots from dragonfruit peels extract. C-Dots that produced from 20 minutes radiation then be applied as a supplement growth enhancer of *Ipomoea aquatica* cultivation. The intensity of photoluminescence of dragonfruit peels extract decreases when irradiated for 30 minutes where C-Dots turns into carbon charcoal.

The photoluminescence mechanism of C-Dots from dragonfruit peels is influenced by the electronic transition π. The electrons in the High Occupied Molecular Orbital (HOMO) band are excited to the Low Unoccupied Molecular Orbital (LUMO) band after received UV energy from outside. The electrons in the LUMO band are unstable so they recombine into the HOMO band by emitting visible light.

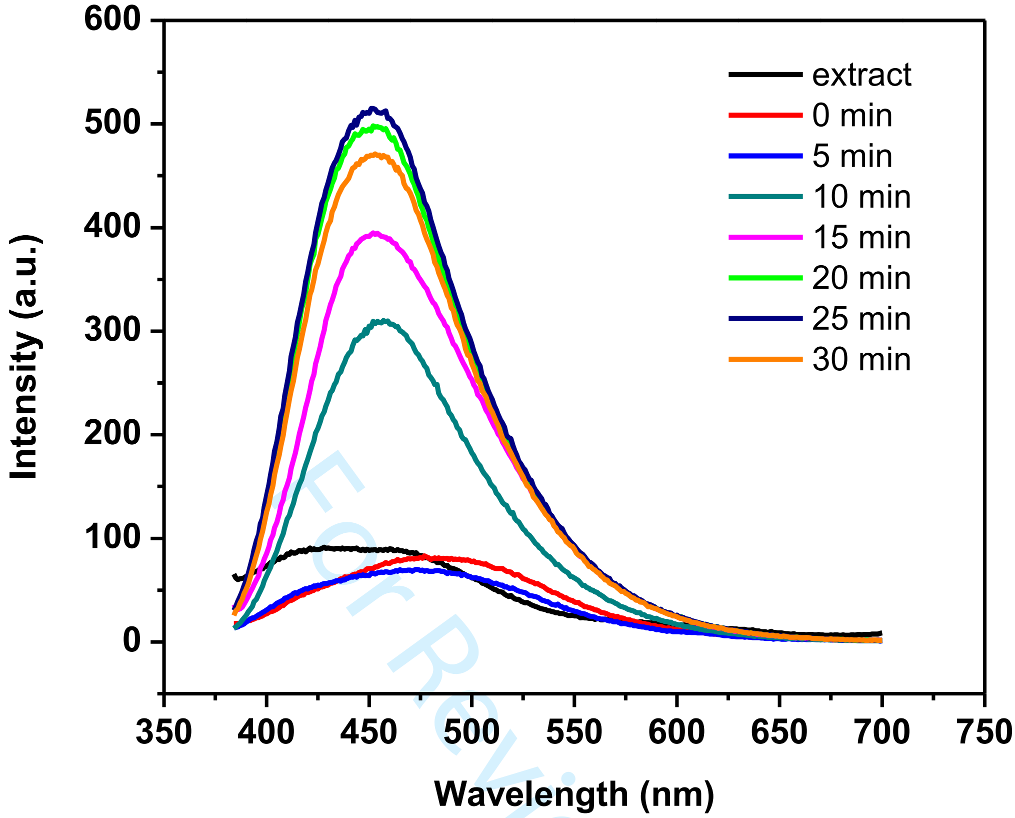


Figure 3. Photoluminescence spectrum of the obtained dragonfruit peels extract irradiated by microwave.

The alteration of functional group of dragonfruit peels extract irradiated by microwave for 20 minutes is shown by the FTIR analysis in Figure 4. The wave number band of 729 cm^{-1} indicates a strong bending of C-H. The band shows changes in spectrum patterns that indicate damaging of the aromatic structures in the pigment caused by microwave radiation. The functional group of OH-streching found in the absorption area of 3478 cm^{-1} which denotes the presence of water (H_2O) as a solvent. The band at wave number of 1639 cm^{-1} shows the bond of C=O. In addition, the bond of C=N appears at wave number of 2123 cm^{-1} [21]. C-H, C=O, and C=N bonds are functional groups formed on the surface of C-Dots. The C=N bond interprets that the addition of urea has successfully modified the surface structure of the C-Dots from the extract of the dragonfruit peels.

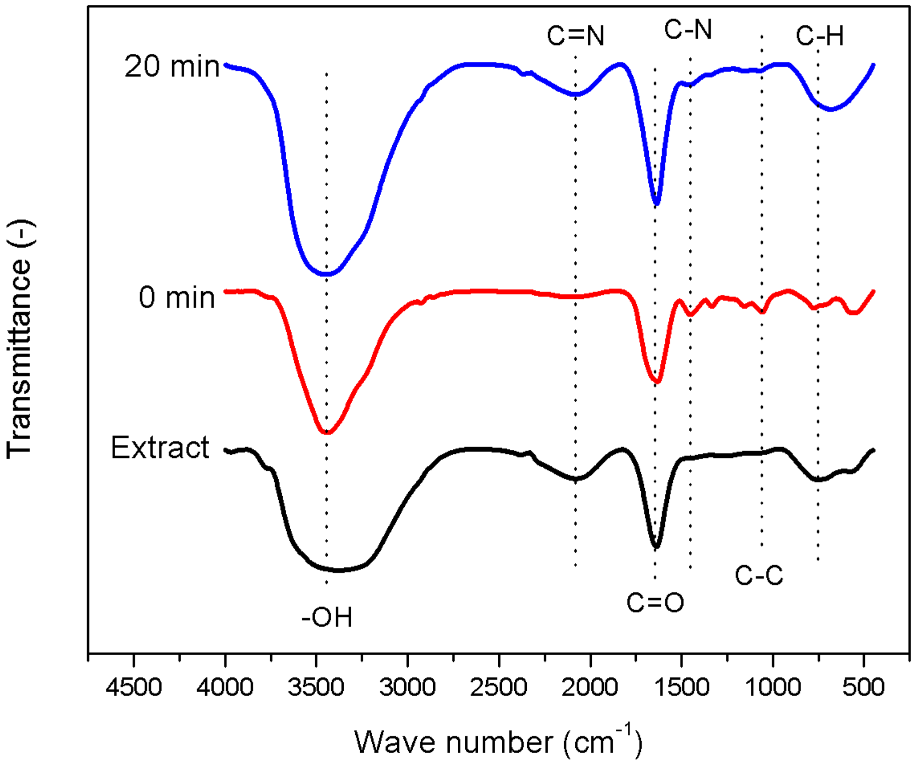
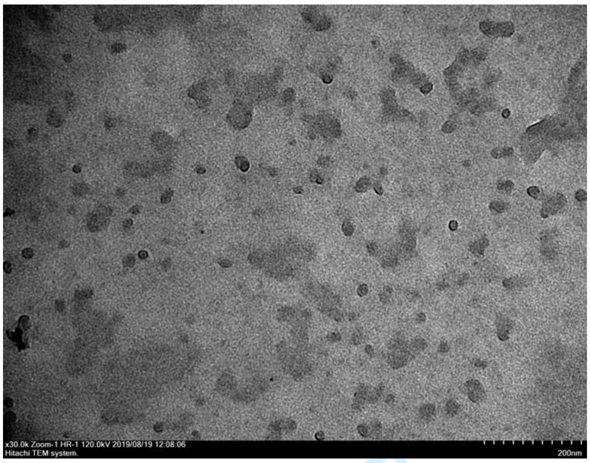
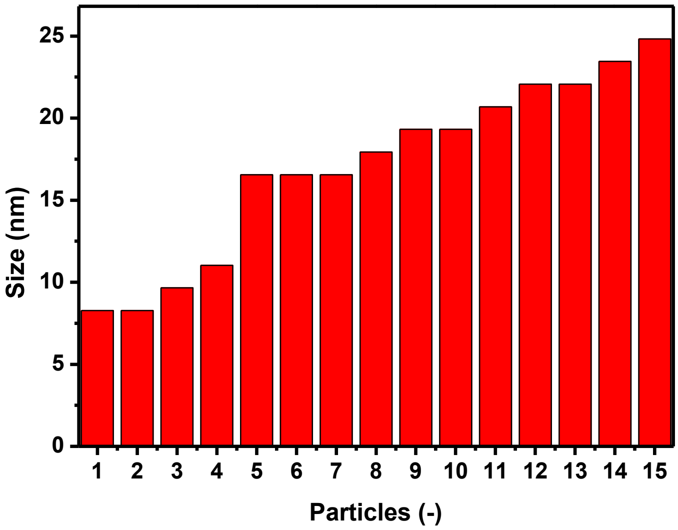


Figure 4. FTIR spectrum of the obtain dragonfruit peels extract, and irradiated by microwave irradiation for 0 minute and 20 minutes.

TEM images of 20 minutes synthesized C-Dots is shown in Figure 5. C-Dots particles have size distribution in range of 8-25 nm. Generally, C-Dots based organic materials—such as from pollen, water melon, sugar, rose flower, etc—have size distribution at <10 nm [16,21,23,24]. TEM image in Figure 5 shows that C-Dots were experienced agglomeration which due to surface interaction between C-Dots particle [29].



(a)



(b)

Figure 5. (a). TEM image of 20 minutes synthesized C-Dots (b). distribution of 20 minutes synthesized C-Dots particle size.

The obtained C-Dots have size in nanometers which very promising for absorption process in fertilization. *Ipomoea aquatica* was chosen for C-Dots performance as growth-enhancer since they are easily to grow in both soil as well as water medium. Furthermore, *Ipomoea aquatica* vegetable has short period of growth and immune to several insects. *Ipomoea aquatica* that has been grown from seeds is then given a solution containing C-Dots with various volume fractions. During the growth process of *Ipomoea aquatica*, environmental parameters of humidity, temperature and light intensity were measured as shown in Figure 6.

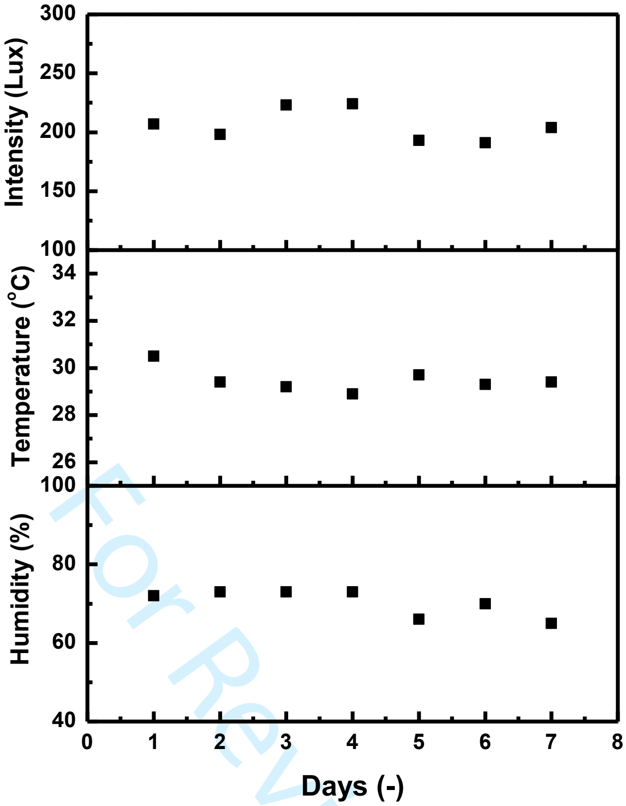


Figure 6. Measured environmental parameters during treatment.

Treatment was conducted under relative stable environmental parameters. The plants were grown under temperature of 28.9°C-30.5°C, 65%-73% humidity and light intensity at 191 lux-224 lux.

Ipomoea aquatica grows taller with the supplementary C-Dots as shown in Figure 7. Generally supplementation C-Dots with 125 mL/L yields higher plant than below. High volume of supplementation leads to high absorption of C-Dots by plant through plant transport mechanisms.

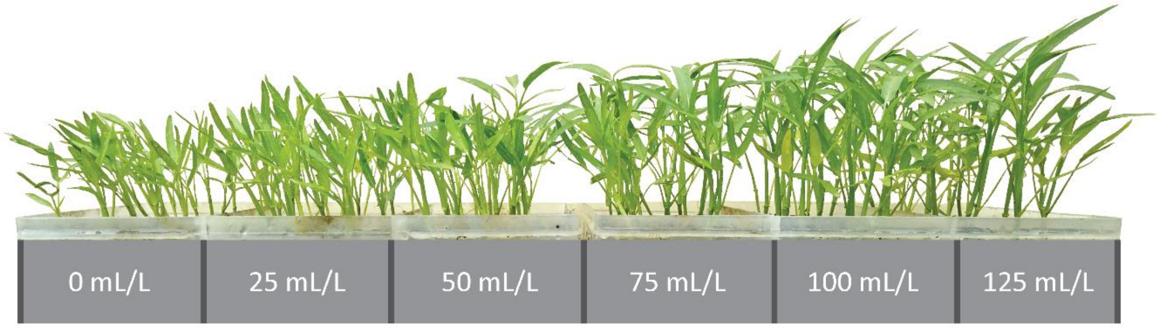
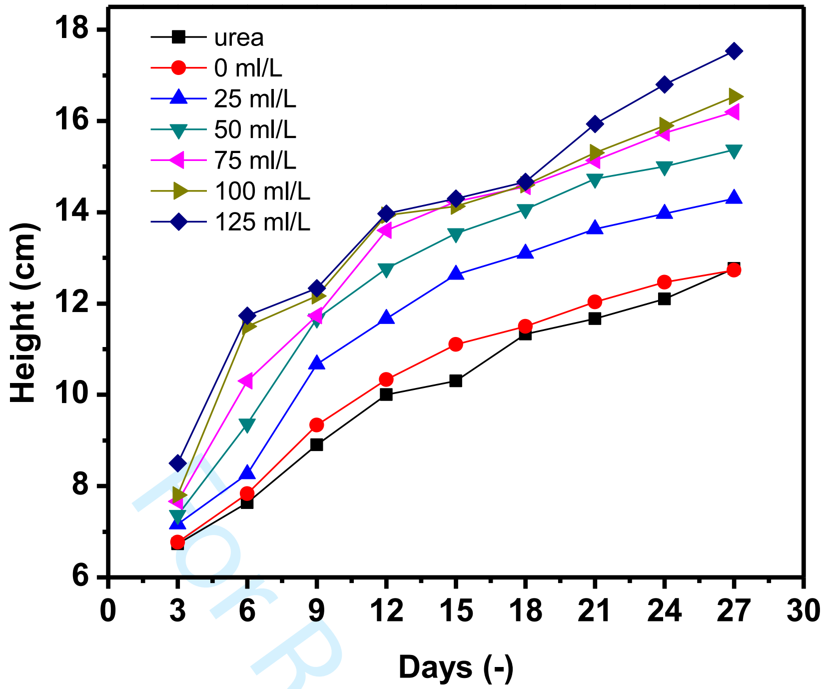


Figure 7. Growth of *Ipomoea aquatica* plants giving various C-Dots after 20 days.

The effect of supplementary C-Dots on the height of vegetable is shown in Figure 8a. The results showed that *Ipomoea aquatica* with supplementary C-Dots grew taller than without C-Dots, and also taller than vegetable which were only given urea. In addition, the greater the volume of supplementary C-Dots, the vegetable grows taller. The effectiveness of C-Dots as growth enhancer is described by the growth rate as shown in Figure 8b. The Growth rate of *Ipomoea aquatica* goes with a positive trend. However, growth rates did not differ significantly when fertilized with a volume fraction of 100 mL/L. This indicates that the volume fraction of 100 mL/L is the limit of the saturation volume of C-Dots given to the plant.

(a)



(b)

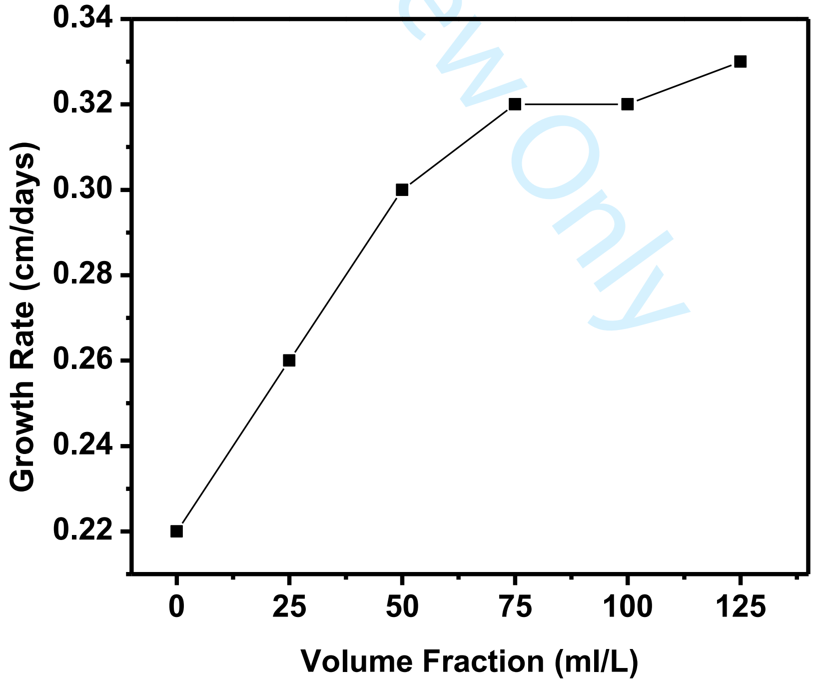


Figure 8. Effect of supplementary C-Dots on *Ipomoea aquatica* physiology : (a) plant height (b) plant growth rate.

The yield and physiology of *Ipomoea aquatica* due to the supplementary C-Dots is shown in Figure 9. Higher volume of C-Dots yield vegetable has thicker and longer roots, longer leaves, and taller stems. This indicates that C-Dots from dragonfruit peels can be effectively used as a growth enhancer of *Ipomoea aquatica*.

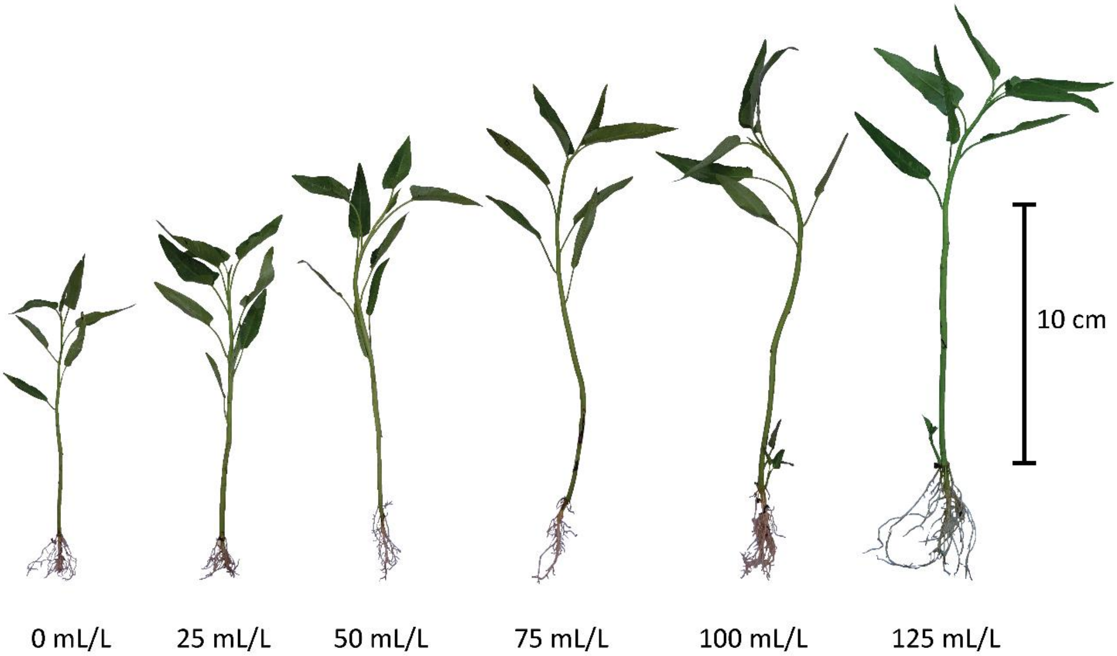


Figure 9. Effect of supplementary C-dots on the physiology of *Ipomoea aquatica* after 30 days growth.

The interaction of C-Dots with Nitrogen—Phosphor—Potassium (NPK) fertilizer is shown in Figure 10. NPK has a C-N functional group at wave number of 1483 cm^{-1}. Whereas C-Dots from dragonfruit peels have no C-N functional group at these wave numbers. The intensity of the C-N functional group was more observed in the mixing C-Dots with NPK. This indicates that there is an interaction between C-Dots and NPK and proves that C-Dots can interact and bind NPK so that it can potentially useful as a nutrients carrier.

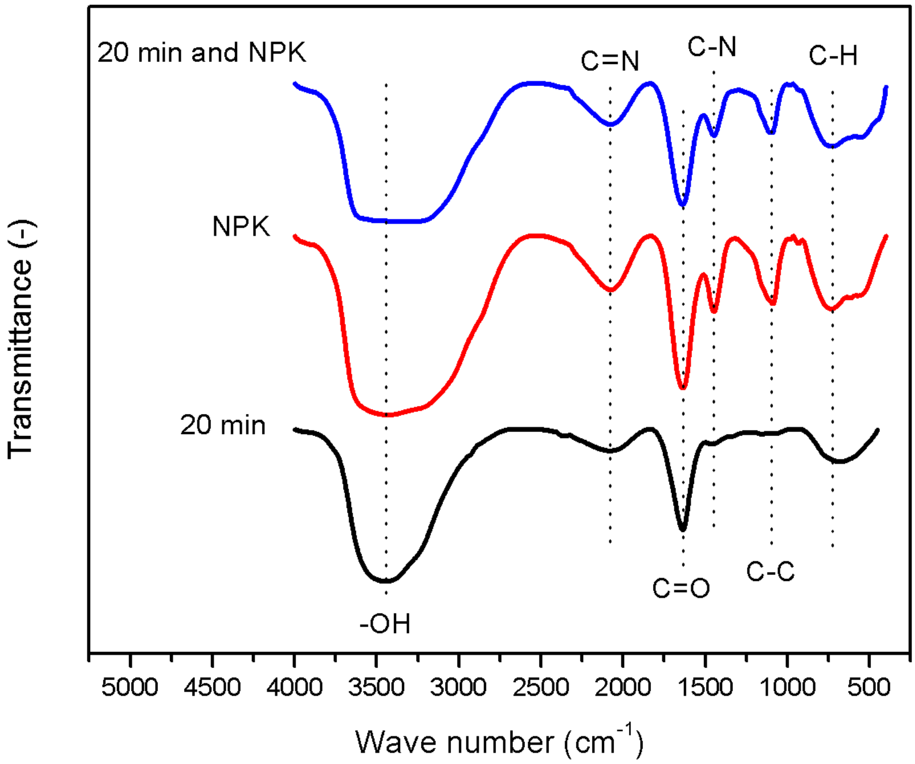


Figure 10. FTIR spectrum of the obtain dragonfruit peels extract with 20 minutes microwave irradiation (C-Dots) with Nitrogen—Phosphor—Potassium (NPK).

4. Conclusion

In this work, C-Dots have been successfully synthesized and implemented as growth enhancer for *Ipomoea aquatica* vegetable cultivation. The optimum C-Dots have been obtained from the extracts of dragonfruit peels irradiated by microwave for 20 minutes. The obtained C-Dots are capable to bind Nitrogen—Phosphor—Potassium (NPK) fertilizer and act as nutrients carrier. It was confirmed that with supplementary of C-Dots enhance the growth of *Ipomoea aquatica* vegetable. This study denoted that C-Dots from dragonfruit peels extracts were successfully act as a growth enhancer to increase vegetable yields.

References

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4. Bukti konfirmasi keputusan manuskrip diterima

(22 April 2020)

Mahardika Prasetya Aji <mahardika@mail.unnes.ac.id>

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Your manuscript entitled "Carbon Dots from Dragonfruit Peels as Growth-Enhancer on Ipomoea aquatica Vegetable Cultivation" is almost accepted for publication in the Advances in Natural Sciences: Nanoscience and Nanotechnology (ANSN). There are still some comments from our reviewers that are quoted at the bottom of this letter. Please do critical revision to meet the requirements of an accepted article, then send the revised one as the attached file to journal@ans.vast.vn for further processing.

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