EFFECT OF SURFACTANT MODIFIED ZEOLITE (SMZ) ADDED IN PROPAGATING SUBSTRATE FOR THE GERMINATION OF SOME VEGETABLES

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Abstract- The effect of using propagating substrate (PS) as a sole growing medium, zeolite-added PS and surfactant-modified zeolite (SMZ) added PS for the germination and growth of okra (Abelmoschus esculentus), white radish (Raphanus sativus) and pakchoy (Brassica chinensis) was studied. SMZ was prepared by modifying clinoptilolite type zeolite with cationic surfactant hexadecyltrimethyl ammonium (HDTMA). SMZ can easily adsorb anionic nutrients such as phosphate, nitrate and nitrite due to HDTMA bilayer formation on zeolite surfaces that reversed negatively charged of zeolite surfaces to positive charge. This can be shown by the results in a controlled release and plant growth studies. The application of SMZ in PS reduced the amount of nutrients leached out from PS compared to zeolite added PS and only PS. The amount of nutrients in SMZ(15)-PS(50) (ratio of SMZ(15): propagating substrate (50)) showed the lowest leaching due to the greater tendency to hold the nutrients and also released them slowly. There were significant difference ($P < 0.05$) in growth parameters of three types of vegetables grown in different substrates. The mean of height, fresh mass and dry mass of A. esculentus, R. sativus and B. chinensis grown on SMZ(1)-PS(50) were significantly higher than those of zeolite added substrate. The results implicitly suggested that the studied plant showed better response if SMZ was used as a controlled release nutrients in propagating substrate rather than the unmodified zeolite.

Index Terms- Zeolite, surfactant modified zeolite, propagating substrate, controlled released system.

I. INTRODUCTION

For centuries, the relationship between plants, their surroundings and environments have been the main focus of many scientists [1]. Recently, soil has been substituted with propagating substrate as the medium for plantations. Replacement begun due to the problem of pathogens originated from soil and environmental pollution which caused by leaching of nutrients and pesticides [2]. Plants need the best growing media (substrate) to propagate that can retain the nutrients in the media. Thus, it is significant to find out the best approach to enhance the effectiveness of growing media during sowing or seedling time for the substrate to hold its nutrients especially phosphate, nitrate and nitrite. Growing media are vital for best germination, growth and development of ornamental and vegetable plants. However, problem of disease in plants caused by soil-borne pathogens becoming a challenge in recent year [3]. Therefore, soilless culture is being introduced in order to cope with the challenge. The substrates in soilless culture for growing seedlings, plant propagation and ornamental plant production are important as well [4], [5]. The component of soilless substrates must have stable physical and chemical properties during plant production [5]. One of the example is the use of coco peat as a growing medium or propagating substrate.

Commonly, the soilless media has no ability to retain major plants nutrients which are phosphorus (P), potassium (K), and nitrogen (N) [6], [7]. Interestingly, this media can be added with zeolite to improve the retaining capacity of the nutrients because of the ability of zeolite in adsorbing cationic compounds. Zeolite has a framework structure enclosing cavities occupied by large ions and water molecules, both of which have considerable freedom of movement permitting ion exchange and reversible dehydration [8]. For the study on the controlled release ability of zeolite, it is limited to nutrients which can be loaded in cationic forms such as ammonium and potassium [9]. Because of this structure, zeolite itself cannot adsorb anions such as phosphate, nitrate or nitrite which are important for rooting development and plant growth. Zeolite tends to repulse the anionic charge compounds. Therefore, it is important that the material for the controlled released system should have adequate affinity for anions to load anionic nutrients efficiently. It was shown that the zeolite that has been modified with cationic surfactant producing surfactant modified zeolite (SMZ) which could adsorb anionic compounds such as chromate and arsenate anions in aqueous solution [10].

Therefore, theoretically the addition of SMZ in the propagating substrate could improve its retaining capacity of major plants nutrients especially in anionic forms. The aim of this research was to study the effects of adding SMZ in propagating substrate as compared to the unmodified zeolite. The study involved controlled released study of major nutrients in anionic forms (phosphate, nitrate and nitrite) from propagating substrate, zeolite added propagating substrate and also SMZ added propagating substrate. Finally, the effectiveness of these substrate were studied in the seedling of okra (Abelmoschus esculentus), white radish (Raphanus sativus) and pakchoy (Brassica chinensis).

II. EXPERIMENTAL

A. Materials

Zeolite type clinoptilolite used in this research was imported from Indonesia, supplied by Provet Group of Companies Sdn. Bhd., Seri Kembangan, Selangor. Propagating substrate (PS) that have been used for planting was imported from Holland (Stender substrate, AGRIFEM). Procedures for the preparation and characterization of SMZ and also its characterisctics were described elsewhere [11]. The origin sources of plants seeds were purchased from Mackem (M) Sdn. Bhd, Muar, Johor. For the preparation of PS added zeolite and SMZ, different amount of SMZ and zeolite (1, 5 and 15 g) were mixed evenly with 50 g of PS. They were homogenized to ensure the even distribution of SMZ and zeolite in the propagating substrate.

B. Controlled Release Study

The method was referred to the experimental setup by [11]. The experiment was set up by using retort stand, polystyrene column with five pierced holes (0.5 cm diameter) at the bottom and 100 mL low-form beakers with handles. 50 g of the samples was placed in the column. Samples in the column was packed loosely and watered by 100 mL of tap water every day. Columns were permitted to drain for 24 hours before collecting the leachate [12]. This experiment was done in three replicates. Lastly, the concentration of phosphate, nitrite and nitrate in leachate were tested by using NANOCOLOR® ortho-phosphate kit (Test 1-77, REF 918 77), NANOCOLOR® nitrite kit (Test 1-67, REF 918 67) and NANOCOLOR® nitrate kit (Test 0-64, REF 985 064) with the aid of spectrophotometer NANOCOLOR® VIS from MACHEREY-NAGEL.

C. Plant Growth Study

The plant growth study was performed in a semi greenhouse facility. The seeds of plants were propagated in 104 cells seed trays. The plants were germinated and raised in seven seed trays for seven different treatments, respectively similar to that of controlled release study. Each tray was filled with ¾ of growing medium and two seeds of each vegetable were placed into each hole on top of the medium. Then, the holes were covered with a thin layer of propagating substrate.

The effect of different propagating substrate on vegetable growth was evaluated by taking several growth parameters after the plants have been harvested (the 40th days after the first day of sowing). The parameters included height, fresh mass and dry mass of vegetables. Data collected were analyzed using SPSS software for Windows (SPSS 16.0 for Windows Evaluation Version software, SPSS Inc., USA). Differences were considered to achieve significance for probability $P < 0.05$.

III. RESULTS AND DISCUSSION

A controlled release study was carried out to investigate the release behavior of nutrients which were phosphate (PO_4^{3-}), nitrite (NO_2^-) and nitrate (NO_3^-) from each sample at different time. Fig. 1, 2 and 3 show the concentrations of PO_4^{3-}, NO_2^- and NO_3^-, respectively released from different studied samples.

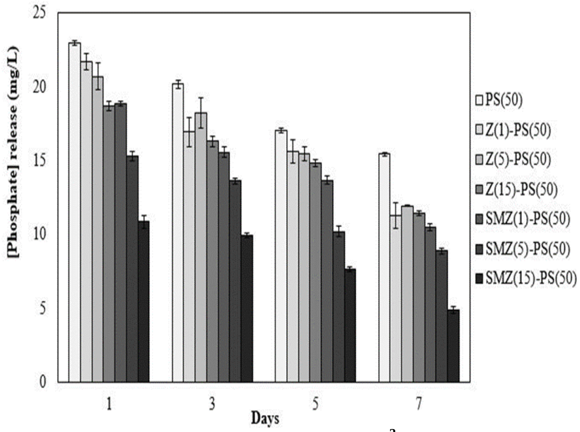

Fig. 1: Concentration of phosphate (PO_4^{3-}) released from different propagating substrate.

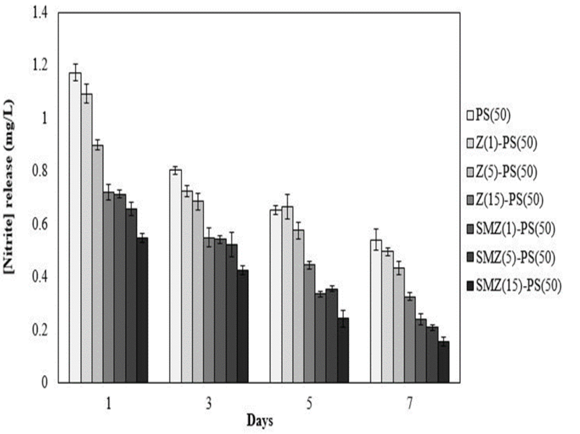

Fig. 2: Concentration of nitrite (NO_2^-) released from different propagating substrate.

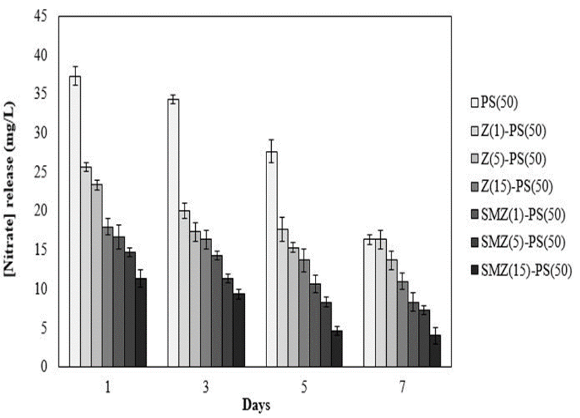

Fig. 3: Concentration of nitrate (NO_3^-) released from different propagating substrate.

Notes: PS(50):Propagating substrate (50 g), Z(1)-PS(50): zeolite (1 g) + PS (50 g), Z(5)-PS(50): zeolite (5 g) + PS (50 g), Z(15)-PS(50): zeolite (5 g) + PS (50 g), SMZ(1)-PS(50): SMZ (1 g) + PS (50 g), SMZ(5)-PS(50): SMZ (5 g) + PS (50 g), SMZ(15)-PS(50): SMZ (15 g) + PS (50 g)

The amount of nutrients released from propagating substrate (mainly with 50 g of PS) decreased significantly after adding with zeolite or SMZ. The order of nutrients released decreased in the following order PS(50) > Z(1)-PS(50) > Z(5)-PS(50) > Z(15)-PS(50) > SMZ(1)-PS(50) > SMZ(5)-PS(50) > SMZ(15)-PS(50). Based on the trend, it can be seen that the amount (in g) of zeolite and SMZ added in propagating substrate plays important role in holding, controlling and releasing of nutrients. PS with higher amount of zeolite or SMZ can retain nutrients in propagating substrate and reduce the amount of nutrients leached out. As a result, Z(15)-PS(50) and SMZ(15)-PS(50) (15 g of zeolite and SMZ added in propagating substrate respectively) showed the lowest amount of nutrients in the leachate from both medium compared to propagating substrate added with 1 g and 5 g of zeolite or SMZ.
Maximum leaching of nutrients is shown in the PS(50). This might be due to the reason that PS without the addition of zeolite or SMZ was not able to hold and retain the nutrients.
Clearly, zeolite can be added in PS to control the release of nutrients from the medium, however, the zeolite demonstrated lower ability to hold and retain anionic forms as compared to SMZ. This behavior could be explained by the negative charge surface of zeolite [13]. Because of this property, zeolite which has negatively charged framework structure cannot hold, retain and release anions effectively compared to SMZ. In addition, reference [14] studied the influences of zeolite and surfactant-modified clinoptilolite zeolite on nitrate leaching and plant growth reported that the concentration of nitrate released in the leachate of SMZ-amended soil were lower than those of zeolite-amended soil. In other previous report, reference [9] also suggested that SMZ was a good sorbent in order to control the release of PO_4^{3-}.
Although anionic nutrients do not readily adsorb onto PS due to lack of positive charges in the PS, SMZ can easily adsorb these nutrients due to HDTMA formation on the zeolite surfaces. As reported by [10], the modification of zeolite by cationic surfactant could enhance the capability of zeolite in the sorption of anionic species. The bilayer structures causes the arrangement of positively charged functional groups toward the solution, which can serve as sorption sites for anions [15]. Due to this characteristic, SMZ was capable in adsorbing negatively charged nutrients, which may explained the observed reduction of these nutrients in the leachate of PS added with SMZ. This suggests that the application of SMZ on the PS or growing medium would be more effective than unmodified zeolite for the reduction of nutrients leaching.
The effect of different growing medium on vegetable growth was evaluated by taking various growth parameters after the plants have been harvested (the 40th days after the first day of sowing). Tables 1, 2 and 3 show the growth parameters okra, white radish and pakchoy, respectively.

Table 1: Growth parameters of okra (A. esculentus) grown in different treatments.

Treatments	Fresh mass (g)	Dry mass (g)	Height (cm)
PS(50)	0.99±0.04bc	0.14±0.010de	14.9±0.1e
Z(1)-PS(50)	1.03±0.02b	0.21±0.010b	16.7±0.2b
Z(5)-PS(50)	0.92±0.04cd	0.13±0.010e	16.5±0.4d
Z(15)-PS(50)	0.88±0.03d	0.11±0.008f	14.8±0.3e
SMZ(1)-PS(50)	1.29±0.04a	0.54±0.005a	21.8±0.1a
SMZ(5)-PS(50)	1.03±0.01b	0.17±0.007c	18.9±0.1b
SMZ(15)-PS(50)	1.02±0.01b	0.16±0.024cd	17.5±0.2c

Means ± standard error of mean followed by the different letter in the same column differed significantly according to Duncan's multiple range test (P = 0.05).

Table 2: Growth parameters of white radish (R. sativus) grown in different treatments.

Treatments	Fresh mass (g)	Dry mass (g)	Height (cm)
PS(50)	0.38±0.02c	0.046±0.002cd	6.9±0.1c
Z(1)-PS(50)	0.58±0.03a	0.056±0.002b	6.9±0.3c
Z(5)-PS(50)	0.39±0.02c	0.047±0.001c	6.3±0.2d
Z(15)-PS(50)	0.37±0.01c	0.030±0.001e	5.0±0.2e
SMZ(1)-PS(50)	0.60±0.02a	0.069±0.001a	11.7±0.1a
SMZ(5)-PS(50)	0.49±0.02b	0.059±0.001b	11.4±0.2a
SMZ(15)-PS(50)	0.44±0.01b	0.042±0.001d	7.7±0.2b

Means ± standard error of mean followed by the different letter in the same column differed significantly according to Duncan's multiple range test (P = 0.05).

Table 3: Growth parameters of pakchoy (B. chinensis) grown in different treatments.

Treatment	Fresh mass (g)	Dry mass (g)	Height (cm)
PS(50)	0.25±0.014b	0.026±0.0005cd	4.2±0.2ef
Z(1)-PS(50)	0.27±0.009b	0.028±0.0012bc	5.3±0.2d
Z(5)-PS(50)	0.22±0.005c	0.024±0.0010e	4.6±0.2e
Z(15)-PS(50)	0.19±0.006d	0.017±0.0009f	3.9±0.1f
SMZ(1)-PS(50)	0.30±0.005a	0.044±0.0006a	9.9±0.1a
SMZ(5)-PS(50)	0.26±0.005b	0.031±0.0006b	7.1±0.1b
SMZ(15)-PS(50)	0.25±0.004b	0.026±0.0006de	6.0±0.1c

Means ± standard error of mean followed by the different letter in the same column differed significantly according to Duncan's multiple range test ($P = 0.05$).

Inspection of these results revealed that the performance of vegetables grown on SMZ containing media was much more vigorous than other treatments. This observation was supported by the statistical analysis which showed that there were significant difference ($p < 0.05$) in growth parameters of okra, white radish and pakchoy grown in PS with different treatment. Because of this, it can be concluded that the mean height, fresh mass and dry mass of the treatments were significantly different.

The application of PS with different amendments had a significant effect on the growth parameters of the plants. The highest plant parameters were shown by three vegetables grown in SMZ(1)-PS(50), where the SMZ and PS were mixed at 1:50 ratio. These are mainly associated with the higher leaves, stem and root weight. This behavior could be explained by the well development of root growth of plants grown on PS added SMZ could attribute to a greater water and nutrients availability as well as favorable aeration compared to others [16]. After the modification of zeolite with the HDTMA, SMZ can hold and retain negatively charge nutrient, phosphate which was important for the root development. This result supported by [17], the total number of root branch and total root system length were greater on higher phosphate concentration. These ultimately resulted in the higher yield of vegetables as compared to other medium.

The optimum ratio of SMZ to PS for the highest growth was SMZ(1 g):PS(50 g). However, the increased amount of SMZ added in PS resulted in lower growth of the plants. This might be due to the availability of the nutrients needed for the plant uptake reduced when there was more SMZ added in PS. The function of SMZ was to hold and retain nutrients in the PS as stated in the controlled released study. Therefore, the higher amount of SMZ added in PS resulted in more nutrients retained in the SMZ and avoiding plants to uptake more nutrients consequently affected the yield. Advantageously, this result showed that only a little amount of SMZ was needed for the higher yield of plants.

Plants grown on PS and zeolite-added PS showed poor performance as recorded in the results. A steady decreased in plants yield was observed with plants produced from zeolite-added PS. This might be due to the fact that poor growth of seedlings on both medium was associated with the nutrients that are available and can be absorbed by the plant itself. Zeolite which has negatively charged structure can only adsorb cation but fail to hold and retain phosphate, nitrate and nitrite which are vital for the germination and growth of the vegetables [18]. This results also supported by the controlled released study. Therefore, both of these growing medium are not favorable for plant growth compared to PS with SMZ. A gradual decreased in mean height, fresh mass and dry mass was observed in both media added with the increased amount of zeolite or SMZ. This can be shown by the growth parameters of the plants added in PS as their growing medium. The condition can be explained by the fact that zeolite and SMZ tend to hold and retain nutrients tightly and the nutrients are released thus less nutrients can be absorbed by the vegetables.

CONCLUSION

It can be concluded that zeolite performed better in adsorbing, holding, controlling and releasing anionic nutrients after modification with cationic surfactant HDTMA (SMZ). The reversal charge from negative to positive on SMZ surfaces aids in adsorbing anionic forms of nutrients which are essential for plant growth. With this property, adding SMZ in propagating substrate is not only can increased the quality and yield of plants, but also help in reducing the problem of nutrients leaching to environment which is known to bring adverse effect to the environment.

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