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Effect of Different Monomers on Water Retention Properties of Slow Release Fertilizer Hydrogel

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Abstract

The combination of hydrogel and fertilizer as slow release fertilizer hydrogel (SRFH) has become one of the promising materials to overcome the shortcomings of conventional fertilizer by decreasing fertilizer loss rate, supplying nutrients sustainably, and lowering frequency of irrigation. A comparative study on water retention and plant growth performances of SRFH made from three hydrophilic monomers; acrylic acid (AA), acrylamide (AAm) and AA-co-AAm was executed. PAA SRFH has smaller swelling rate constant, k as it required only 166.67 minutes to absorb 0.63 of its equilibrium capacity of swelling, followed by P(AA-co-AAm) SRFH and PAAm SRFH. Although PAAm SRFH has the lowest swelling rate constant, it has the most excellent water retention ability in soil followed by P(AA-co-AAm) SRFH. Additionally, the presence of PAA SRFH in soil has enhanced the plant growth performances of model plant (capsicum annum) in term of its average leaf width and plant height. The synergistic effects of acrylic acid and acrylamide in P(AA-co-AAm) SRFH could be utilized to produce hydrogel used in agriculture.

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Keywords: Hydrogels; water absorbency capacity; water retention; plant growth performance

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1. Introduction

In agricultural area, as far as the plant growth performance is concerned, a suitable distribution of fertilizer and water plays a very significant role. However, about 40–70% of nitrogen, 80–90% of phosphorus and 50–70% of potassium of the conventional fertilizers are released to the environment through leaching or volatilization without being absorbed by plants [1, 2]. Excessive nitrogen can be lost via two pathways; it is released as gas during microbiological transformation or it undergoes leaching with the seepage water. Nitrogen leaching is accelerated in sandy soils due to high rates of precipitation [3].

Slow release fertilizer hydrogel (SRFH) is a combination of hydrogel and fertilizer mainly created to reduce evaporation losses and frequency of water irrigations [4]. The SRFHs act by helping the absorption of some nutrient elements into its structure, holding them tightly, and delaying their dissolution. Hydrogel has been used to improve water retention of soil and water managing materials for degraded land [5]. Hydrogels can be identified as hydrophilic polymeric materials with network structures and appropriate degree of crosslinking. Hydrogel has the ability to absorb large amount of water during a short period of time and

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hold the absorbed water even under pressure. When fertilizer is incorporated in hydrogel, it produces SRFH that can improve water retention in soil [6], lower death rate of plants, and increase the plant growth tremendously [7, 8].

Hydrogel can be loaded with the active component such as fertilizer by two techniques; absorption of the fertilizer solution by dried hydrogel until the equilibrium swelling is reached [9], or SRFH is prepared directly (*in-situ*) into the fertilizer solution [10]. In this research, the latter technique was employed as it give better absorption properties being reported in our previous research [11]. Different types of hydrophilic monomer have been used as starting raw materials to produce hydrogels that suitable for specific applications. SRFHs base acrylic acid or acrylate can be considered environmentally compatible to forest soil and it showed no adverse effects on the microbial community of forest floor [5]. On the other hand, SRFH based acrylamide and aldehyde derivatives are able to self-crosslink at high temperatures and can be considered economically attractive to reduce the usage of crosslinking agent. However, several side reactions are also involved, leading to the formation of formaldehyde by-products which is undesirable because of its toxicity [12].

There are wide choices of monomers employed to produce hydrogels, therefore a proper choice of monomer is very crucial for an effective SRFH. Thus, the aim of this research is to study the effect of hydrophilic monomers on the three main properties of SRFH which are swelling rate, water retention test and plant growth performance of a model plant. Three hydrophilic monomers; acrylic acid (AA), acrylamide (AAm) or acrylic acid-co-acrylamide (AA-co-AAm) were used to combine with liquid fertilizer to produce SRFH.

2. Materials and Method

2.1. Materials

5M Acrylamide (AAm), 5M acrylic acid (AA), sodium hydroxide (NaOH), urea fertilizer (diluted to 1%), ammonium persulphate (APS) and N'N-Methylenebisacrylamide (NMBA) were purchased from Merck (M) Sdn. Bhd. All chemicals were used as purchased.

2.2. Neutralization of Monomers

At room temperature, NaOH was added into monomer to get the 60% degree of neutralization. After 30 minutes, the mixture was transferred into five-necked flask, which was equipped with a mechanical stirrer, a condenser and a nitrogen line. Water bath was used to supply heat into the flask at the temperature of 70 °C. Neutralization is important to increase the electrostatic repulsion in carboxylate anions of the SRFH networks. The negatively charged carboxylate ions attached to the polymer chains that will set up an electrostatic repulsion that tends to expand the network. This results in the increase of water absorbency with the increase of degree of neutralization.

2.3. SRFH Synthesis Reaction

The reaction was carried out in 500 ml five-necked round-bottom flask equipped with a mechanical stirrer, a condenser, a thermometer and a nitrogen gas supply. Memmert Water Bath was used to supply heat to the mixture. Once the temperature reached 70 °C, weighted amount of neutralized monomers, NMBA, APS, and urea were mixed together with distilled water. The mixture was vigorously stirred at 170 rpm and dissolved oxygen was flushed out by nitrogen gas throughout the process. After all materials have completely turned into hydrogel, the synthesis reaction was stopped. To remove any unreacted materials, the synthesized SRFH was then filtered and washed with distilled water for several times. The SRFH was dried in oven at 70 °C for 24 hours. To avoid any moisture contact, all products were stored in a desiccator.

2.4. Swelling Rate of SRFH

Absorbency rate test is important to study the absorbency tendency and the time needed for SRFHs to reach equilibrium water absorbency. 0.5 grams of sample with various particle sizes were poured into numbers of weighed tea bags and immersed in 200 ml distilled water at room temperature. At certain intervals, the water absorbency of the sample was measured according to Eq.1.

$$WAC = (W_2 - W_1)/W_1 \tag{1}$$

where W_1 and W_2 are the weights of the dry sample and water absorbed sample, respectively. WAC was calculated as gram of water per gram of sample (g/g).