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Formulation of Slow Release NPK Granules with Addition of Polystyrene-Polycaprolactone Matrix and and Its Effect on the Growth of Chilli (*Capsicum annum* L.)

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Abstract: *Slow release NPK granules were formulated with the addition of polystyrene-polycaprolan matrix and their effect on chilli (Capsicum annum L.) was tested. Chili plants were grown in-planta for 18 weeks with the dose distribution of 16 g/ plant for conventional NPK fertilizer as a control and slow release NPK bioblend PCL-PS with different doses (8, 16 and 32 g/ plant) determined by plant height, number of flowers, number of fruit and fruit weight at harvest. Bioblend PS-PCL has a good compatibility with NPK granules so it was able to reduce the release of nutrients from fertilizer. The results showed that the release rates of NPK bioblends PS-PCL and conventional NPK in distilled water media after 48 hours were 24.732% and 86.141%, respectively. There were no significant differences of the S1 dose compared to controls. At S2 dose, weeks 12 and 18 had a significant difference in controls for fruit count (p <0.05). At the dose S3, there was a significant difference in the control of all test parameters except of plant height. The dose of S3 was the highest compared to all doses (S1 and S2) given to the growth of chilli plants (height, number of flowers, number of fruits and weight of fruit at harvest). The large dose of slow release NPK fertilizer given affected the growth of chilli plants and the dose of S3 was better than other doses in this study. In this study the use of slow release PS/ PCL bioblends fertilizer has been proven to increase the growth of chilli plants in both height, number of flowers, number of fruits and fruit weight.*

Keywords*: fertilizer, bioblends, polystyrene, polycaprolactone, growth and yield, Capsicum*

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I. Introduction

Chilli (*Capsicum annuum* L.) is the third essential plant of the Solanaceae family after the tomatoes and potatoes (1). Economically, chili is grown as a commercial plant (2). Genus *Capsicum* has almost 20 species and only 5 species are cultivated. Among these species, *Capsicum frutescens* and *Capsicum annum* are regularly cultivated throughout the world (3). Nitrogen, phosphorus and potassium (NPK) are the main nutrients in commercial fertilizers. Each of these basic nutrients plays an important role in the growth and yield of plants (4). Apart from the benefits of fertilizer for the plants, there are some obstacles that arise in the use of fertilizers by being spread such as some part of fertilizers will be carried away by rain or ground water and some part of the fertilizer will form emissions gas into the air that can cause climate change (5). This can be dangerous to human health and has a negative impact on the environment because it can pollute the soil, water and air. The inefficient use of fertilizers also causing a negative impact on farmers, namely the waste of resources. More than 800 experiments stated that on average 51% of nitrogen is left on the surface of the soil 6). About 80-90% phosphorus, 50-90% potassium and more than 95% micronutrient content of fertilizers are lost to the environment and cause large economic losses (7). Slow release fertilizer is one of the methods that can be used to increase crop production and the efficiency of use, also to minimize adverse environmental impacts (8). Bioblend Polystyrene-Polycaprolactone has good compatibility with NPK granules which can reduce the release nutrients from fertilizers. Bioblend Polystyrene-Polycaprolactone-PCL shows the slower rate of NPK granule release than conventional NPK granules which was 21.05% in distilled water media after 48 hours (9). The purpose of this study was to see the effect of slow release NPK fertilizer formulated with the addition of Polystyrene-Polycaprolactone matrix to height, the number of flowers and the number of fruits to the chilli plant (*Capsicum annuum* L).

II. Materials And Methods

Materials

Polystyrene, polycaprolactone (Aldrich Chemical), NPK granules 2-3 mm diameter (NPK fertilizer Crown 16-16-16 Origin of Russia, PT. Wilmar Chemical Indonesia), technical ethyl acetate, Potassium dihydrogen phosphate (Merck), concentrated sulfuric acid (Merck Merck), ammonium molybdate (Merck), Potassium antimonyl tartrate (Merck), ascorbic acid (Merck) and aquadest.

Preparation of NPK Granules

The conventional NPK granules were sieved using 2-3 mm sieves to obtain uniform NPK granule sizes, then it were washed with technical ethyl acetate and then dried in an oven at 50-55^{0}C for 30 minutes. Coating formulations can be seen in Table 1.

Table 1. Formula Coating for Bioblends PS-PCL

Materials (g)	Formula Coating (mL)
NPK	1000
PS	80
PCL	20
Ethyl acetate	1200

Preparation of the Coating Solution

Polystyrene and polycaprolactone in the amount according to Table 1 were dissolved with 1200 mL of ethyl acetate. The coating process used bioblend polystyrene-polycaprolactone with 4: 1 ratio. 80 gram Polystyrene was dissolved in 900 mL of ethyl acetate and 20 grams of polycaprolactone was dissolved in 300 mL of ethyl acetate, then it stirred with magnetic stirrer with a speed of 70 rpm and a temperature of 60^{0}C until everything dissolved. The two solutions were mixed and stirred using a magnetic stirer at a speed of 1000 rpm and a temperature of 60^{0}C for 10 minutes.

The Coating Process

The spray coating method was used in this study. NPK granules were sprayed with a coating solution that has been made before. As many as 1000 grams of NPK granules were put in a coating pan then the coating solution was poured into a solution container on a spray gun. Then the NPK granules were sprayed with a coating solution with a coating pan rotational speed of 70 rpm. After spraying was completed, NPK granules were dried using an oven at 50-55^{0}C for 30 minutes ..

Characterization of NPK granules

Granule Topography

Characterization of the surface morphology of the granules was carried out to see the characteristics and compatibility between the coating polymer and NPK. This evaluation was carried out using a scanning electron microscopy (SEM) tool.

Chemical Interaction

This evaluation was carried out to determine the possible interaction between the components of the coating material with NPK granules. This analysis was performed using a Fourier transform infrared spectroscopy (FTIR) tool.

Determination of Slow Release NPK in Water Media

0.5 g of coated NPK fertilizer was put into 100 ml of distilled water at a temperature of 25-30 °C. The liquid from the container was taken at predetermined times (0.83, 0.25, 0.5, 1, 4, 12, 24 and 48 hours) as much as 5 ml, then the water in the container was replenished by adding as much aquadest as possible taken. As much as 3 ml of the liquid taken at the time unit was added with 3 ml of ammonium molybdate dye reagent (10). The absorbance of each sample was measured using a spectrometer.

Treatment and Experimental Preparation in Chilli Plants

The test was conducted in-planta on the Buluah Sarumpun farm, Agam Regency, West Sumatra, Indonesia with a spacing of 50 x 50 cm. The experimental design consisted of four treatments with different doses, each treatment was applied in five replications based on a randomized block design (RCBD). The dosage used can be seen in Table 2.

Table 2. Doses and Treatments

Treatments	NPK Granule	Dose (g/plant)
Control	Non coated NPK	16
S1	Slow release NPK	8
S2	Slow release NPK	16
S3	Slow release NPK	32

Statistical Analysis and Measurement of Plant Growth

The plant growth parameters such as plant height, number of flowers and number of fruits were measured routinely every week. The data presented was an average value of five repetitions for each treatment processed with one-way ANOVA IBM SPSS version 2.0. Least Significant Difference (LSD) test was used to compare and evaluate the significance of the mean value at $P \leq 0.05$.

III. Results and Discussion

Morphology and Characteristics

SEM Analysis

Figure 1A showed SEM micrographs of NPK granule coated polystyrene-polycaprolactone bioblend. Figure 1B showed SEM micrographs of non coating NPK granules. Figures 1A and 1B showed the morphology of NPK granules with magnification of 300 times each.

Figure 1A showed clearly polystyrene-polycaprolactone bioblend polymer layers, where the layers of polymer bioblend polystyrene-polycaprolactone on the outside and NPK granules on the inside with a thickness of 98.6 µm-113.4 µm thereby reducing the rate of water diffusion to the core and diffusion of NPK out of the core and provided a slow release effect (11). Figure 1B showed a SEM micrograph of a coated NPK granule with a rough and bumpy surface.

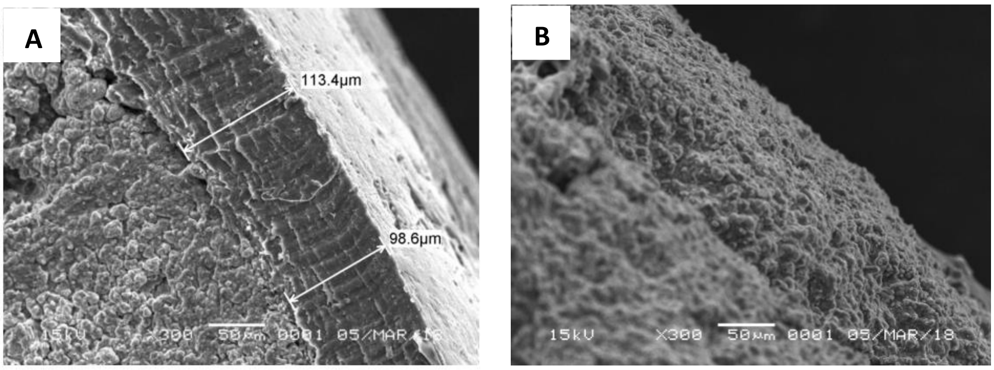

Figure 1. SEM micrograph of NPK granules with magnification of 300 times each. A) SEM micrographs of NPK coated polystyrene-polycaprolactone bioblend. B) SEM micrographs of non-coated NPK granules

FTIR Analysis

The FTIR spectrum of the NPK granules coated polystyrene-polycaprolactone bioblend samples showed similarities to the non-coated NPK granules spectrum (Figure 2) (12). The 1080 cm^{-1} peak in non coated NPK granules and 1047 cm^{-1} in coated NPK granules were the bending vibration of the C-O group. The peaks of 890 $cm^{-1}$and 753 cm^{-1} on non coated NPK granules and coated NPK granules were C-H buckling vibrations. The peaks of 2940 cm^{-1} and 2924 cm^{-1} on the polycaprolactone and coated NPK spectra showed –CH2 asymmetric strain vibrations. The 1721 cm^{-1} and 1727 cm^{-1} peaks on the polycaprolactone and coated NPK spectra were the vibrations of the C=O carbonyl strain. The peaks of 754 cm^{-1} and 753 cm^{-1} in the polystyrene and coated NPK spectra were benzene stretch vibrations. The peaks of 2919 cm^{-1} and 2924 cm^{-1} in the polystyrene and coated NPK spectra were C-H strains.

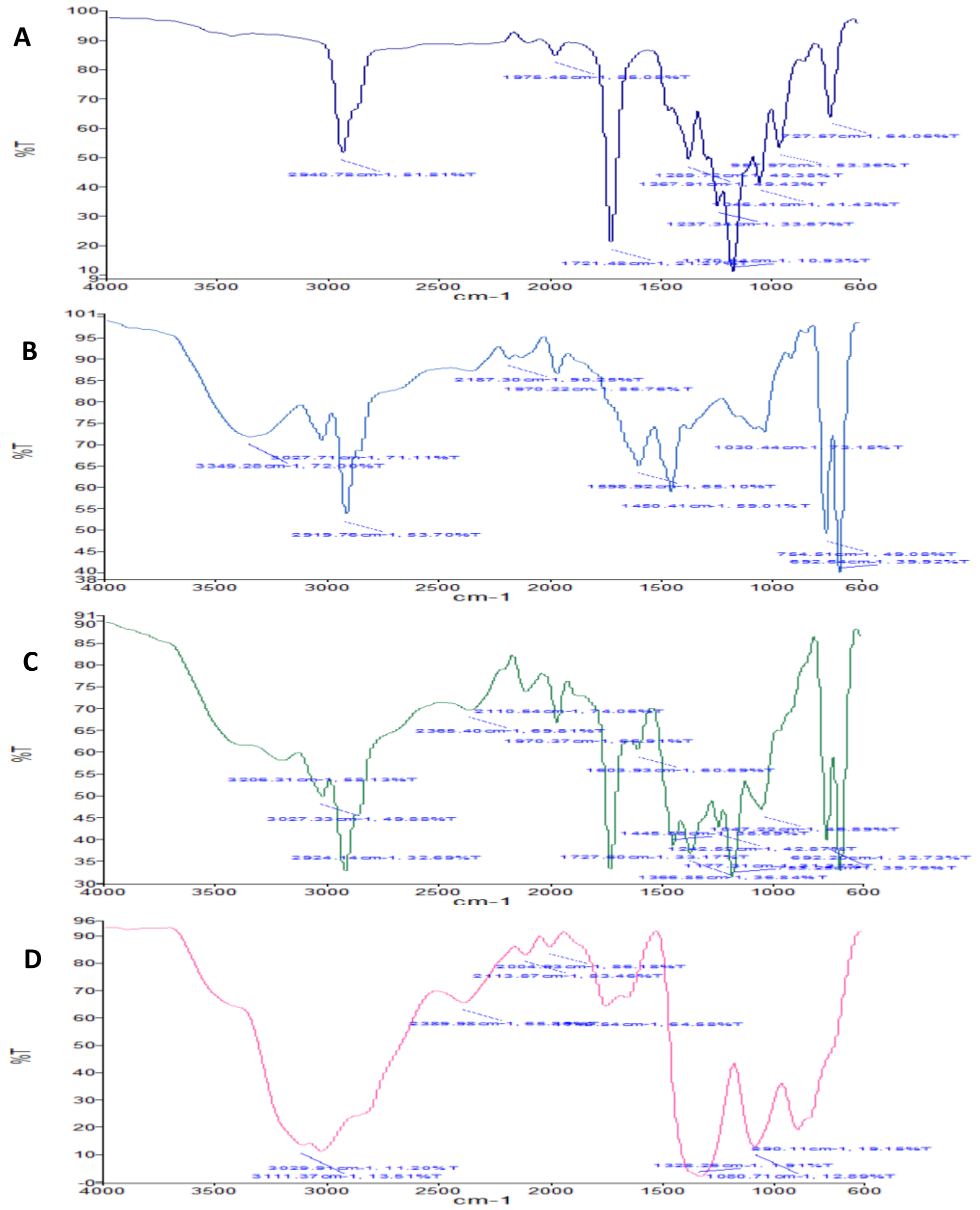

Figure 2. FTIR Spectra of a) Polycaprolactone, b)Polystyrene,
c) NPK Coated polystyrene/polycaprolactone Bioblend, d) Non coated NPK

Characteristics of Phosphate Release of Slow Release NPK Granules

Phosphate release was observed from 5 minutes to 48 hours in distilled water media at room temperature. The slow release of phosphate in NPK granules in this study occurred because immersion and penetration of water vapor penetrated the coating layer into the core of the granule which dissolved a small amount of fertilizer resulted in partial release. The release occured due to the trapped osmotic pressure which resulted in the swelling of the granules, the fertilizer core will be released slowly through a diffusion mechanism due to the driving force which might be due to the concentration or pressure gradient, or a combination of both, this mechanism known as “diffusion mechanism” (13). This was due to the layer of the polymer coating. The release rate occured constantly because of the solution concentration in the granule became saturated and eventually became constant, so that the NPK diffusion also became constant from inside the granule threw out the polymer layer. During the reduction stage of NPK release rate , all parts of the NPK had dissolved, the concentration gradient began to decreased and the diffusion rate became reduced. In short, the NPK release stage started with the acceleration of release rate and ended with the reduction of the release rate. This was in accordance with what was reported by Yang et al. (14).

Figure 3 showed the release profile of slow release NPK phosphate release and conventional NPK granules in distilled water media at room temperature. The percentage of phosphate release from conventional

NPK granules after 48 hours was 86.141%, while the percentage of phosphate release from slow release NPK granules was 24.732%. Based on these results it can be seen that the release profile of conventional NPK granules was faster than the slow release NPK granules.

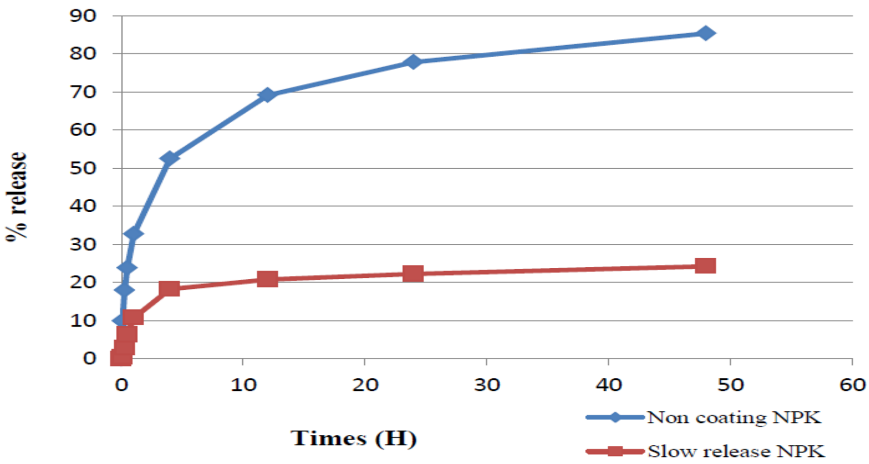

Figure 3. Profile of phosphate in slow release formula compared to conventional NPK granules in the distilled water media.

Effects of Slow Release NPK Granules and Conventional NPK Granules on Plant Growth

Data on growth parameters from chilli plants were shown in Table 3 and Figure 4. The highest plant height was observed in S3 treatment, while in the S1 treatment had the lowest plant height. However, there was no significant difference in the plant height parameter (control, S1, S2 and S3). The highest number of flower was recorded in S3, while S1 had the lowest number of leaves. However, there was no significant difference between S1 and control for the number of flowers. At the 12th and 18th weeks, the amount of flowers was recorded to have a significant difference to controls ($p < 0.05$). The number of fruits in S3 was recorded as the highest number, while the lowest number of fruits was recorded in the control. There was no significant difference between the control and S1 for the number of fruits. At the 12th, 16th and 18th there was a significant difference between S3 treatment and control for the number of fruits ($p < 0.05$). Fruit weight at harvest in S3 was also the highest in all treatments and controls. There was no significant difference between S1 and S2 for the control for fruit weight. However, in S3 there was a significant difference in control for fruit weight at harvest ($p < 0.05$). The statistics data obtained in this study implied that the treatment or dosage of slow release NPK granules affected the growth of chili plants. Although, at S1 plant height and the number of flowers was lower than the control, there would be no significant difference between the two. S3 treatment was the highest compared to all treatments or doses given to the growth of chili plants. This implied that the amount of slow release NPK fertilizer given was affecting the growth of chili plants and the dose in S3 treatment was better than the other doses in this study.

The use of slow release fertilizer has been shown to increase plant growth and has been widely reported on oil palm (15), mustard greens (16), tomatoes (17, 18), rice (19, 20), wheat (21), bean crops (22) and *Brassica napa* (23). Slow release fertilizers provides nutrients for a longer period in the amount needed for plant growth and productivity, reduce leaching, nutrient volatilization and therefore increase plant nutrition efficiency in an environmentally friendly way.

Table 3. Data Effects of Slow Released NPK Granules and Conventional NPK Granules on Plant Growth

Treatment/ Doses	Average Plant Growth												Fruit Weigh at Harvest (g/plant)
	Plant height				Number of flowers				Number of fruits				
	12th week	14th week	16th week	18th week	12th week	14th week	16th week	18th week	12th week	14th week	16th week	18th week	
Control	35.34	37.96	39.16	39.26	2.80	7.83	9.00	5.80	1.60	7.40	9.00	11.60	18.70
S1	32.98	35.80	36.72	37.04	3.80	7.20	7.20	5.40	3.80	9.40	9.40	7.60	38.02
S2	38.82	40.86	42.08	42.30	3.80	7.00	11.80	8.40	6.40*	11.00	12.60	21.20*	47.28

S3	40.54	45.18	45.82	46.00	9.40*	12.80	13.40	9.40*	6.20*	14.80	19.00*	23.60*	53.34*

Data were analyzed with one-way ANOVA (LSD) <0.05.
* = Data have a significant difference to the control (LSD) <0.05

Figure 4. Effects of Slow Released NPK Granules Produced Compare to Conventional NPK Granules on Plant Growth

IV. Conclusions

The test parameters did not showed a significant difference in S1 treatment over control. At S2 treatment, weeks 12th and 18th had a significant difference in controls for the number of fruits. At S3 treatment, there was a significant difference in the control for all test parameters except plant height. S3 treatment was the highest compared to all treatments or doses (S1 and S2) given to the growth of chili plants (height, number of flowers, number of fruits and weight of plants at harvest). This implied that the large dose of slow release NPK fertilizer affected the growth of chili plants and the dose in S3 treatment was better than other doses in this study. In this study the use of slow release PS/ PCL bioblends fertilizer has been proven to increase the growth of chili plants including plant height, number of flowers, number of fruits and fruit weight.

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