Release test of N, P, and K of complete slow release fertilizer (PUKAP JESTRO-1) and its effect on the growth of young siam citrus (Citrus nobilis Lour.)

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Abstract. The research aimed to study the release of N, P, K elements from slow release complete fertilizer (PUKAP JESTRO-1) and its effect on the growth of Siam citrus in a high density planting system (HDP). The release test of PUKAP JESTRO-1 was carried out in a laboratory, where the remaining N, P, K content in fertilizer was measured periodically. The influence test of PUKAP JESTRO-1, which compared with conventional fertilizer in the form of a single fertilizer and NPK compound fertilizer, was carried out on a 1-month old Siam citrus planted on Grumusol (vertisol). The study used randomized block design with 5 treatments and 3 replications, namely 400 g/plant/year mixed fertilizer (200 g Urea + 150 g SP36 + 50 g KCl); 200 g/plant/year PUKAP JESTRO-1; 300 g/plant/year PUKAP JESTRO-1; 400 g/plant/year PUKAP JESTRO-1; 400 g/plant/year NPK YaraMila (16-16-16). The experimental results showed that PUKAP JESTRO-1 released N, P, and K until the fourth, tenth, and eighth week respectively. Application of PUKAP JESTRO-1 at 25% lower dosages produced better plant height compared to mixed fertilizer applications but did not significantly increase leaf N, P, and K levels due to the effect of dilution of elements in plant tissue.

1. Introduction
The development of a high-density citrus planting system (HDP citrus) is a rational solution when the increasing trend of demand for citrus fruits is contrary to the provision of agricultural land which decreases in size. HDP citrus cultivation technology in Indonesia began to developed by the Indonesian Citrus and Subtropical Fruits Research Institute (ICSFRI) since 2017 and began to be favored by farmers in Batu City and Banyuwangi Regency-East Java and introduced in Batang Regency-Central Java, Pelalawan Regency-Riau and Bengkulu. HDP citrus cultivation has long been developed in several citrus-producing countries in the world, including China [1], the United States of America [2], and Japan [3].

High-density planting causes draining of soil nutrients in a heavier and faster manner so that improper nutrient management can result in decreased productivity and plant health. Nutrient management using conventional high-dissolved fertilizer with the high dosage in HDP citrus cultivation has the potential to cause higher pollution because of its low efficiency. Furthermore [4] reported that nutrients lost from the use of conventional NPK compound fertilizers reached around 40-70% N, 80-90% P, and 50-70% K. Nitrogen loss through denitrification and leaching caused significant detrimental impacts to the environment such as the effects of greenhouse gases and groundwater pollution.
The application of slow-release fertilizer is one approach developed to overcome the weaknesses of the use of conventional chemical fertilizers in several types of plants, including citrus plants [5–8]. The application of slow-release fertilizer can effectively reduce fertilizer loss while reducing environmental pollution because nutrients contained in fertilizer are released according to plant growth [9,10]. Slow-release fertilizers can be made by coating conventional fertilizers with certain materials to control the rate of nutrient release of fertilizers such as N-serve material (Nitrapyrin), sulfur, calcium carbide, polysulfone, and porous material [9, 11–13].

Although synthetic fertilizer coating materials are widely used in several countries, the price is relatively expensive and difficult to obtain in Indonesia. Therefore, in 2018 ICFSRI assembled a complete slow-release fertilizer which is produced using natural mineral coatings (PUKAP JESTRO-1). This fertilizer contains complete nutrients (macro and microelements) which elemental composition is adjusted to the needs of young citrus plants. The presence of microelements in this fertilizer is expected to increase the resistance of citrus plants to Huanglongbing (HLB) disease and improve the plant's growth [7,14]. This fertilizer has been patented in 2018 with the patent number IDS000002033. Before being applied en masse, the character of nutrient release and effectiveness of PUKAP JESTRO-1 need to be analyzed so that the nutrition management in young citrus plants can be carried out properly.

2. Methods

The main materials used for fertilizer nutrient release tests are PUKAP JESTRO-1 fertilizer (17% N, 8% P₂O₅, 6% K₂O and microelements) and quartz sand, while chemicals used for fertilization tests include PUKAP JESTRO-1, Urea (46% N), SP 36 (36% P₂O₅), KCl (59% K₂O), YaraMila NPK (16% N - 16 P₂O₅ - 16 K₂O). The plants used in fertilizer tests were one-month-old Siam citrus which was grafted on Japansche Citroen's rootstock planted in three locations with a high-density planting system (1,200 trees/ha). The soil of the experiment site is vertisol, the texture is clay, the reaction of the soil is neutral (pH H₂O = 6.72), the organic content is very low, the N content is very low–low, the available P is very low, exchangeable K is medium – very high, exchangeable Ca and Mg are very high, and cation exchange capacity is high (Table 1).

| Test parameters | Location | Criteria |
|-----------------|----------|----------|
| pH H₂O (1:5)    | Site I   | 6.53     | Neutral |
|                 | Site II  | 6.93     |
|                 | Site III | 6.91     |
| C-Organic (Walkley & Black) | Site I | 0.88 % | Very low |
|                 | Site II | 0.87 % |
|                 | Site III| 0.74 % |
| Total nitrogen (Kjeldahl) | Site I | 0.11 % | Very low–low |
|                 | Site II | 0.10 % |
|                 | Site III| 0.09 % |
| Available P₂O₅ (Olsen) | Site I | 4.74 ppm | Very low |
|                 | Site II | 5.47 ppm |
|                 | Site III| 4.28 ppm |
| Exchangeable K (NH₄OAc 1M, pH 7) | Site I | 1.18 me.100g⁻¹ | Medium – very high |
|                 | Site II | 0.37 me.100g⁻¹ |
|                 | Site III| 0.55 me.100g⁻¹ |
| Exchangeable Ca (NH₄OAc 1M, pH 7) | Site I | 24.16 me.100g⁻¹ | Very high |
|                 | Site II | 23.81 me.100g⁻¹ |
|                 | Site III| 23.34 me.100g⁻¹ |
| Exchangeable Mg (NH₄OAc 1M, pH 7) | Site I | 20.05 me.100g⁻¹ | Very high |
|                 | Site II | 9.27 me.100g⁻¹ |
|                 | Site III| 8.73 me.100g⁻¹ |
| Exchangeable Na (NH₄OAc 1M, pH 7) | Site I | 0.84 me.100g⁻¹ | High |
|                 | Site II | 0.88 me.100g⁻¹ |
|                 | Site III| 0.93 me.100g⁻¹ |
| Cation exchange capacity | Site I | 33.37 me.100g⁻¹ | High |
|                 | Site II | 29.35 me.100g⁻¹ |
|                 | Site III| 27.50 me.100g⁻¹ |
| Texture (Hydrometer) | Clay | Clay |

2.1. Release test of N, P, K elements in fertilizer

A number of PUKAP JESTRO-1 fertilizers are embedded in white sand soil material in a plastic pot container (1 part weight of fertilizer: 50 parts weight of sand) covered with black plastic and incubated
in a laboratory room. During incubation, the soil moisture content is maintained around the field capacity. The remaining fertilizer was taken to analyze the content of N, P, K on day 7; 14; 21; 28; 42; 56; 70; and 84 from the incubation period. The day before taking fertilizer sample, the soil was leached with distilled water (30% of the weight of sand). The fertilizer element released is the difference from the initial fertilizer element content reduced by the fertilizer element after incubation.

2.2. Test of PUKAP JESTRO-1 fertilizer on citrus plants
Five fertilizer dosage treatments were (A) 400 g/tree/year mixed fertilizer (200 g Urea + 150 g SP36 + 50 g KCl), (B) 200 g/tree/year PUKAP JESTRO-1, (C) 300 g/tree/year PUKAP JESTRO-1, (D), 400 g/tree/year PUKAP JESTRO-1, and (E) 400 g/tree/year YaraMila NPK fertilizer (16-16-16). The dose was divided into 6 to be applied every 2 months. Fertilizer was inserted into a circular hole under the outer canopy and covered with soil. Data collected included plant height, stem diameter, canopy width, and leaf N, P and K content. The experiment was arranged using a randomized block design, conducted in 3 locations as a replication, with the number of plants is ± 150 trees. Data collected included plant height, stem diameter, canopy width, and leaf nutrient content, namely N (wet ashing with H2SO4), P (spectrophotometer with the wavelength of 693 nm) and K (photometer). The sample leaves are terminal leaves with normal growth and health. Plant height is measured from the grafting plane to the highest growing point. The diameter of the stem is measured at a height of about 10 cm from the grafting area. Canopy width is measured in the north-south and east-west direction and then the average is calculated.

3. Results and discussion

3.1. Release test of N, P, K elements in fertilizer
The availability of optimal N, P, K elements in the soil over time is one of the keys to achieving good citrus plant growth. Therefore, the release of fertilizer elements is one of the important characteristics in choosing the type of fertilizer for citrus plants. The results of incubation in the laboratory showed that the PUKAP JESTRO-1 fertilizer on the 7th day after incubation released a fairly large amount of N, which was around 76%, while the P and K elements were 43% and 63% respectively. Nitrogen levels in the fertilizer on the 28th day remained around 5%, while P and K were 28% and 16% respectively. In line with the incubation time, more element in fertilizer is released and the N content in fertilizer in the sixth week is immeasurable, while the remaining P and K elements are 20% and 11% respectively. The phosphor element in fertilizer starts to be immeasurable at week twelve, while the K element at week tenth (Figure 1).

![Figure 1. Element content in PUKAP JESTRO-1 during 12 weeks of observation in the laboratory](image)
The release of N in this study was very fast compared to the results of research conducted by Medina et al. [6]. This difference in results is mainly due to differences in the type of fertilizer tested and the sampling method to measure the release of N. In this study, the release of N was measured based on the levels of N remaining in the fertilizer, while the study of Medina et al., based on N levels in leachate water. In general, the release of the three elements of PUKAP JESTRO-1 fertilizer from the fastest to the slowest is the N> K> P elements. This phenomenon is related to the differences in the mobility of each element in the soil [15,16] and the high correlation between the fast soluble fraction and leaching [17].

3.2. Test of PUKAP JESTRO-1 fertilizer on citrus plants

Analysis of variance showed that the PUKAP JESTRO-1 slow release fertilizer had a significant effect on the plant height and canopy width of Siam citrus plants in the first year. The application of PUKAP JESTRO-1 slow-release fertilizer at a dose of 400 g/tree/year yields higher plant height and canopy width of Siam citrus plant than the application of mixed fertilizer at the same dose. PUKAP JESTRO-1 at a lower dose (300 g/tree/year) produced citrus plant growth (plant height, canopy width, and stem diameter) not significantly different from the results achieved by the application of 400 g/tree/year PUKAP JESTRO-1 and YaraMila fertilizer. However, the plant height achieved by the application of 300 g/tree/year PUKAP JESTRO-1 was significantly better than the application of 400 g/tree/year of mixed fertilizer (Table 2). This shows that the dose of 300 g/tree/year PUKAP JESTRO-1 slow release fertilizer applied 6 times a year is an optimal dose for Siam citrus grown on vertisol in the first year. This phenomenon also proves that the use of PUKAP JESTRO-1 slow-release fertilizer is more efficient compared to conventional fertilizers with the character of a fast release. The saving of fertilizer use up to 25% obtained from the application of PUKAP JESTRO-1 slow-release fertilizer. It has the potential to reduce environmental pollution compared to conventional fertilizer while having greater compensation than the relatively more expensive price of slow-release fertilizer.

| Fertilizer | Plant height (cm) | Canopy width (cm) | Stem diameter (mm) |
|------------|-------------------|-------------------|------------------|
| 400 g/tree/year mixed fertilizer (200 g Urea + 150 g SP36 + 50 g KCl) | 108.67 b | 58.00 b | 166 a |
| 200 g/tree/year PUKAP JESTRO-1 | 92.00 c | 51.00 b | 143 a |
| 300 g/tree/year PUKAP JESTRO-1 | 133.00 a | 64.00 ab | 187 a |
| 400 g/tree/year PUKAP JESTRO-1 | 134.00 a | 66.67 a | 180 a |
| 400 g/tree/year NPK YaraMila (16-16-16) | 132.67 a | 64.67 ab | 182 a |

Values followed by different notation in the same column means significantly different at α=5%

Plant growth parameters are higher in PUKAP JESTRO-1 applications compared to conventional fertilizers because PUKAP JESTRO-1 has a slow-release character so it is able to provide plant nutrients longer to be absorbed by plants. In addition, this fertilizer does not only contain primary macroelements (N, P, K) but also secondary macroelements (Mg, Ca, S) and microelements that have an important role in physiological activities in plants [16,18–22].

Even though it produced better growth, the application of PUKAP JESTRO-1 did not significantly increase the levels of N, P, and K elements in leaves compared to the application of mixed or compound fertilizer NPK YaraMila. This is caused by the effect of dilution of the elements on plant tissue because in general, the growth of citrus plants using PUKAP JESTRO-1 is relatively better compared to conventional fertilizer applications (Figure 2).
4. Conclusion

In the incubation experiment, JESTRO-1 PUKAP can release N until the fourth week, while P and K until the tenth and eighth week. The application of PUKAP JESTRO-1 slow-release fertilizer on citrus plants in vertisol is around 25% more efficient compared to conventional fertilizers. PUKAP JESTRO-1 application produces better growth of citrus plants compared to mixed fertilizers but does not significantly increase N, P, K leaves due to the effect of dilution of elements in plant tissue.

References

[1] Aubert B 1990 *Proceedings of the 4th International Asia Pacific Conference on Citrus Rehabilitation* (Rome: FAO) p 149–55
[2] Wheaton T A, Castle W S, Whitney J D, Tucker D P H and Muraro R P 1990 *Proceedings of the Florida State Horticultural Society* (Florida: Florida State Horticulture Society) p 55–9
[3] Tachibana S and Nakai S 1989 *J. Japanese Soc. Hortic. Sci.* **58** 91–6
[4] Wu L and Liu M 2008 *Carbohydr. Polym.* **72** 240–7
[5] Engelsjord M E, Fostad O and Singh B R 1997 *Nutr. Cycl. Agroecosystems* **46** 179–87
[6] Medina L C, Obreza T A, Sartain J B and Rouse R E 2008 *Horttechnology* **18** 475–80
[7] Vashishth T and Grosser J 2018 *J. Hortic.* **5** 244–8
[8] Trenkel M E 1997 *Improving Fertilizer Use Efficiency. Controlled-Release and Stabilized Fertilizers in Agriculture* (Paris: International Fertilizer Industry Association)
[9] Trenkel M E 2010 *Slow- and Controlled-Release and Stabilized Fertilizers: An Option for Enhancing Nutrient Use Efficiency in Agriculture* (Paris: International Fertilizers Industry Association)
[10] Ni B, Liu M, Liu S, Xie L and Wang Y 2011 *J. Agric. Food Chem.* **59** 10169–75
[11] Erickson J E, Cisar J L, Violin J C and Snyder G H 2001 *Crop Sci.* **41** 1889–95
[12] Tomaszewska M and Jarosiewicz A 2002 *J. Agric. Food Chem.* **50** 4634–9
[13] Jarosiewicz A and Tomaszewska M 2003 *J. Agric. Food Chem.* **51** 413–7
[14] Morgan K T, Rouse R E and Ebel R C 2016 *HortScience* **51** 1482–93
[15] Bahuelos G S and Ajwa H A 1999 *J. Environ. Sci. Heal. Part A Toxic/Hazardous Subst. Environ. Eng.* **34** 951–74
[16] Jones C and Jacobsen J 2001 *Nutr. Manag. Modul.* **12** 11-20
[17] Vallejo A, Cartagena M C, Rodriguez D and Diez J A 1993 *Fertil. Res.* **34** 121–6
[18] Njira K and Nabwami J 2015 *African J. Food, Agric. Nutr. Dev.* **15** 9777–93
[19] Yu Q and Rengel Z 1999 *Ann. Bot.* **83** 175–82
[20] Ilyas A, Ashraf M Y, Hussain M, Ashraf M, Ahmed R and Kamal A 2015 *Pakistan J. Bot.* **47**
[21] Hänsch R and Mendel R R 2009 *Curr. Opin. Plant Biol.* **12** 259–66
[22] Tripathi D K, Singh S, Singh S, Mishra S, Chauhan D K and Dubey N K 2015 *Acta Physiol. Plant.* **37** 139