

Riandy, Andika Putra; Sofyan, Dini Fuadilah; Palembang, Jl. Raya

Article

Applying nano-carbon as coating material for slow-released fertilizer to increase Indonesian rice yield and to reduce nitrogen loss in surface water of paddy soil

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**APPLYING NANO-CARBON AS COATING MATERIAL FOR SLOW-RELEASED FERTILIZER TO
INCREASE INDONESIAN RICE YIELD AND TO REDUCE NITROGEN LOSS IN SURFACE WATER
OF PADDY SOIL**

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ABSTRACT

Excessive amount of fertilizer applied to the Indonesian agricultural land caused environmental pollution i.e. soil toxicity, and eutrophication. The use of slow-released fertilizer has become a new trend to save fertilizer consumption, and to minimize environmental pollution. Due to its high surface energy and chemical activity, the application domain of nano-materials has been considered to be potentially conducted in agriculture. This study aims to identify the influence of slow-released fertilizer coated by nano-carbon material on rice yield and nitrogen loss in surface water of paddy soil. All of materials needed for this study are gathered from various references such as journals, published reports, and newspaper. By the literature survey and interview methods, the rice grain yield and nitrogen use efficiency were increased significantly after applying slow-released fertilizer added nano-carbon. These results suggest that it is possible to use nano-carbon as coating material for slow-released fertilizer.

Keywords: nano coated slow-released fertilizer, Nitrogen loss, rice grain yield

1 INTRODUCTION

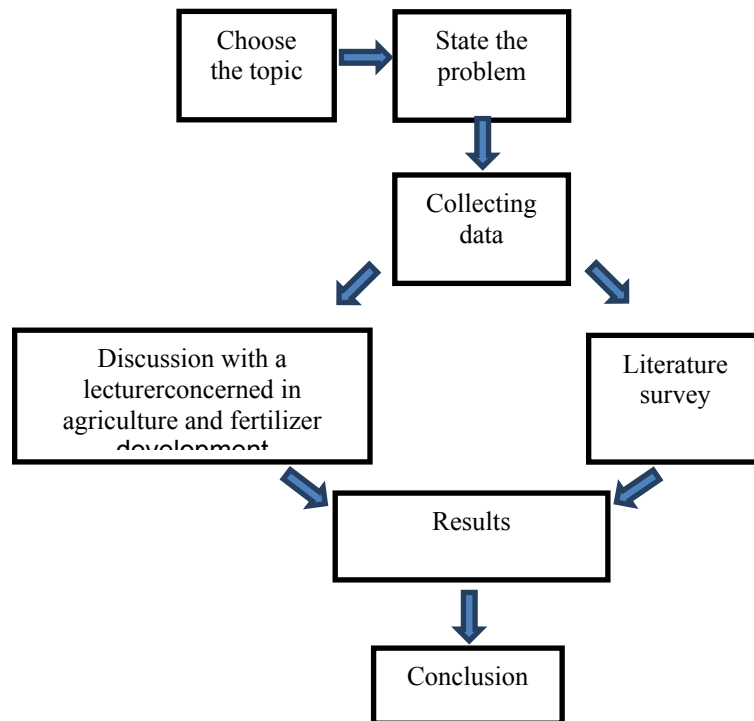
Indonesia is an agricultural country with most of its population working as a farmer. According to the government, Indonesia has agricultural land as much as 40.7 million hectares or 22 per cent of the total land area. But even so Indonesian farmers are still not able to satisfy Indonesian rice consumption. It is considered as most local farmers are still applying the traditional methods in producing rice. Indonesian rice cultivation has been traditionally concerned in obtaining either maximum yield or high quality, or both to satisfy national rice consumption. These goals have been reached by applying fertilizers well in excess of paddy nutrient requirements. Fertilizer is one of the important factors for agricultural production. The existence of fertilizer in terms of quantity, type, quality, price, place, and time will determine the quantity and quality of agricultural products produced. Fertilizer can also donate 20% of the success of increasing agricultural production, agricultural products including rice self-sufficiency in 1984. Besides that, the agricultural sector until now sustained by inorganic fertilizer consumption increased from time to time in line with the more expensive organic fertilizer (Setneg, 2009). Inorganic fertilizer consumption is greatest during the urea fertilizer, with an average consumption rate of 71% from 1995 to 2003 (Fertilizer Handbook 2003 cited by Wirjodirdjo et al). Fertilizers are, as a rule, not fully utilized by the crop with much of the fertilizer material being lost to the soil environment and the atmosphere. This occurrence is encountered practically with all fertilizers and is particularly pronounced with nitrogen-based fertilizers. The main reason for this deficiency is the very water solubility of the fertilizer a result of

which undesired dissipation of the fertilizer by drainage, its consumption or decomposition by microbes and losses to the atmosphere in form of NH_3 , N_2O , NO and NO_2 , compete with the root uptake thereof (Gordonov et al, 1995).

It has been considered to overcome this problem by means of slow-released fertilizer which is a new trend to save fertilizer consumption, and to minimize environmental pollution especially in Indonesia. There are two main types of fertilizer: Fast-release fertilizer and slow-release fertilizer. Fast-release fertilizer is a method that most Indonesian farmers have been traditionally used for farming. Fast-release fertilizer can share their nutrients immediately to plants but if they are applied too heavily, the plant can be damaged usually by burning. Not only that, but the nutrients can leach out and hurt the water supply. Slow-release fertilizers are coated in time-release shells that slowly leech nutrients into the soil. There are several benefits of slow-release nitrogen in fertilizers. They provide more uniform grass growth. They are less likely to burn the lawn or other plants. They can last 6 to 8 weeks or longer so they don't need to be applied as frequently as fertilizers with quick-release nitrogen. Coated fertilizers (typically in pellet form) depend on soil moisture and temperature to release nutrients. Nutrients are released over a period of time, some lasting up to 12 months, so fewer applications are needed. They provide good color without excessive leaf growth. During the last three decades, many coated fertilizers have been developed for agricultural and horticultural crops. These products are generally referred to as Controlled-Release Fertilizers (CRF) or Slow-Released Fertilizers (SRF) due to their unique characteristics of nutrient release over an extended period. The slow-released fertilizer and controlled release fertilizers are made to release their nutrient contents gradually and to coincide with the nutrient requirement of a plant. These fertilizers can be physically prepared by coating granules of conventional fertilizers with various materials that reduce their dissolution rate (Ge et al., 2002; Shavit et al., 2002). So, nutrient uptake efficiency is greater and leaching losses are lower for CRF products as compared to readily available forms of fertilizers (Douand Alva, 1998). The release and dissolution rates of water soluble fertilizers depend on the coating materials. This brings out the idea of developing the entrapped within nano-materials (Teodorescu et al., 2009). Consequently, the fertilizers are protected by the nano materials for better survival in inoculated soils, allowing for their controlled release into the soil (Saigusa, 2000). This study aims to identify the influence of slow-released fertilizer coated by nano-carbon material on rice yield and nitrogen loss in surface water of paddy soil. This research questions about how can a slow-release fertilizer coated by nano-carbon affect rice yield and reduce nitrogen loss into environment.

2 RESEARCH METHODS

This research was conducted through comprehensive literature survey method. The survey examine the technical literature back to the earliest dates available on the topic of using nano-carbon as coating material of slow-released fertilizer and its influences to improve rice yield and to reduce nitrogen loss in surface water of paddy soil. The specific terms searched were “nano-carbon,” “slow-released fertilizer,” or “rice cultivation.” Besides that, we also gathered some information about the topic from a lecturer of Faculty of Agriculture, Sriwijaya University. The stages of research were expressed in diagram below:



Description:

1. We choose the topic based on the national issues which still happen for over years. In this case we choose the agricultural sector.
2. Indonesian rice production is inadequate to satisfy national rice consumption.
3. After the problem has been stated, we gathered some data related to the topic and the problem from various sources i.e. digital newspaper, articles, journal and other media.
4. Research was conducted through literature survey and interview with a lecturer who ever conducted research about fertilizer and concerned in fertilizer development. In the interview section, we were also invited to the fertilizer production area and practiced about how to produce fertilizer with assistants.
5. The literature survey examine the technical literature back to the earliest dates available on the topic of using nano-carbon as coating material of slow-released fertilizer and its influences to improve rice yield and to reduce nitrogen loss in surface water of paddy soil. The specific terms searched were “nano-carbon,” “slow-released fertilizer,” or “rice cultivation.”
6. Explaining the results of literature survey and interview related to the topic.
7. Conclude the results whether it is possible or not to be applied in Indonesia in increasing national rice yield and reducing nitrogen loss on the surface water of paddy soil.

3 RESULTS

A. Literature Review Results

Total nitrogen concentration in surface water of paddy soil: In the experiment, total nitrogen concentration in surface water of paddy soil after applying slow-released fertilizer incorporated nano carbon is shown in Fig. 1.

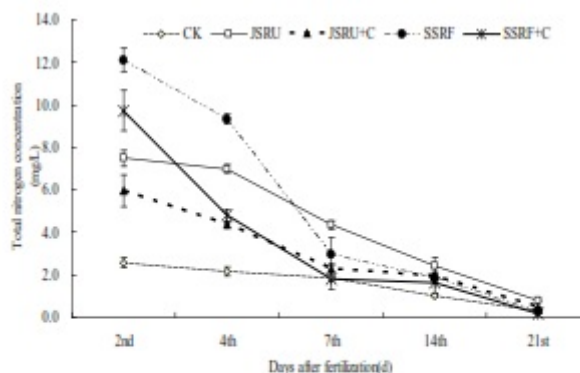


Fig. 1: Total nitrogen concentration in surface water of paddy soil in different kinds of fertilizer treatment

The results indicated that total nitrogen concentration was increased rapidly at the 2nd day (June 7) after fertilizer application, subsequently decreased gradually. Compared with JSRU, total nitrogen concentration under JSRU+C treatment was significantly reduced by 20.4, 37.6, 46.8 and 19.1%, at the second, 4th, 7th, 14th and 21 day ($p < 0.05$), respectively. Similarly, under SSRF+C treatment, total nitrogen concentration in surface water of paddy soil was significantly decreased by 19.6, 48.6, 39.0 and 12.1% compared with SSRF, respectively.

N loss caused by rainfall and draining for sunning the fields: As noted earlier, there were four times rainfall above 40 mm and N loss happened at the first three times. For SSRF, total nitrogen concentration was higher than JSRU that resulted from the faster N released rate from the third to fourth day after fertilization and the flux of nitrogen runoff was increased significantly by 28.2% after the first rainfall compared with JSRU. With the growth of rice, nitrogen in JSRU was released gradually. So, the flux of nitrogen loss for JSRU was higher than SSRF from the second rainfall. From total nitrogen runoff, there was no significant difference between JSRU and SSRF. However, the flux of total nitrogen in surface water of paddy soil after applying slow-released fertilizer incorporated nano-carbon was decreased significantly by 38.4% for JSRU+C compared with JSRU and 37.4% for SSRF+C compared with SSRF. The main reason for N loss is rainfall and sunning the fields during the growth period of rice. In order to inhibit the excess tillers during the experiment, sunning the fields was conducted one time by draining; therefore, nitrogen loss was inevitable.

From the data, less nitrogen was run off because sunning the fields was done for a long time after fertilization. For JSRU+C, JSRU, SSRF+C and SSRF treatment, the flux of N loss was 0.20, 0.55, 0.03 and 0.06 kg/hm, respectively. N loss was decreased by 63.6% for JSRU+C compared with JSRU and 50.0% for SSRF+C compared with SSRF. This result suggested that N loss caused by draining for sunning the fields was reduced because of nano-carbon application.

Grain yield and nitrogen agronomic utilization efficiency: Grain yield and nitrogen agronomic utilization efficiency in different kinds of fertilizer treatment is shown in Table 5. The results indicated that grain yield was improved significantly after applying slow-released fertilizer compared with CK. For JSRU+C and SSRF+C treatments, grain yield was increased by 11.3 and 5.6% compared to JSRU and SSRF, respectively. And ratio of saving nitrogen of per 1kg rice grain was increased by 10.1% for JSRU+C compared to JSRU and 5.3% for SSRF+C compared to SSRF. In other words, applying slow-released fertilizer incorporated nano-carbon was benefit for improving the grain yield and saving nitrogen and JSRU+C was better than SSRF+C, which may be related to the synchronization of nutrient released characteristics for JSRU+C and crop require. Table 5 presents the effects of applying slow-released

fertilizer on nitrogen agronomic utilization efficiency of rice. The results also showed that nitrogen agronomic utilization efficiency was 21.4 kg/kg N for JSRU+C and 18.4 kg/kg N for SSRF+C, which was increased by 7.9 kg/kg N compared to JSRU and 4.4 kg/kg N compared to SSRF, respectively. This suggests that it is a trend for adding nano-carbon into slow-released fertilizer.

B. Interview Results

Dr. Leon Susanto, Head of Soil Department Sriwijaya University, said that fertilizer is classified into two parts. They are organic and inorganic fertilizer. Nowadays inorganic fertilizer is widely used by Indonesian farmers but it remains some environmental and economic problems. The excessive use of inorganic fertilizer has turned Indonesian soil to a higher level of toxicity. Plants have become dwarfed and other problems. In short he said that Indonesia will dominate AEC or AFTA in agriculture sector if we could solve some lacks due to the problems either in organic or inorganic use of fertilizer. When AFTA come in 2015, fertilizer using cheap technology and potentially one of the technologies used is Nano Technology will reduce a lot of negative impacts to the environment. Otherwise, Dr. Mulyana Ahmad as CEO Nano Inti Tech Indonesia told us about the revolution of fertilizer in the world. The revolution of fertilizer in agriculture begin with the Haber and Bosch discovery in urea synthesis by means of nitrogen fixation from the air with hydrogen gas from methane. After walking a few decades, it is known that nitrogen fixation in this manner contributes to environmental degradation. Conversion of methane gas to produce hydrogen gas CO₂ in large quantities. Each kg of fertilizer urea produces 1.5kg of CO₂ gas. 150 million tons of urea is produced every year or equivalent to 225 million tons of CO₂ released in to air. And finally we have found the solution to use nano technology with nano catalyst. That is related by the literature survey and interview methods, the rice grain yield and nitrogen use efficiency were increased significantly after applying slow-released fertilizer added by nano-carbon.

4 DISCUSSION

N runoff loss for farmland both affects the improvement of the nitrogen utilization efficiency, but also brings about the pollution of water body. In this experiment, total nitrogen concentration in surface water of paddy soil was increased rapidly at the 2 day after applying slow-released fertilizer, subsequently decreased gradually and also reported by Qiu *et al.* (2004). According to Xiao *et al.* (2008), NO-N leaching was decreased by applying slow-released fertilizer coated with nano-materials in the rotation of wheat-maize. In our experiment, total nitrogen concentration in surface water of paddy soil was declined from 19.1 to 46.8% for JSRU+C and from 12.1 to 48.6% for SSRF+C; the average was 31.0 and 29.8%, respectively. The results also showed that the time of N loss caused by rainfall was shorten 2.2 days for JSRU+C compared with JSRU and 1.8 days for SSRF+C compared with SSRF. That is, N runoff loss could be reduced by applying slow-released fertilizer incorporated nano-carbon when it was rain before the threshold of safe drainage. As we estimated, total nitrogen runoff loss was decreased by 38.4% for JSRU+C compared to JSRU and 37.4% for SSRF+C compared to SSRF. The result suggests that it is a new trend adding nano-carbon into slow-released fertilizer. The mechanism needs to further research. Liu *et al.* (2008b, c, 2009) indicated that grain yields of rice, spring maize, soybean, winter wheat and vegetables were increased by 10.29, 10.93-16.74, 28.81 and 12.34-19.76% after applying fertilizer adding nanomaterials. As reported by Liu *et al.* (2007), nanomaterials could promote germination and rooting early for rice seeds and seedlings and the growth of rice at tillering stage was affected obviously by nanocomposites. Our results indicated that SPAD value of rice leaves at booting stage, the grain yield and nitrogen agronomic utilization efficiency was increased after applying slow-released fertilizer incorporated nanocarbon and ratio of saving nitrogen of per 1 kg rice grain was increased by 10.1% for JSRU+C compared to JSRU and 5.3% for SSRF+C compared to SSRF.

The possible reasons are: As a low-lighted and non-conductive modified carbon, nano-carbon could detach N from NH and thus H⁺ was released, which promoted the plant to absorb the water of soil and the nutrients in water and improve the photosynthesis. In the soil, HCO₃⁻ is one of ion adjusting the balance between anion and cation, which is absorbed directly by plant root and promotes the photosynthesis of leaves. EC value of the soil is improved by 30% when nanocarbon dissolved in the soil water, which promoted the composition of HCO₃⁻. N, P and K are flowed into the plant and transformed into starches and proteins with absorbing HCO₃⁻ in plant root. So, nano-carbon is considered the biological pump for

the plants to absorb nutrients and water (Ma *et al.*, 2009). As reported by Liu and Liao (2008a), the activity of water after adding nano-materials was increased and N, P and K were absorbed into the plants with the absorbing of water, thus the production was also increased. From the experiment, total nitrogen concentration in surface water of paddy soil was increased rapidly at the 2nd day after applying slow-released fertilizer, subsequently decreased gradually. The time of N loss caused by rainfall was shortened 2.2 days for JSRU+C compared with JSRU and 1.8 days for SSRF+C compared with SSRF. The results also showed that SPAD value of rice leaves at booting stage, the grain yield and nitrogen agronomic utilization efficiency was increased after applying slow-released fertilizer incorporated nano-carbon and JSRU+C was better than SSRF+C.

5 CONCLUSIONS

From the explanation above, we can conclude that it is possible to apply slow release fertilizer coated by nano carbon in Indonesian soil. By the survey, it was indicated that grain yields of rice was increased after applying fertilizer adding nanomaterials. It was also found that the use of slow release fertilizer with nanomaterials subsequently decreased total nitrogen concentration in surface water of paddy soil after the 2nd day applying slow-released fertilizer.

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