Smart agriculture practice for intensively rice cultivation in both irrigated and rainfed rice field

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Abstract. A smart agricultural practice called Panca Kelola Ramli has been developing by the Indonesian Agricultural Environment Research Institute (IAERI). The smart practise was applied in intensively rice cultivation both in irrigated and rainfed rice field in Pati District, Central Java Province, Indonesia. The objective of the study was to identify plant performing and rice productivity both in irrigated and rainfed rice field. Five components of Panca Kelola Ramli consisted of high yielding rice varieties, Urea coated by biochar (UBICHAR), biochar-compost, integrated pest and disease management and also water management. In the rainfed rice field, the Panca kelola ramli was applied and modified to four treatments consisted of biochar-compost + UBICHAR, compost + UBICHAR, biochar-compost + Urea and compost + Urea. The observation was carried on methane emission, plant growth and rice yield. The study showed that methane emission, number of tillering, plant height and rice yield in irrigated rice fields were 172.13 kg ha\(^{-1}\), 14 tillers, 94.75 cm and 6.0 t ha\(^{-1}\), respectively. While in the rainfed rice field, the plant parameters vary among the treatments. The highest rice grain was produced by the treatment of compost + UBICHAR which was supported by the highest root weight. The Panca Kelola Ramli in irrigated rice field could reduce Urea and chemical pesticide use.

1. Introduction

Nitrogen (N) is the most important component of rice cultivation. It is provided to support the photosynthetic process to chlorophyll production. Plants absorb N both as a mineral nutrient from soil and ammonium (NH\(_4^+\)) and nitrate (NO\(_3^-\)) which can be supplied from Urea. Almost of Indonesian farmers have been using chemical fertilizer to supply N for rice paddy. According to Asosiasi Produsen Pupuk Indonesia (APPI) from January to June of 2020, there was more than 2.9 million t y\(^{-1}\) of total domestic Urea consumption in Indonesia which was divided into three classes of consumption as agriculture, estate crops and industry. The dominated consumption was from agriculture practices [1].

In rice cultivation, a large amount of nitrogen was required for rice growth, development and grain production. Unfortunately, because the primary supply N in the soil is often limited, the farmer increases the amount of chemical fertilizer to accomplish higher rice yield. Increasing N fertilizer led over-fertilization which contributes to environmental pollution. Therefore, the N-losses method should be implemented not only to reduce the negative impact but also to increase rice production.

The organic amendment is one of the methods to enhance N use efficiency. The application of organic amendments in combination with N fertilizer could also produce the highest yield [2]. Farmyard manure combined with corn cob biochar improved productivity of rice significantly ranged 8 to 26% [3].
Indonesian Agricultural Environment Research Institute (IAERI), one of technical institutes under the Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture (MoA) Indonesia, has been developing a method called “Panca Kelola Ramah Lingkungan” (Panca Kelola Ramli)-Five environmentally friendly management. The component of the method was collected from separately previous research studies. The component includes biochar, compost, and Urea coated by biochar (UBICCHAR). Some studies showed that both biochar and compost provided a positive impact on soil and plant yield [4-7].

The application of biochar combined with chemical fertilizer could enhance N availability to plants and crop yields, instead could reduce N$_2$O emissions [4]. Biochar could improve N uptake and utilization by plants [5], increase paddy soil fertility and grain yield, and also reduce endosulfan residue [6]. Biochar-compost provides multiple advantages including improving compost performance and enhancing activities of the microbe and also reducing GHGs and NH$_4$ emissions [7].

Five components of the Panca Kelola Ramli is expected could increase N efficiency by reducing N-losses. For the first step, the plant performing should be an observed important parameter to support the plant yielding. Therefore, the objective of this study was to identify plant performing and rice productivity both in an irrigated and rainfed rice field.

2. Materials and methods

2.1. Study site

The study was conducted in two locations for representing the condition of both irrigated and rainfed rice fields (figure 1). The first study site was a farmer field located at Wotan, sub-district of Sukolilo, district of Pati, Central Java. The location lies between 110°90’ E and 06°91’ S. The farmer field has received water through a small channel regularly based on the schedule of irrigation. The second study site was the research station of the Indonesian Agricultural Environment Research Institute, located at Sidomukti, sub-district of Jaken, district of Pati, Central Java. The location lies between 111°10’ E and 06°45’S (figure 2). The source of water irrigation in the research station was from rainfall collected in water harvesting during the rainy season.
2.2. Materials and Methods
The study was a part of IAERI’s dissemination activities to evaluate the application of the Panca Kelola Ramli in cooperative farmer field particularly in the irrigated rice field. Five components of Panca Kelola Ramli were applied in the farmer field. It consisted of 1) High-yield rice variety, 2) Biochar-compost, 3) Urea coated by biochar, 4) Integrated pest and disease management, and 5) Water management. Around 1 ha of rice field was cultivated using **jajar legowo** planting technique. The Panca Kelola Ramli was also applied in the research station but we modified the treatments of biochar-compost application. The four modifications were 1) Biochar - compost + Urea coated by biochar (UBICHAR), 2) Compost + UBICHAR, 3) Biochar-compost + Urea, and 4) Compost + Urea (table 1).

| Table 1. Components of the Panca Kelola Ramli both in irrigated and rainfed rice field |
|---------------------------------|---------------------------------|
| Irrigated rice field | Rainfed rice field |
| 1. High yielding rice variety | 1. High yielding rice variety |
| 2. Biochar-compost | - Biochar-compost+UBICHAR |
| | - Biochar-compost+Urea |
| | - Compost+UBICHAR |
| | - Compost+Urea |
| 3. Urea coated by biochar (UBICHAR) | 2. Urea coated by biochar (UBICHAR) |
| 4. Integrated pest and disease crop management | 3. Integrated pest and disease crop management |
| 5. Water management | 4. Water management |

The doses of each component were 3 t ha⁻¹ (biochar-compost), 200 kg ha⁻¹ (UBICHAR) and 200 kg ha⁻¹ (single Urea). Other synthetic fertilizers such as KCl and SP-36 were also applied as much as 150 kg ha⁻¹ and 300 kg ha⁻¹, respectively. Measurement of plant parameters was conducted on plant height, the number of tillers, and harvest components.

Soil samples were analyzed for pH using the extract of double-distilled water; organic C using Walkey Black; total N content using Kjeldahl; available P using Olsen extract and available K using Morgan Wolf extract, at The Integrated Laboratory of Indonesian Agricultural Environment Research Institute (IAERI).
3. Results and discussion
Soil type in location 1 was dominated by clay from alluvial sediment and received water irrigation from Jratunseluna channel [8]. The Jratunseluna is a watershed in Central Java Province which consists of two main watersheds namely the Jratung watershed (Jrakah and Tuntang River) and the Seluna Watershed (Serang, Lusi and Juwana River). The tertiary channel connected the Jratunseluna with rice field area therefore the irrigation has been conducting regularly. The chemical properties of location 1 were characterized by low C organic and total N but high available P and K (table 2).

| Soil characteristic | Value |
|---------------------|-------|
| pH                  | 7.76  |
| Total N (%)         | 0.22  |
| C organic (%)       | 2.47  |
| Available P (ppm)   | 94.03 |
| Available K (ppm)   | 57.49 |

Chemical attributes of location 2 (before treatment) were characterized by low C organic content, low total N, total K and CEC (table 3) and it is categorized as Inceptisol and low chemical fertility status [9].

| Soil characteristic | Value |
|---------------------|-------|
| pH                  | 5.96  |
| Total N (%)         | 0.42  |
| C organic (%)       | 1.24  |
| Available P (ppm)   | 34.69 |
| Available K (ppm)   | 9.17  |
| CEC (cmol(+))kg⁻¹   | 6.15  |

3.1. Plant parameter
Measurement of plant height and number of tillering in Location 1 was carried out five times on 14, 28, 45, 60 and 77 days after transplanting. The plant height was reported as 43.75, 56.13, 79.38, 94.00 and 94.75 cm, respectively. While the number of tillering was 8, 19,14,14,14 tiller, respectively. The plant height and number of tillering at Location 2 was shown in table 4.

| Treatment | 30  | 51  | 66  | 73  | 103 | 30  | 51  | 66  | 73  | 103 |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Day after Transplanting |
| 1         | 31.9| 52.6| 84.1| 99.0| 108.9| 13  | 20  | 25  | 21  | 17  |
| 2         | 32.1| 56.1| 84.8| 97.3| 108.9| 10  | 22  | 24  | 20  | 15  |
| 3         | 33.4| 53.6| 88.1| 99.8| 110.5| 9   | 22  | 27  | 21  | 19  |
| 4         | 33.5| 52.8| 85.0| 98.1| 103.1| 9   | 24  | 30  | 24  | 20  |

The application of biochar – compost + Urea (3) showed the highest plant height as 110.5 cm, biochar – compost + UBICHIAR (1) and compost + UBICHIAR (2) produced the same plant height as 108.9 cm. While the compost + Urea (4) treatment showed the lowest high of plant as 103.1 cm. Treatment 1 led
tiller production in the early vegetative phase (15 day after transplanting per DAT) until maximum tillering phase (43 DAT) but only 17 tillering remain in the effective tillering phase. This pattern was similar found in Treatment 2. Both the treatment 3 and 4 showed sharply increasing number of tillering in 29 DAT and the peak of number tillering were 27 and 30 tillers, respectively. Treatment 4 showed the highest number of tillering followed by Treatment 3.

Weight of straw, panicle and root per hill were presented in Table 5. The highest weight of straw was produced by Treatment 4 (59.0 g), followed by Treatment 1 (54.2 g), 2 (53.5 g) and 3 (49.4 g). The highest weight was also produced by Treatment 4 (62.3 g). While the highest weight of root was from Treatment 2 (28.4 g).

| Treatment | Straw (g) | Panicle (g) | Root (g) |
|-----------|-----------|-------------|----------|
| 1         | 54.2      | 57.2        | 27.7     |
| 2         | 53.5      | 61.6        | 28.4     |
| 3         | 49.4      | 48.8        | 23.0     |
| 4         | 59.0      | 62.3        | 26.7     |

3.2. Rice yield

Grain yield components were taken from five sample points in Location 1. Panicle length was ranged 21 to 24 cm, around 13% of rice grain was unfilled grain and more than 86% was filled grain. Rice yield from this location reached 6 t ha\(^{-1}\).

Components of grain yield from Location 2 were presented in Table 6. Treatment 1 showed the highest panicle length and weight and also both filled and unfilled grain. The 1000 grain weight was 26 g and the grain yield was 4.25 t ha\(^{-1}\). Treatment 2 and 3 showed the closed result on the length and weight of panicle, filled and unfilled grain. Both treatments 1 and 2 produced a lower value of grain yield components. But treatment 2 produced the highest of 1,000 grain weight which contributes to the highest grain yield (4.60 t ha\(^{-1}\)). Treatment 4 produced higher panicle length and weight than Treatment 2 and Treatment 1. The grain yield of Treatment 4 was 4.30 t ha\(^{-1}\). The weight of root was positively correlated to the rice yield on both biochar treatment (\(r^2= 0.519\)) and compost treatment (\(r^2= 0.335\)).

| Treatment | Panicle length (cm) | Panicle weight (g) | Grain unfilled | Grain filled | 1,000 grain weight (g) | Grain yield (t ha\(^{-1}\)) |
|-----------|---------------------|-------------------|---------------|-------------|------------------------|--------------------------|
| 1         | 21.33               | 3.07              | 18            | 102         | 26.00                  | 4.25                     |
| 2         | 19.83               | 2.29              | 15            | 74          | 27.35                  | 4.60                     |
| 3         | 19.99               | 2.43              | 14            | 81          | 25.90                  | 3.80                     |
| 4         | 21.15               | 2.57              | 17            | 85          | 26.45                  | 4.30                     |

3.3. Methane emission

The measurement of methane emissions was only conducted at Location 2. The sampling of gases was taken at 24, 42, 52, 70 and 80 DAT which covered three rice growth phases (vegetative early and maximum tillering, generative and before harvest time). The average of pH and soil temperature during the observation were 7.31 and 34.5°C, respectively. Rice cultivation using the *Panca Kelola Ramli* produced 172.3 kg ha per season.

3.4. Discussion
Alluvial sediment and regular water irrigation supported rice cultivation in Location 1. Generally, alluvial soils show better chemical properties which affected by accumulated materials during soil formation. The availability of macro and micro nutrients from alluvial sediment contribute to rice growing. A better rice yield could be reached through better crops management, particularly from fertilizer application [10]. Base on a direct interview with the farmer, the average grain yield produced by the cooperative farmer in the previous rice season-without the treatment- was around 6 to 7 t ha\(^{-1}\), depending on rice variety. Application of the Panca Kelola Ramli in the farmer field reduced both Urea and chemical pesticide use without decreased grain yield. The conventional practice of rice cultivation required four times or more Urea use but the Panca Kelola Ramli was only need three applications of Urea (in form of UBICHAR) based on the LCC (leaf colour card).

In Location 2, biochar application showed a good performance on agronomical traits both in Treatment of Biochar - compost + UBICHAR and Biochar - compost + Urea. Application of biochar to soil could improve N utilization, available N was converted to grain yield and enhanced crop performance [4]. Biochar affected height of the paddy [11,12] and increased linearly from 50 DAT until 90 DAT [11]. Positive effects of biochar on rice growth were caused by nutrients directly supplied by biochar [13]. Application of biochar - based compound fertilizer (BCF) to soil increased dry plant biomass and plant N, P, K. Interaction biochar and rhizoplane took a part to supply the ion potential and improved macronutrient uptake [14]. Another finding was that the application of rice straw biochar showed positive effects on rice yield and stem height as resulted in available nutrition for rice plant. Biochar could increase nutrient uptake which useful for plant growth [13].

Biochar application could also reduce methane emission. The combination of biochar and slow-release fertilizer produced the lowest methane emission but it had the highest rice yield compared to Urea use only and a combination of Urea and biochar. Increasing soil aeration and oxygen availability due to biochar application could obstruct methanogenesis process. Decreasing plant biomass as a result of slow-release fertilizer application also contributed to decrease in methane production [15]. Annual fresh biochar application promoted methanotrophs [16] and increased biodiversity and abundance of methanotrophic microbes that leading the methane reduction rate [17]. Biochar also takes a part in \(N_2O\) emission reduction. Amendments of biochar in N-treated soils decreased both the daily and total seasonal \(N_2O-N\) emission [18].

Interestingly, the application of compost + UBICHAR (Treatment 2) showed the highest of grain yield. It might be supported by root activities which supplied available nutrient from the soil. The application of organic materials such as livestock manure and crop residue could enhance soil productivity and crop performance [19]. The lower grain yield of biochar treatment might be contributed by poor distribution of assimilating to the grain.

4. Conclusions
Organic materials both in biochar and compost could be applied as a soil amendment to provide a better crop performance. A combination of compost and UBICHAR showed the highest rice yield in a rainfed rice field. The Panca Kelola Ramli in irrigated rice fields could reduce Urea and chemical pesticide use.

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