

Direct seeding rice: A solution to improve establishment of rice under unpredictable climate condition

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Abstract. Swampy is identified as a potential areas to boost national rice production, however, Fe exposure and lack of labour are some of main obstacles to get high yield of rice. Specific land preparation, puddling and levelling without exposing active Fe is required to maintain high yield. A field experiment aims to examine the effectiveness of perfect land levelling to increase yield under direct seeding method. The trial was arranged in large areas, each treatment was set in 0.5 ha, with 5 replications in 2021 dry-season in Central Kalimantan. The treatments were combination of land preparation and establishment system with direct seeding rice (DSR) or transplanting (TRP). The results showed that land levelling used the farming bulldozer improved the number of productive tillers lead to higher grain yield compare to that of hand tractor. Highest grain yield was produced in FB-TRP (land preparation done by Farming Bulldozer in combination with transplanting) at average 3326 kg/ha, followed by HT-TRP (Hand Tractor-Transplanting) at 3064 kg/ha. Whereas FB-DSR yielded at 2146 and FB-TRP at 1778 kg/ha. Good land levelling had greater effect on the seed germination and increase the number of tiller by 17.6% under direct seeding with farming bulldozer compare to hand tractor.

1 Introduction

Manual transplanting is the most popular crop establishment method of rice in Indonesia, particularly in Java Island. Rice seed is sowed in a nursery and transplanted at the field at about 21 days after sowing (DAS). Transplanting could be successfully done even the field is not levelled adequately and has several water level. More importantly, 21 DAS seedlings have a head start over emerging weeds [1]. Transplanting is practiced to get a uniform standing crop to ensure high yield with less weed problem, however, manual transplanting demands more labor and time consuming. Recently, majority of rice producing areas in

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Indonesia are lack of agricultural labour due to high economic growth [2]. Therefore, manual transplanting often resulted in delayed planting time. It's difficult to get enough daily workers at peak period of planting time. Moreover, contract transplanting may lead to low plant density because of too wide plant spacing, such as 30 x 30 cm.

Java has an important role in rice supply, however Java also renowned as the most densely populated island where 60% of the population lives in Indonesia [3] [4]. Due to its massive population, some limiting factors such as land conversion from agricultural sector to other usages such as housing and industrial sectors became serious problem. [5] Estimated about 30,000 to 50,000 ha of rice field has been converted per year. In Java alone, over 63,000 ha of agricultural land have been converted every year. Therefore, Indonesian Government identifies avenues to boost national rice production by intensifying sub-optimal lands such as swampy areas outside Java. Started in early 2020 until 2022, Government designates a food estate under swampy area in Central Kalimantan province to become a national rice barn.

Establishing rice cultivation in swampy area in Central Kalimantan could be one of the solutions to maintain rice self-sufficiency and population problem, however, Fe toxicity could be the common problem occurs in those area [6] [7]. Swamp is basically soil in mud form where characteristically flooded for a long period. The swampy area with Fe problem is dominantly distributed in Central Kalimantan. Thus, specific land preparation, puddling and levelling without exposing active Fe (reducible Fe) is required. Iron-toxicity is occurred when a large amount of Pyrite (FeS₂) [8] is mobilized in soil solution and being absorbed by rice plant, generally Iron is exposed to soil surface due to deep land preparation. The absorption of another nutrients particularly Phosphorus and Potassium is also affected by the high concentrations of Fe in soil solution [6]

Perfect levelling as the final result of land preparation without exposing Fe to soil surface is crucial to ensure good performance and yield of rice at swampy area. Moreover, levelling plays important role in facilitating easy seedling establishment under direct seeded method [9] [10]. Direct seeding method is suitable for rice production areas where farmers have large paddy field and lack of daily labour in agriculture [11] [12]. Farmers in Central Kalimantan generally have been shifting from transplanting method to direct seeding due to the scarce of daily labour. DSR method at Central Kalimantan required only 1 farmer to sow for approximately 3 hours per ha. It cost only 300 thousands Rupiah, lots cheaper compare to transplanting. DSR therefore has evolves to be the cheap, low cost alternative method of crop establishment. Furthermore, some studies showed that direct seeding method resulted in high yield, does not significantly different compare to transplanting [14].

Major challenges of direct seeding method particularly in swampy area are preparing soil, weed infestation which may lead to large yield losses, as well as crop lodging due to high density of rice hills [15] [16]. Although DSR likely will be popular crop establishment in the future, but DSR also has potential problem especially when applied during rainy season. Direct Seeding (broadcasting) method had limitation in placing the seed accurately [17]. The rainfall may move the rice seeds from its position.

2 Material and Method

A field experiment was carried out in the 2021 dy-season at swampy area in Blantisiam, Pulang Pisau, Central Kalimantan. The study was arranged in a large area, each treatment was set in 0.5 ha, with 4 major treatment as listed in Table 1.

Table 1. The treatments consisted of combination of different land preparation and planting system, Blantisiam – Central Kalimantan, 2021

No	Land Preparation	Planting System
T1	Farming Bulldozer D21PL-8 (FB)	Direct Seeding (DS)
T2	Farming Bulldozer D21PL-8 (FB)	Transplanting (TRP)
T3	Hand Tractor (HT)	Direct Seeding (DS)
T4	Hand Tractor (HT)	Transplanting (TRP)

Rice variety, Inpari 42 variety which tolerant to Fe was planted. Land preparation was done as treatment using Farming Bulldozer D21PL-8 (FB) and hand tractor (HT) as control existing condition. Herbicide was applied 3 days prior to the first land preparation, both in FB and HT due to high weeds infestation. Herbicide, with active ingredient glyphosate, was sprayed to clear weeds and avoid slip on the hand tractor or land preparation machine. The paddy field before land preparation and after herbicide application were shown in Figure 1. Furthermore, dolomite was applied at total dosage of 2 tons per ha before levelling (final land preparation). At the beginning of crop-establishment. Weeds were controlled manually at the age of 21 and 35 days after sowing. Pests and diseases are prevented by giving carbofuran using a 20 kg / ha, while the recommended use of insecticides is in accordance with the target pests and diseases

Soil sample was collected after land preparation. Samples were collected at 12 points at the depth of 20 cm in a zig-zag pattern. Another data variables included plant height and number of standing crop per m², namely the average number of tillers from (1mx1m) or 1m² randomly selected sample hills. Observations were made at the age of 14 DAS, 28 DAS, and 42 DAS and before harvest. While yield components were measured from (1m x1m) or 1 m² of sample plants taken randomly. Moreover, samples of yield (GY t/ha) were taken from 2.5 x 2.5 m in size as many as 5 replications per treatment.

3 Results and Discussion

3.1. Soil Characteristic

The main character of swampy soil at Blantisiam was acidity. Swampy areas have highly fragile; as such their intensive use or recklessly land clearing which created many problems, particularly acidification (at location of experiment – Blantisiam was grouped as acid, with pH (H₂O) averaged at 4.2. This condition elevated levels of toxic elements especially Iron (Fe). The soil is a silky clay loam, with the proportion of sand was 5%, Silt 60% and clay 35%. C-organic was categorized as very high at 8.6%. Whereas the total Nitrogen was very low at 0.53%. The organic matter of the soil at experimental site was unfavourable (very high) for rice. While the available P (Olsen P Method) was significantly low inclusive at 9.0 ppm, in contrast the available Potassium K content is around 0.40 cmol.kg-1 (very high), Ca 0.47 cmol.kg-1 (low), and Mg 0.78 cmol.kg-1 (very high). Moreover, cation exchange capacity also low at 12.61 cmol/kg

3.2. Soil Preparation

Land preparation of rice field at swampy area (at Blantisiam) was significantly different with the land preparation of the rice field in mineral soils (at Majority irrigated rice in Java). Soil in Blantisiam was soft and wet (could not be drain). Before they start the planting season, paddy field was left, without any plant as long fallow period for more than 3 months. During

the fallow period, the growth of weeds was accelerated due to wet condition at field. As results, infestation of weeds was tight and high when we start the land preparation (Figure 1). Beside the physical condition of the soil, Fe toxicity was also the main problem in swampy area. Swampy at the location of experiment was grouped as swampy Type A, which has a layer of pyrite (or Fe) at depth ≤ 50 cm. Pyrite layer is a layer or layers of sulfidic soil levels > 2 percent. Sulfuric horizon is a layer that shows the brown layer or pyrite oxidation.

Deep puddling may have resulted in pyrite oxidation which identified by the bronzing (brown colour on top of soil – or on the surface of water above soil surface at paddy field. At swampy area where Iron toxicity was main problem to grow rice, land preparation was done by minimizing soil disturbed. In aerobic conditions, pyrite will react with oxygen to form Fe^{3+} and SO_4^{2-} causes decreasing soil pH and be toxic to plants. There were two types of land preparation done in this experiment. The first one was done by farming bulldozer, and another land preparation using hand tractor.

The massive growth of weeds at wet-swampy area was one of the reason of difficulty of land preparation. Minimum land preparation may necessary to minimize the possibility of Pyrite exposure, however, weeds massively cover the soil surface, therefore puddling was required. Land preparation was effectively to turn over soil and cut weeds, thus recognized as weed control practice. Moreover, land preparation indirectly affects rice yield through resultant better field conditions. Also, good land preparation facilitates better water management and to a lesser extent fertilizer management in swampy rice production. Land preparation was a necessary key for successful wetland rice production.

3.3. Plant height

Plant height was significantly affected by the crop establishment, direct seeding rice and transplanting. The plant height data of comparison FB-DSR and HT-DSR treatments and FB-TRP and HT-TRP was presented in Figure 2. The two crop establishment showed strong difference in early growth. Seeds were raised in nursery for transplanting at high density and limited space, while seeds were directly grown at the field for DSR, without paused growth due to transplanting shock. At 7 DAS, the plant growth of FB-DSR treatment recorded height at 11.65 cm, as well as the HT-DSR reached height at averaged 10.05 cm. While at the nursery, seedling recorded height at 7.75 cm or reduced height by 33%. Based on the weekly data of plant height, at beginning Inpari 42 performed better under direct seeding, however, the highest plant height was recorded from FB-TRP and HT-TRP at 110 cm and 105 cm respectively at harvest time, both under transplanting treatments. The growth pattern of rice crop could be divided into maximum growth when vegetative growth was greatest and followed by a slowing down or plateau in growth. Transplanting had longer life duration for 10 days compare to direct seeding rice.

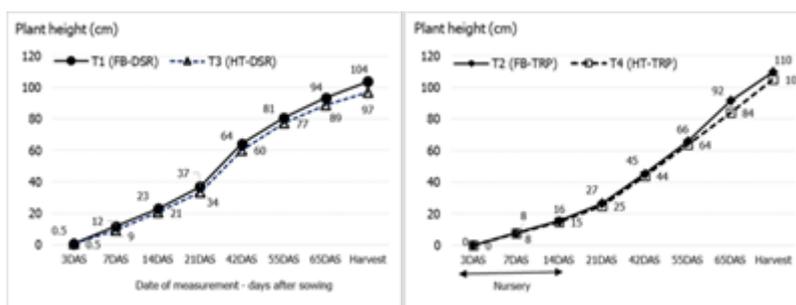


Figure 1. Comparison of plant height (cm) under 2 planting system and land preparation.

It is showed that there was a delay in plant's growth under transplanting, due to transplanting shocked. Therefore the direct seeding rice had speedy growth at the beginning of growth. The same trend occurred both under land preparation done by farming bulldozer as well as hand tractor. Final observation at harvest time showed that FB-TRP and HT-TRP recorded higher plant height compare to FB-DSR and HT-DSR due to longer life duration under transplanting.

3.4. The number of tiller (standing crop) per m²

The grain yield was directly influenced by the number of tiller (standing crop) per m². The method of establishment, direct seeding or transplanting was significantly affected the plant population. Plant population was defined as the total number of hills (productive tillers) present at unit area of land. The population of plant should not so much high that can drain out most of the moisture from the field before the crop reaches to maturity stage. As well as population should not too low that moisture remain unutilized. The yield of a crop is the end result of final plant population which is influenced by the number of viable seed germination and survival rate. Land levelling as the result of land preparation was significantly influenced the percentage of seed germination per m².

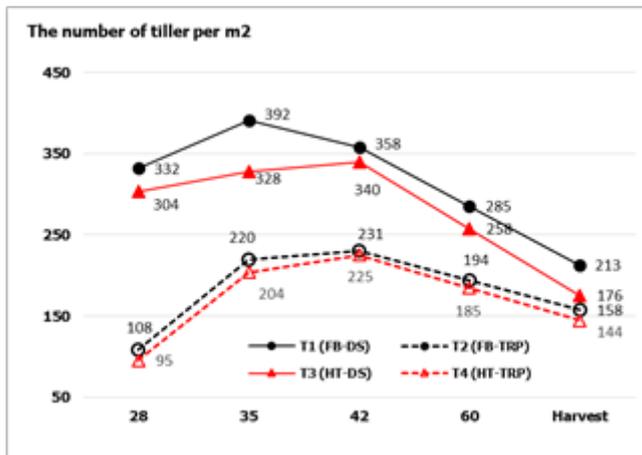


Figure 2. Comparison of the number of tiller per m² under direct seeding rice and transplanting with 2 different land preparation, Blantisiam Central Kalimantan, 2021.

The number of tiller per m² (NoT) was influenced by land preparation and the method of establishment – DSR (direct seeding rice) or TRP (transplanting). Direct seeding method showed significantly different in the number of tiller per m² compare to transplanting. The comparison of the number of tiller per m² under direct seeding rice and transplanting with 2 different land preparation is presented in Figure 6. In FB-DSR, the highest NoT was recorded at 332 and reached a peak at 392 at 28 and 35 DAS respectively. The NoT started to gradually decrease due to senescence at 358 (at 42 DAS), 285 at 60 DAT and final number of tiller at 213 at harvest. While under land preparation using hand tractor in combination with DSR, the NoT recorded at 304 (at 28 DAS), grew to 328 at 35 DAS and reached maximum tillering at 340 at 42 DAS. After flowering, the NoT started to decrease. Reached the final number of tiller at 176 at harvest, decreased by 48% due to dying of some tillers. As can be seen in Figure 3, different land preparation was always significant at all data measurement, since the first establishment. The number of tiller under land preparation done by farming bulldozer (FB-DSR) had more tiller than that done by hand tractor (HT-DSR). At 28 DAS, the FB-DSR

treatment produced more tiller by 8.5% than HT-DSR; the same trend occurred at final measurement when the number of tillers of FB-DSR had 17.6% more tillers than HT-DSR.

3.5. Yield components

Grain yield was directly determined by yield components which consisting of the number of productive panicles (tillers) per m², the number of grains (spikelet) per panicle, the percentage of filled grains and 1000 grain weight. $YIELD = (\text{No of Panicles productive tillers/m}^2) \times (\text{no. of grains/panicle}) \times (\% \text{ filled grains/panicle}) \times (1000 \text{ grain weight})$

The observation results of yield components are presented in Figure 4. The results of the analysis for the number of productive panicles per m² at harvest (Figure 4-a) showed the land preparation and method of establishment were always very significant. In general, there were 2 factors determined the number of panicles per m². At the beginning of rice cycle, land preparation was the important factor to ensure seed germination which led to the sufficient number of productive panicle at harvest, particularly for direct seeding rice. Land preparation done by farming bulldozer in combination with DSR produced more productive panicle (tiller) at 212.67, or increased by 17.5% compare to that done by hand tractor. Similarly, land preparation by farming bulldozer in combination with transplanting system produced 158 productive panicles, while hand tractor produced only 144 productive panicles per m². The results showed the importance of well-levelled soil when we used drum seeder for fast planting. Drum seeder operated best on a well-levelled and smooth soil, thus the farming bulldozer land preparation produced higher productive tillers due to better levelled compare to that done by hand tractor. Even though 1-2 days before broadcasted, the well puddled soil was drained to minimize the difference between the highest and lowest portions of a rice field as well as minimize water requirement to achieve complete water coverage, for the homogenous of above ground soil leverage (surface).

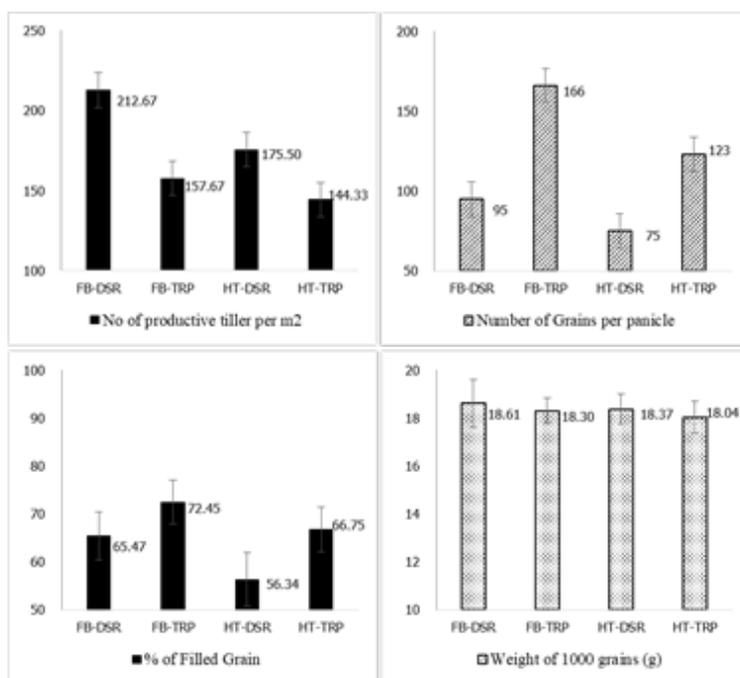


Figure 3. Yield components of Inpari 42 grown under combination of 2 different land preparation and planting system, Blantisiam – Central Kalimantan, 2021.

Different trend occurred for the number of grains per panicle. The number of grains per panicles decreased linearly with increasing number of productive panicles (Figure 7.b). This is due to competition in densely plant population, since the greater number of rice tillers in the same area, the greater the competition for nutrition as well as another available resources in the soil which resulted in a reduction of the number of grains per panicle. In FB-DSR treatment, recorded 95 grains per panicle, or 21% more grains compare to HT-DSR treatment (Figure 7.b). The highest number of grains per panicle was obtained from the FB-TRP treatment (land preparation by farming bulldozer in combination with manual transplanting) averaged at 166 grains, while land preparation done by hand tractor in combination with transplanting resulted in significantly less number of grains per panicle by 26%, averaged at 123 grains.

The percentage of filled grain was ranged from 56% to 72%. The highest percentage of filled grain was recorded from FB-TRP treatment (land preparation using farming bulldozer in combination with transplanting system, followed by HT-TRP (hand tractor and transplanting) at averaged 72.45% and 66.75% respectively. Moreover, a significant lower percentage of filled grain was observed in FB-DSR (Farming bulldozer – Direct Seeding Rice) treatment with only 65.47%. While the lowest percentage of filled grain was recorded from the HT-DSR at 56.34%. Direct seeding rice, in general, susceptible to lodging. Rice planted with direct seeding system usually too close to each other. Positively, we get high number of productive tillers, however, too high population rice can develop thin stems and high possibility to lodge. Despite of the density, it was hypothesized that manual transplanting produced deeper roots system compare to direct seeding, therefor transplanting was more tolerant to lodging. Cultivation under submerged at swampy area, root lodging was frequently observed and considered to be one of the most serious problems, under Direct seeding rice system, seeds were sown on the surface or to the shallower layers of soil, thus Inpari 42 grow with less physical support of soil. The experiment was conducted during rainy season, therefore the percentage of filled grain as well as the yield was significantly influenced by lodging.

With respect to 1000 weight of grain, there was no significant variation between treatments. The weight of grain was mostly influenced by genetic factor of variety Inpari 42. The weight of grain was ranged from 18.04 to 18.61 g per 1000 grains. It is interesting to note that under favourable conditions, the weight of Inpari-42 can reach up to 24.42 g per 1000 grains (ICRR, 2021). Thus indicate that grains were prevented from fully filled and could not reach its potential. Decreasing the weight of grain of Inpari-42 at experiment by 25% compare to its potential, may due to (1) deficiency of some nutrients, particularly Phosphor (P_2O_5) and Potassium (K_2O) which mostly unavailable at submerge swampy field, and (2) grains were prevented from maturing completely due to lodging damage.

3.6. Yield components

There are many challenges associated to rice production at swampy area particularly specific condition at Blantisiam-Central Kalimantan. However, improper land preparation in combination with crop establishment (transplanting or direct seeding) were the key constraints of low grain yield at Swampy area.

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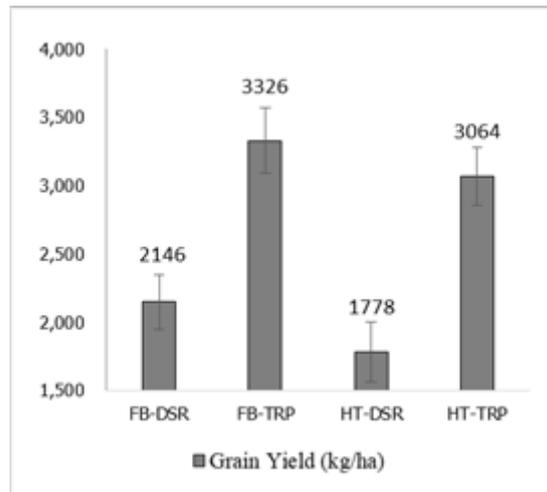


Figure 4. Grain yield (kg/ha) of Inpari 42 grown under combination of two different land preparation using farming bulldozer or hand tractor and two planting system direct seeding or transplanting at Blantisiam, Central Kalimantan, dry season 2021

Higher grain yield was recorded in treatment FB-TRP and HT-TRP at average 3326 and 3064 kg/ha respectively compare to FB-DSR which yielded at 2146 and FB-TRP at 1778 kg/ha. The grain yield of two different land preparation and planting was presented in Figure 5. The results showed that 2 main factors affecting grain yield, which were (1) Crop establishment. Transplanting significantly produced higher grain yield compare to direct seeding, however, direct seeding was required less cost, labour and time, and (2) land preparation and levelling which done by farming bulldozer resulted in better grain yield compare to hand tractor.

The results revealed that the treatment with the highest milled dry grain results was found in the treatment using seedlings and transplanting systems compared to direct seeding systems using drum seeder. This is because in the transplanting system, the distance between plants is more organized so that plants get sufficient sunlight intensity and nutrients for plant growth. Whereas in the direct seeding system, the distance between plants is irregular and tends to be solid, so the competition between plants in absorbing the nutrients and sunlight is quite high. This causes plant growth is not optimal and yields tend to be lower than the transplanting system.

4 Conclusion

Good land levelling had greater effect on the seed germination and significantly increase the number of tiller by 17.6% under direct seeding with farming bulldozer land preparation compare to hand tractor. Highest grain yield was produced in FB-TRP (land preparation done by Farming Bulldozer in combination with transplanting) treatment at average 3326 kg/ha, followed by HT-TRP (Hand Tractor-Transplanting) yielded at 3064 kg/ha. Whereas FB-DSR yielded at 2146 and FB-TRP at 1778 kg/ha respectively. Land preparation-land levelling which done by farming bulldozer improved the growth of rice particularly the number of productive tillers per m² which lead to higher grain yield compare to land preparation done by hand tractor. Better levelling as the result of land preparation resulted in better growth of rice and more number of tiller per m². Using farming bulldozer, soil was better levelled to improve seed germination. Land levelling increases the number of tillers to a large extend because it improves weed control at swampy area.

Crop establishment was another factor affecting grain yield. Due to the lack of daily labour, the price of transplanting method reached up to 3.500.000,00 Rupiah compare to 400.000,00 Rupiah under direct seeding rice. Transplanting significantly produced higher grain yield compare to direct seeding, however, direct seeding was required less labour, cost and time. Based on the data of number of tillers per m², land preparation had greater effect on the germination and the growth of tiller of direct seeding compare to transplanting.

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