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Drip Irrigation Technology Performance on Rice Cultivation

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ABSTRACT

This study aims to determine the performance of drip irrigation technology as compared to conventional farmer's practice on rice growth and yield, grain quality, and water consumption. The research was carried out at the Sukamandi Experimental Station, Subang, West Java in July - October 2019. The test was arranged by a nested randomized block design with 5 replications. The main plot was water management with 2 levels: (1) Drip Irrigation Technology (DIT) and (2) Conventional Farmer's Practice (CFP) (flooded condition) as a comparation. Subplot was varieties with 4 levels: two hybrid rice (1) Hipa 8 and (2) Hipa 18, upland rice (3) Inpago 11, and irrigated inbred rice (4) Inpari 42. The result showed that yield of DIT not significantly different to CFP with higher number of tillers per m2. However, it was lower for plant height, tillering ability, grain filling, 1000 grains weight, transpiration rate, assimilation rate and stomatal conductance. For grain quality determination, DIT gave an increase in the average of grain density and impurities, but decreased in the average percentage of chalky and immature grains. In Hipa 18, DIT was able to produce a higher percentage of head rice. DIT only consumed 3864 m^3/ha/season water irrigation compared with average water consumption in Sukamandi Field Station which range of 7460-8740 m^3/ha/season.

1. INTRODUCTION

The dependence of food security on irrigated rice ecosystems in the long term will face a crisis. This is because production systems with transplanting and optimum land preparation required large amount of labor, water and energy, where these resources are becoming increasingly scarce (Kumar & Ladha, 2011). Flooded condition in irrigated rice is carried out to ensure sufficient water and weed control. This is not only causes water wastage but also causes environmental degradation, contributes to methane emissions and reduces the fertilizer efficiency (Kumar & Ladha, 2011; Singh *et al.*, 2019). The limited resources and the negative impact caused by the irrigated rice system encourages the improvement of cultivation techniques especially on water management.

Aerobic rice system is one approach to improve water management on water scarcity in agricultural land. According to Kato & Katsura (2014), growing rice under continuously unsaturated soil conditions can maximize water use efficiency, minimize labor requirements, and reduce greenhouse gas emissions. The challenge in this system is identification of adaptive varieties and proper nutrient and water management (Kato & Katsura, 2014; Ouyang *et al*., 2017) in order to promote growth at an early stage, provide a sink-source balance for better tillering ability and grain filling, increase yield and water use efficiency. One of the technology to applied aerobic rice system is drip irrigation (Parthasarathi *et al*., 2018). Appropriate water consumption according to crop requirements with constant duration can be achieved using drip irrigation (Hanson & May, 2007). Compared to flooded condition, drip irrigation can save 40% water consumption (Sharda *et al*., 2016), increases 1.52 – 2.12 times water use efficiency (He et al., 2013), enhance plant physiological activity as well as yield (Parthasarathi *et al*., 2015; Parthasarathi *et al*., 2018). In addition, fertigation through drip irrigation can increase crop yield by applying appropriate fertilizer (dosage, time, and spot) (Adekoya *et al*., 2014). Several application timing of N fertilizer in drip irrigation system can also increase N efficiency, N uptake, and reduce leaching of NO^{3-} (Rajwade *et al*., 2018).

Drip irrigation technology has been used especially for commercial scale horticultural and plantation crops. However, its application for rice is still limited, especially in Indonesia. Further information on rice response is needed to identify the feasibility of drip irrigation technology application. This study aims to determine the performance of “Drip Irrigation” technology as compared to conventional farmer’s practice on rice growth and yield, grain quality, and water consumption.

2. MATERIALS AND METHODS

The research was carried out at the Sukamandi Experimental Station, Subang, West Java in July - October 2019. The experimental design was a nested randomized block design with 5 replications. The main plot was water management with two levels: (1) Drip Irrigation Technology (DIT) which is installed on an area of 2 ha with a distance between irrigation pipes of 75 cm and (2) Conventional Farmer’s Practice (CFP) (flooded condition) on an area of 0.8 ha as a comparation. Subplots were varieties with 4 levels, namely two hybrid rice or Hipa varieties (V1) Hipa 8 and (V2) Hipa 18, (V3) Inbred upland rice (Inpago 11), and (V4) Inbred irrigated rice (Inpari 42) as presented in Table 1.

Table 1. Treatments for drip irrigation technology testing in rice cultivation

Code	Treatment
Water Management (P)	
P1	Drip Irrigation Technology (DIT)
P2	Conventional Farmer’s Practice (CFP)
Varietas (V)	
V1	Hybrid rice (Hipa) – Hipa 8
V2	Hybrid rice (Hipa) – Hipa 18
V3	Inbred upland rice (Inpago) – Inpago 11
V4	Inbred irrigated rice (Inpari) – Inpari 42

The cultivation technique applied to P1 treatment were dry tillage with direct seeding which had been soaked for 8 hours. P2 treatment used optimum tillage followed by transplanting at 21 days after sowing (DAS). Soaking for P1 and P2 treatments was carried out at the same time. Both treatments used *legowo* 2:1 planting system (Figure 1). Fertilization recommendations for P2 treatment based on Soil Test Kit results: 250 kg/ha Urea, 50 kg/ha KCl, and 50 kg/ha SP 36. Fertilizer was applied in 3 stages: first was applied at the age of 7-10 DAT (days after transplanting) using 1/3 dosage N fertilizer + P fertilizer + 1/2 dosage K fertilizer. The second fertilization at 28 DAT by applying 1/3 dosage N fertilizer while the third fertilization applied when panicle initiation phase used 1/3 dosage N fertilizer + 1/2 P fertilizer. P1 treatment used 150 kg/ha NPK (15:15:15), 242 kg/ha Urea and 66 kg/ha KCl. NPK (15:15:15) was given as basic fertilizer, while Urea and KCl were given by fertigation every 10 days regarding to drip irrigation procedure. In terms of the nutrients provided, the amount of nutrients in the drip irrigation was 12.48% (N), 20% (P) and 54.55% (K) higher compared to conventional farmer's practice. Organic matter also given as much as 2 t/ha. Weeds are controlled chemically and manually, while controlling pests and diseases accordance to recommendations for Integrated Pest Management (IPM).

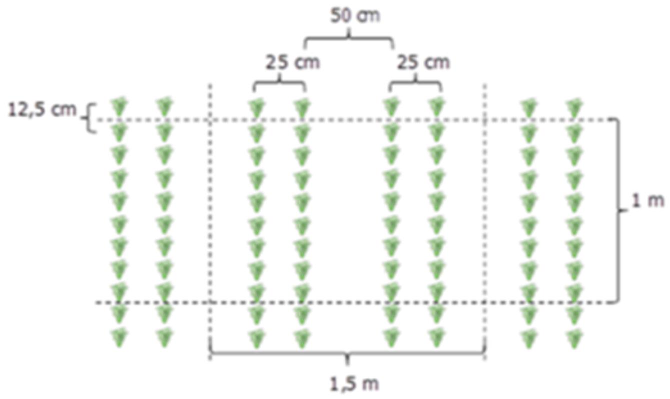

Figure 1. *Legowo* 2:1 planting system (50 cm; 25 cm;12,5 cm)

The composite soil was taken before the experiment as initial soil characteristics information, while after experiment soil characteristics were taken from each main plot. Soil analysis included texture (pipetting), pH H2O and 1 N KCl (1:5), C-organic (Walky and Black), N (Kjeldhal), P and K, and CEC (Cation Exchange Capacity) (NH4OAc 1N pH7). The water level is periodically observed to obtain the amount of water consumption during growth. Rice response were observed on characters: (1) plant height at harvest; (2) tiller number per m2 and greenness leaf level (Konika Minolta chlorophyll meter SPAD-520) at 50 DAS, 60 DAS, 70 DAS and at harvest; (3) root volume, transpiration rate, assimilation rate, and stomatal conductance (Licor LI-6800 portable photosynthesis) at 50 DAS, 70 DAS and harvest; (4) yields (t/ha) were determined from a sample (size: 7.5 m2) collected from the center of each plot at harvest maturity, reported yields correspond to paddy rice adjusted to 14% grain moisture content; (5) yield components include the panicle number per m2, number of grains per panicle, filled grain percentage, and 1000 grains weight; (6) grain quality which included nutrient uptake and grain quality. The collected data were analyzed using Analysis of Variance (ANOVA) and if there was a significant effect at 5% level, continued with the LSD test.

3. RESULTS AND DISCUSSION

3.1. Soil and Water Characteristics

Based on the results of soil analysis, it was known that the experimental land had a clay loam soil texture. Experimental location had slightly acidic pH. After the experiment, soil pH in DIT and CFP was seen to increase. The C-organic content in the soil before the experiment was very low (0.56). Therefore, along with tillage, the land was given organic matter at a dose of 2 t/ha. After the experiment, it was seen that the application of organic matter could increase the C-organic content in both water managements.

Initially, the land had very low N content, and after the experiment the N content was in the low category, both in DIT and CFP (Table 2). For P nutrient, land with DIT water management experienced decreasing total P_2O_5. However, in CFP area there was no change in the category of P_2O_5 content. In the case with K nutrient content, there was a decreasing in K content for both DIT and CFP. For the CEC (Cation Exchange Capacity) of the experimental land, both before and after the experiment, it was low, so it was suspected that it could not provide sufficient nutrients for plant growth.

Table 2. Soil physicochemical analysis of drip irrigation technology testing in rice cultivation, 2019

Criteria	**Experiment location**		
	Before experiment	**After experiment**	
		Drip Irrigation Technology	**Conventional Farmer's Practice**
Texture (%)			
Sand	21	-	-
Silt	45	-	-
Clay	34	-	-
pH			
H_2O	6,5	5,1	5,5
KCl	5,2	4,2	4,6
C (%)	0,56	0,89	1,08
N (%)	0,05	0,10	0,12
C/N	11	9	9
P_2O_5 (mg/100g)	45	23	44
Ca (cmol/kg)	7,22	7,71	8,75
Mg (cmol/kg)	1,62	1,62	1,98
K (cmol/kg)	0,13	0,04	0,03
Na (cmol/kg)	0,45	0,68	0,60
CEC	12,58	10,05	11,36

Table 3. Water quality analysis of drip irrigation technology testing in rice cultivation, 2019

Parameter	pH	Pb	Cd	Co	Cr	Ni	Mo	Sn	Se	As	Hg	Mud
						mg/L					ppb	mg/L
Sample	7.4	0.12	0	0	0	0	0.07	0.63	0	0	0	216
Criteria for good irrigation water	6.0-8.5		0.01	0.1	0.1	0.5			0.005	0.1	0.01	1000

Water source for irrigation was often become one of the causes of crop failure, in terms of quantity, quality, and the supply schedule. Although Government Regulation No. 20/2006 on Irrigation does not mention water quality for irrigation, but in fact to increase food production, it requires water quality aspects (Yusuf, 2014). The analysis result of water quality at the experimental site could be seen in Table 3. The water pH 7.4 indicated that water was in good condition, as well as mud content of 216 mg/l of water which was still below the threshold. Regarding toxicity parameters that will interfere plant growth, its contained lead 0.12 mg/l, molybdenum 0.07 mg/l, and tin 0.63 mg/l. Other heavy metals such as cadmium, cobalt, chromium, nickel, selenium, silver, and mercury did not appear to be present in water sample.

3.2. Water Consumption

Monitoring of the water movement in the experimental plots using a hollow PVC pipe every 2 days showed that there was no standing water in the DIT treatment (Figure 2). DIT received water intake from the beginning of growth until before harvest with a total water consumption of 3846 m^3/ha/season. Meanwhile, in CFP irrigation water could only be given 3 times until halfway stage, and plants faced drought for the rest stage. This could be seen in the water consumption used, where CFP only consumes 3170 m^3/ha/season. Normal rate of water consumption per season based on Abdulrachman *et al.* (2009) in Sukamandi Field Station with sandy clay texture required 7031 m^3/ha/season with an efficiency of 0.79 kg/m^3 to reach a productivity of 5.53 t/ha (14% moisture content). The low water consumption in the CFP due to limited water still produced slightly higher yields that results in the higher water use efficiency as compared with DIT (Table 4.) However, when compared to normal water consumption in Sukamandi Field Station, water management using drip irrigation could save 45% water consumtion per season.

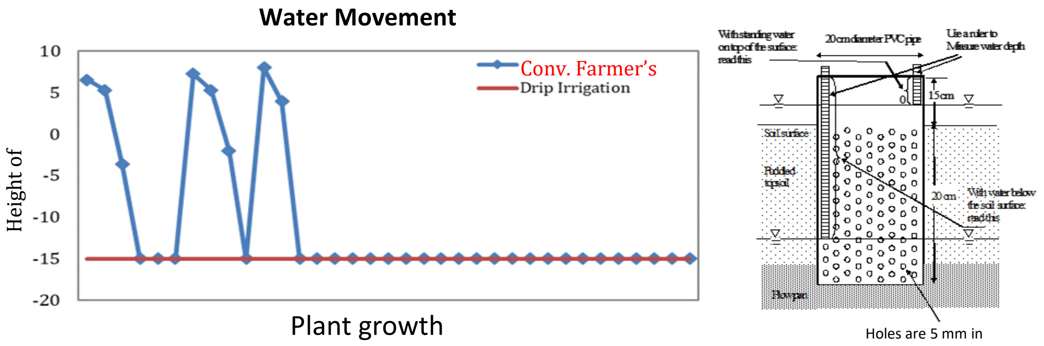

Figure 2. Water movement during plant growth (left) through monitoring pipe (perforated PVC, right) of drip irrigation technology test in rice cultivation, 2019

Table 4. Yield, water consumption, and water use efficiency of drip irrigation technology test in rice cultivation, 2019

Treatment	Yield (t/ha, MC 14%)	Water consumption (m^3)	Water use efficiency (kg/m^3)
Drip Irrigation Technology (DIT)	4,91 a	3864	1,27
Conventional Farmer's Practice (CFP)	5,26 a	3170	1,66
Average	5,09	3517	1,47

Note: Values within columns followed by different letters are statistically different at P = 0.05

3.3. Plant Growth

The water management treatments gave significant difference in plant height. Similar results were obtained by Xu et al. (2020) where plant height changed significantly due to differences in soil water conditions. DIT treatment showed a lower plant height than CFP except for Inpago 11 (Figure 3). Short posture can increase the ability to absorb greater light which related with better rate of photosynthesis if supported by the high tiller ability and stiff leaves (Suprihatno & Daradjat, 2009). According to Kato & Katsura (2014), rice plants with medium posture and many tillers are types of rice that able to adapt aerobic conditions.

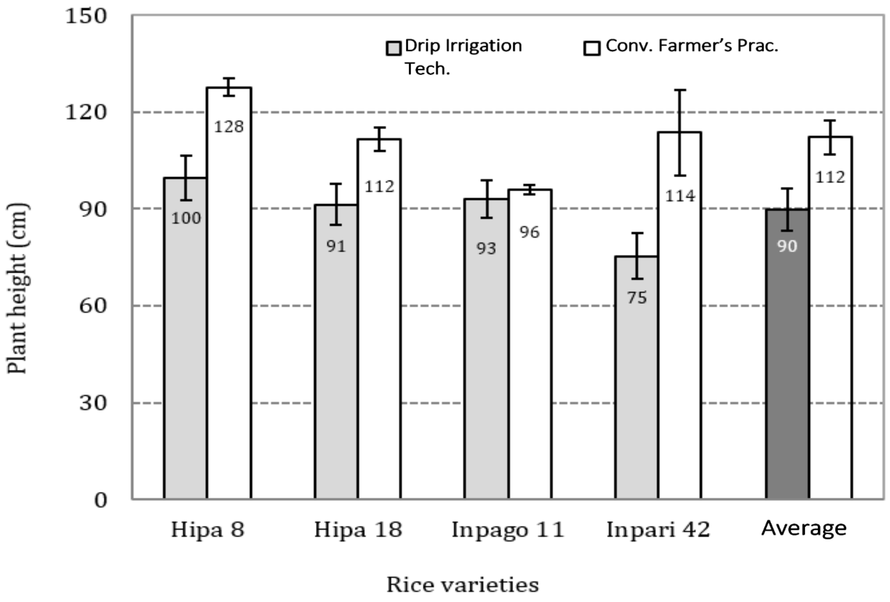

Figure 3. Plant height (cm) based on irrigation methods and rice varieties, 2019

Regarding the number of tillers per m^2, our results were in line with He *et al.* (2013), where DIT gave the maximum tillers number faster than CFP. Furthermore, tillers number per m^2 before harvest in the DIT treatment was slightly higher than the CFP (Figure 4). However, the mortality tiller rate was quite high in this treatment where only 54% of tillers were able to survive from the total tillers per m^2 formed start from the beginning of growth. Among four varieties used, Hipa 18 was able to get highest tillers number per m^2 than the other three varieties which had the equal tiller ability. The death of tillers (unproductive tillers) was caused by competition for the use of sunlight, nutrients (especially N), and also growth energy from photosynthesis between the formed tillers (He *et al.*, 2013; Wang *et al.*, 2017). The decreasing in soil water content during tillering stage appositively with decreasing productive tiller number (Xu *et al.*, 2020).

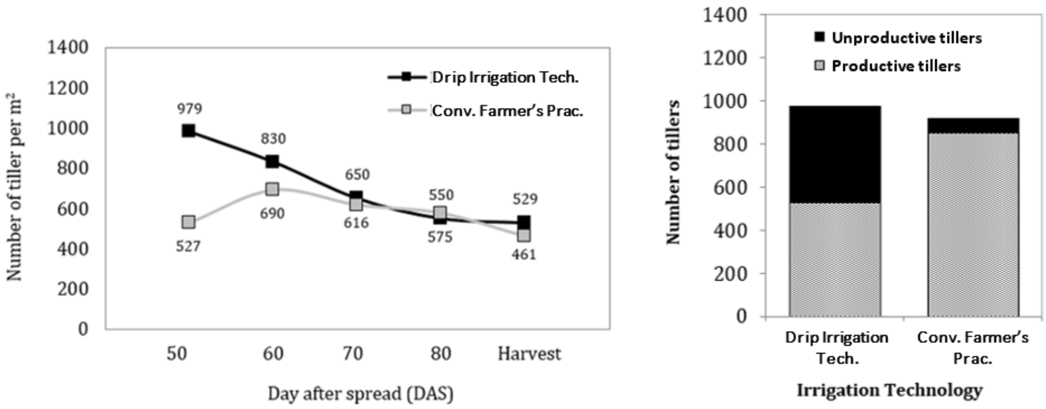

Figure 4. Development of tiller number per m^2 on drip irrigation technology test activities in rice cultivation, 2019

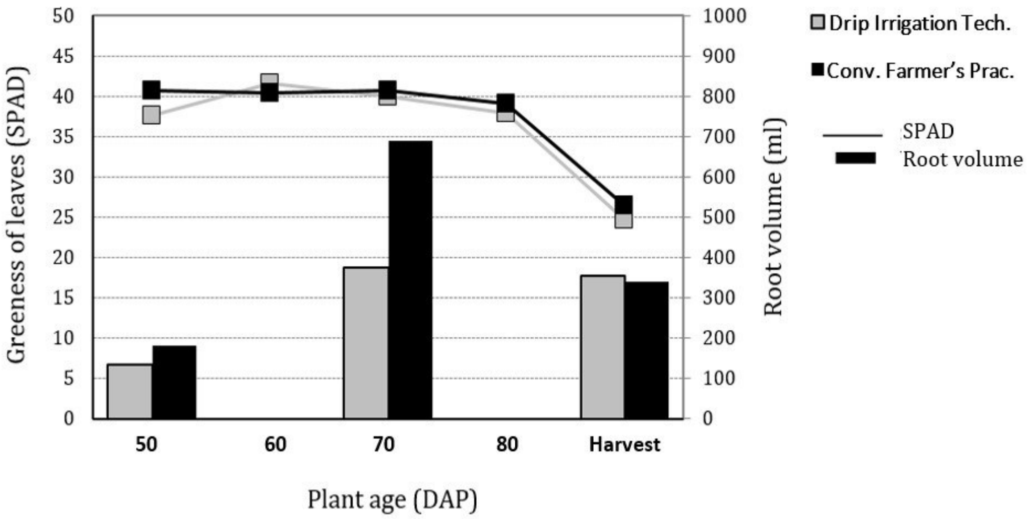

Figure 5. Development of greenness leaf level and root volume on drip irrigation technology test in rice cultivation, 2019

Greenness leaf level of a variety is one of the important factors of growth variables that will affect production because it describes the adequacy of the main nutrient N. In aerobic cultivation, fertilization management have to meet nitrogen requirements and control grain formation to achieve sink-source balance (Kato & Katsura, 2014). From the beginning of growth until 80 days after sowing (DAS), the greenness leaf level in the tested varieties was in the range of 35-42 with SPAD readings (Figure 5). It indicates that greenness leaf level in both water treatments was at normal level which correlated with the adequacy of N in rice plants (Ghosh *et al.*, 2013). The greenness leaf level showed a significantly different response only at the beginning of growth, both between water treatments and varieties. Prior to harvest, the greenness leaf level of DIT was lower than CFP. According to Wu *et al*. (2018) on post-flowering stage was unadequte N, then leaf senesence or symptoms of yellowing of the leaves occur faster and reduce filled grains number which resulted in low yield. In addition, senesence could also reduce the rate of photosynthesis due to chlorophyll degradation and decreased chloroplast function (Tamary *et al.*, 2019). Water stress significantly affects the roots volume. Up to 70 DAS, the CFP showed significantly higher root volume, but when water was very limited, both water treatments resulted in equally low root volumes. Likewise, between varieties showed no differences of root volumes under drought stressed. Indeed, under aerobic conditions, adaptive responses such as adventive root emergence, lateral root branching, and root penetration will protect the plant against drought stress (Kato & Katsura, 2014).

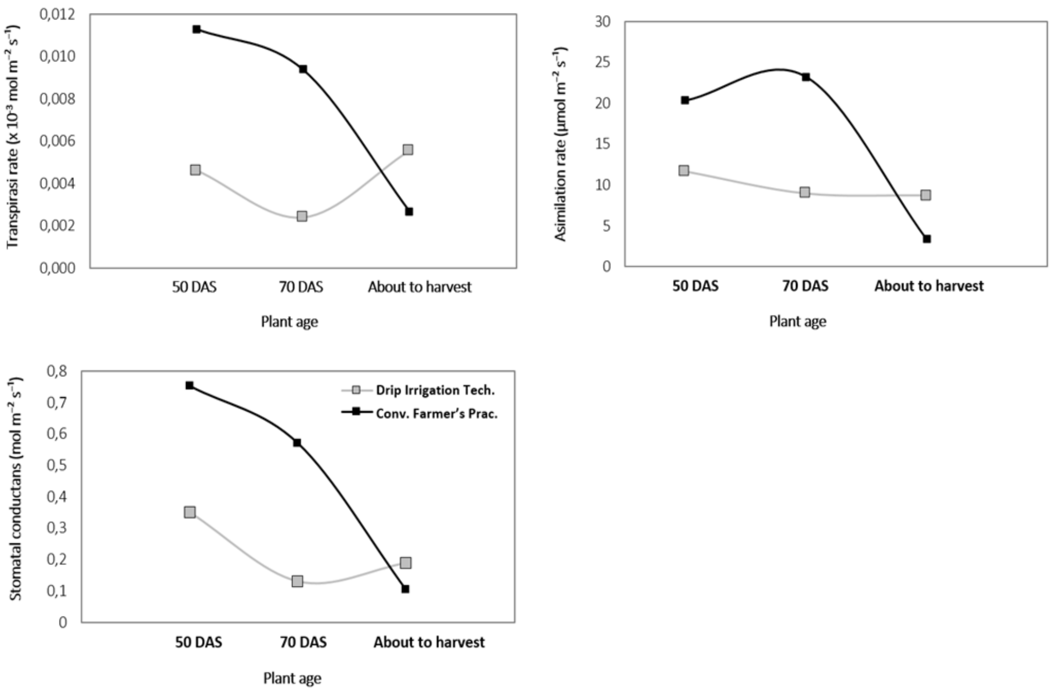

Figure 6. Transpiration rate, assimilation rate, and stomatal conductance on drip irrigation technology test in rice cultivation, 2019

3.5. Yield and Yield Components

The average yield between two water management was not significant different, moreover Hipa 18 and Inpari 42 had the highest yields than two other varieties. Phyu *et al*. (2021) stated that rice productivity does not only depend on the accumulation of dry matter production, but also how dry matter can be translocated to the grain portion. Limited water due to drought stress in generative stage caused low yield in CFP. However, CFP was able to provide 7% higher yield than DIT. Lower yield under DIT was due to the reduction in plant dry matter accumulation after flowering, as well as a low photosynthesis rate and leaf area index during filling (Hu *et al*., 2013; Singh *et al*., 2019).

DIT produced a higher panicle number per m^2 but lower in filled grain percentage in line with Rajwade *et al.* (2018). However, it's could not support the increasing yield, because other yield components including grain number per panicle, filled grains, and 1000 grains weight decreased (Table 5). The low panicle number was related to preflowering spikelet abortion as a mechanism to avoid drought stress (Kato *et al.*, 2008). Unfilled grain is influenced by many factors, including the adequacy of assimilates produced from the photosynthesis process as energy for grain filling phase, as well as the availability of materials in photosynthesis such as sufficient water during the flowering and ripening phases (Vijayaraghavareddy *et al.*, 2020), carbon dioxide (CO_2), and sunlight intensity.

Table 5. Yield components of drip irrigation technology test on rice cultivation, 2019

Treatments		**Number of panicle (m^{-2})**	**Filled grain (%)**	**Grain per panicle**	**1000 grain Weight (g)**	**Yield (t/ha, MC 14%)**
Water Management						
DIT	P1	306,98 a	62,05 a	131,98 b	20,60 b	4,91 a
CFP	P2	242,33 b	69,02 a	177,83 a	23,34 a	5,26 a
Varietas						
Hipa 8	V1	245,30 b	58,05 c	195,59 a	23,19 a	4,78 b
Hipa 18	V2	342,67 a	67,37 b	136,55 c	23,00 a	6,18 a
Inpago 11	V3	207,00 b	57,47 c	154,54 b	21,75 b	3,54 c
Inpari 42	V4	303,67 a	79,23 a	132,94 c	19,93 c	5,86 a
Average		274,66	65,53	154,90	21,96	5,09

Note: Values within columns followed by different letters are statistically different at P = 0.05

3.6. Grain Quality

Nutrient Uptake. It was carried out on various macro and micro nutrient contents, including heavy metals in grain and straw. The differences in grain nutrient content was seen in lower P, K, Mg, Fe, Ni, and B level for DIT than CFP. DIT also show lower content for Ca, Al, Mn, Cu, and a small amount of Fe, B, Ni, and Pb. On the other hand, DIT increased Cu and Zn in the grain and Zn in the straw (Figure 7). Drought stress has an impact on osmotic pressure in plant roots which is correlated with plant cell metabolism and mineral uptake by plants. Plants are reported to have a wide range of abiotic stresses, including drought. Nutrient adequacy is one of the important factors to help plants increase their tolerance. N, K, Ca, Si, Mg, and Zn were reported to help plants increase the antioxidant content in cells to reduce the level of Reactive Oxygen Species (ROS) which increased due to drought stress. In addition, P, K, Mg, and Zn also affect root growth in increasing the ability of plants to absorb water. Other nutrients such as Cu and B also play an indirect role in tolerating drought stress, especially as promoters of plant metabolic, physiological, and biochemical activities (Waraich *et al.*, 2011).

3.4. Transpiration Rate, Assimilation Rate, and Stomatal Conductance

Before the drought stress occurred in CFP area, the transpiration rate, assimilation rate, and stomatal conductance were higher than DIT. Furthermore, when in the CFP faced a shortage of irrigation water while the DIT still received continuing water supply, the transpiration rate, assimilation rate, and stomatal conductance in the DIT were seen to be higher. Photosynthesis is a key process of primary metabolism, and its capacity can affect plant performance and productivity (Gu *et al.*, 2014). According to Osakabe *et al.* (2014), lack of water is one of the limiting factors in the photosynthesis process. Sun *et al.* (2017) stated that under water deficit conditions, plants close their stomata to prevent large water losses which result in a reduction in photosynthesis through a decrease in CO_2 concentration. Under conditions that inhibited plant metabolism, stomatal conductance will decrease or even stop altogether (Waraich *et al.*, 2011; Soleh *et al.*, 2017). Each variable (stomatal conductance, photosynthesis rate and transpiration rate) had indirect correlation with water use efficiency (Xu *et al.*, 2020). The low transpiration rate is one of the desirable properties related to the ability to maintain leaf moisture in limited water conditions (Parthasarathi *et al.*, 2015;).

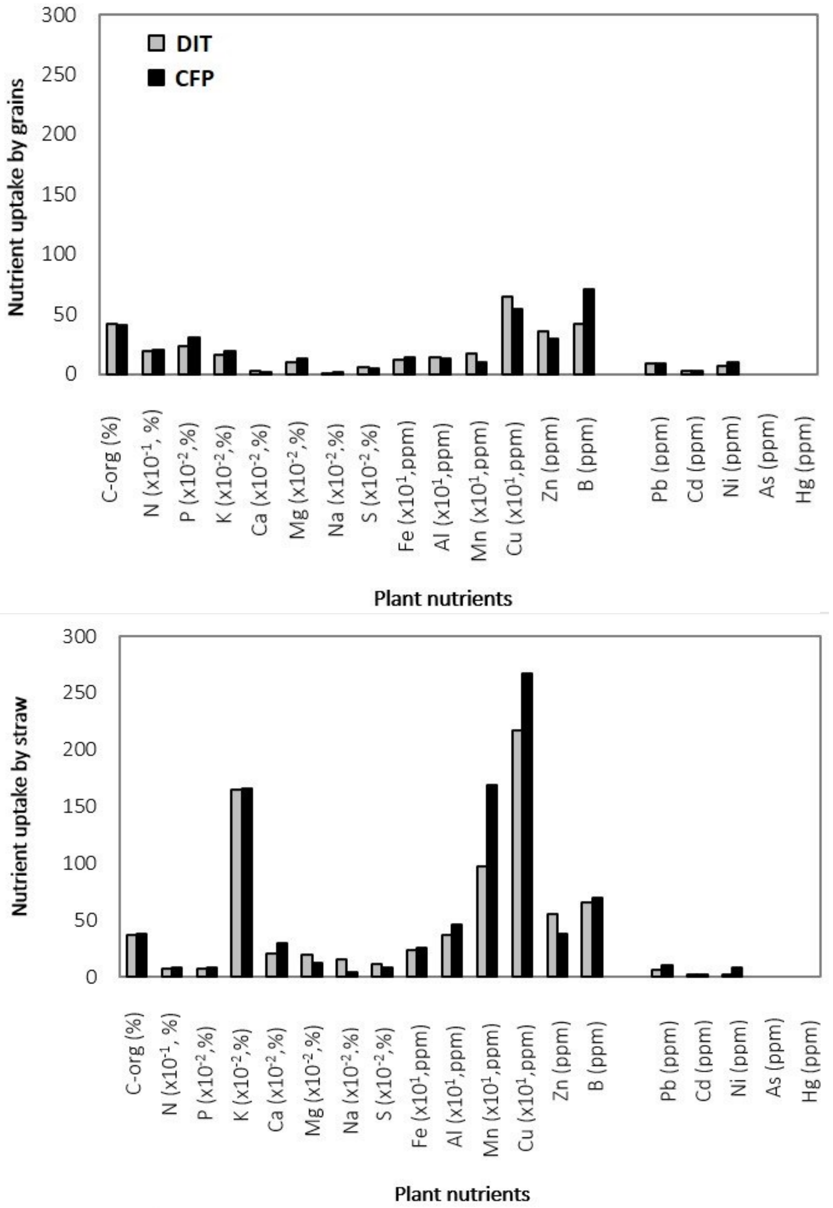

Figure 7. Uptake of nutrients and heavy metals by grain (upper) and straw (lower) from drip irrigation test on rice cultivation, 2019

***Grain Quality*.** The quality of rough rice greatly determines the quality of milled rice. Good quality rough rice if processed properly will produce high quality milled rice. All rough rice samples's moisture content met the grain quality requirements of SNI No. 0224-1987 (max. 14%). The fresh harvested paddy was dried to 12.3 – 13%. The moisture content of a food materials greatly affects their shelf life. According to Belitz *et al.* (2009), water supports the occurrence of various types of chemical reactions, and as direct reagent in the hydrolysis process. Therefore, the removal of water can slow down the occurrence of various chemical reactions and prevent the growth of microorganisms.

DIT resulted higher grain density than CFP (Figure 8). The percentage of impurities and empty grain samples was quite high, ranging from 9.58 – 21.91%. The average percentage of impurities and empty grains in DIT was higher than CFP (Figure 8). This is also in line with the observational data of yield components where the CFP provides a better filled grains. Research by Rajwade *et al.* (2018) on rice cultivation with drip irrigation and aerobic rice by Ishfaq *et al.* (2021) showed that cultivation with limited water produced grain with a high percentage of empty grain.

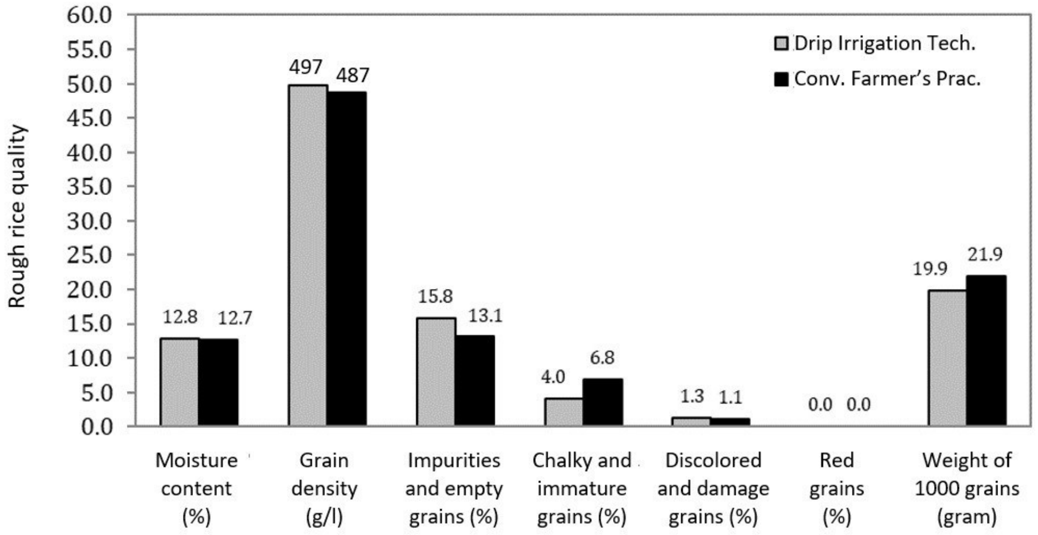

Figure 8. Comparison of rough rice quality of two different water management methods in rice cultivation, 2019

The percentage of chalky and immature grains in the sample ranged from 0.82 to 11.12%. DIT produced grain with a lower percentage of chalky and immature grain than CFP for all varieties used. Chalky grains are known to be formed due to too high temperatures during grain filling (Lyman *et al.*, 2013). Based on these data, high temperatures in excess water conditions during the grain filling process resulted in higher chalky and immature grain formation than in limited water conditions. The percentage of discolored and damage grains was equivalent between the two water management, which ranged from 0.35 to 2.04%. Discolored and damage grains formation can be triggered by the activity of microorganisms at planting stage (e.g. fungal species *Alternaria alternata* and *Dreschelera oryzae*) and storage, due to grain fermentation in wet stacking conditions for a certain period of time (Mustafa & Mohsan, 2017; NIIR Board of Consultants and Engineers, 2017). In all samples, no red grains were found.

The 1000 grains weights of three varieties (Hipa 8, Hipa 18 and Inpari 42) with DTI was lower than CFP. Only Inpago 11 had 1000 grain weight higher in the drip irrigation. The reducing of 1000 grains weight was caused by the exposure of drought during the filling phase (Moonmoon & Islam, 2017; Pandey *et al.*, 2014). Inpago 11, which is an upland rice variety, has better resistance to drought than other varieties.

The moisture content of milled rice samples were 13.5 to 14.3% (Figure 9). Most of the samples fulfilled the Indonesian's standard requirement (SNI 6128:2020) of moisture content (max. 14%). Rice with lower moisture content has a longer shelf life. The yields of brown rice and milled rice ranged between 75.42 – 76.93% and 60.31 – 68.53%, respectively. It was found in Hipa 18, that DIT was able to increase the percentage of milled rice and head rice with lower level of broken rice and brewers than CFP. High drought stress due to the low level of water consumption in CFP is thought to be the cause of the low quality of milled rice.

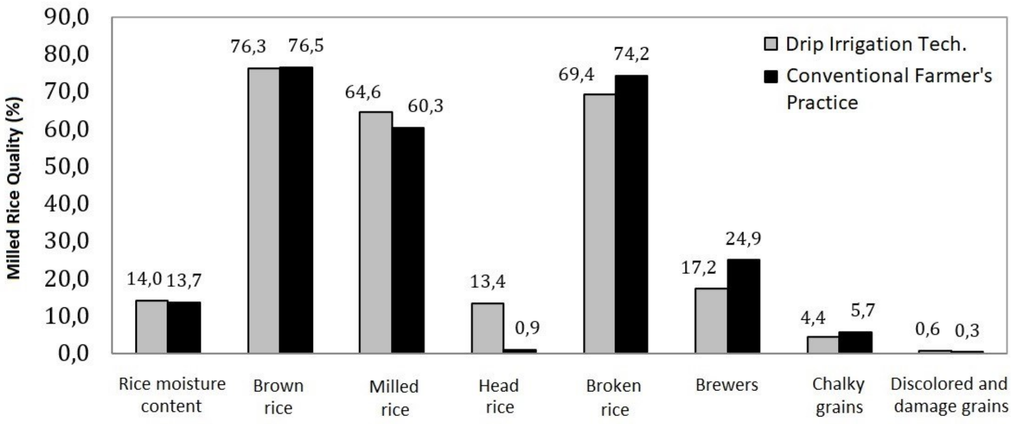

Figure 9. Comparison of the milled rice quality of Hipa 18 rice with two water management, 2019.

The percentage of head rice, broken rice and brewers are the main parameter in determining milled rice quality in the market. The percentage of head rice, broken rice and brewers of all samples were not fulfilled the Indonesian's standart requirement (SNI 6128:2020). Drought that happened during planting promote low quality of milled rice. Bleoussi *et al.* (2016) stated that paddy subjected to drought stress conditions produced milled rice with a lower percentage of head rice. Chalky grain and discolored and damage grain are defects that reduce the quality of rice. Based on Indonesian's standard requirement (SNI 6128:2020) for premium, medium 1, and medium 2 class, the maximum of chalky grains and also discolored and damage grain in milled rice are 0,5%, 2%, and 3% respectively.

The shape of rice is genetic characteristic. Based on the ratio of length and width, Hipa 8, Hipa 18, and Inpari 42 varieties were slender-shaped rice, while Inpago 11 variety was medium-shaped rice (IRRI, 2014). Measurement of whiteness, percentage of transparency, and degree of milling of rice were conducted using Satake Milling Meter. According to Yadav & Jindal (2008), the increase in whiteness is directly proportional to the length of polishing time. Inpari 42 has lower whiteness and degree of milling than the other samples. Consumers generally prefer rice with higher degree of milling whiteness. The comparison of the differences in the milled rice quality of

Hipa 18 was descriptively seen in the degree of milling, and transparency, where DIT had higher value than CFP (Figure 10).

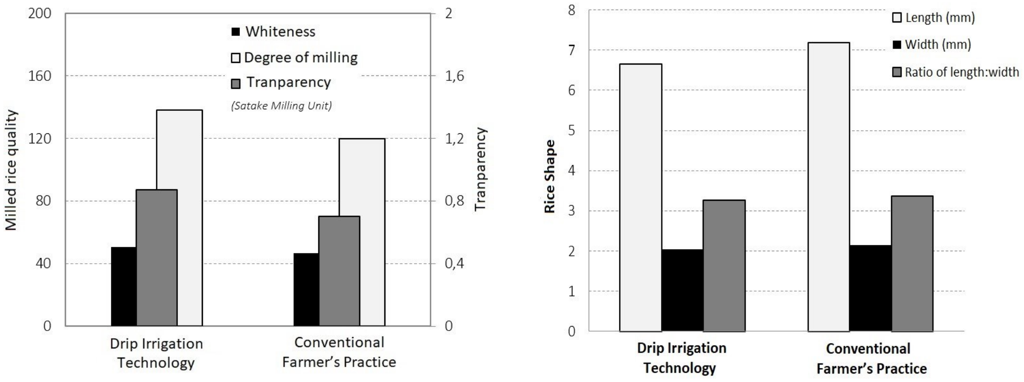

Figure 10. Comparison of the milled rice quality of Hipa 18 rice with two water management, 2019.

4. CONCLUSION

Drip Irrigation Technology resulted insignificant yield production to conventional farmer's practice water management with a higher number of tillers per m^2. Drip Irrigation Technology gave lower for plant posture, tillering ability, grain filling, 1000 grains weight, transpiration rate, assimilation rate, and stomatal conductance compare to conventional farmer's practice. For grain quality determination, drip irrigation gave an increase in the average of grain density and impurities, but decreased in the average percentage of chalky and immature grains. In Hipa 18, drip irrigation was able to produce a higher percentage of head rice. Drip irrigation only consumes 3864 m^3/ha/ season water irrigation compared with average water consumption in Sukamandi Field Station which range of 7460-8740 m^3/ha/season.

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