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Comparisons among soil tillage system and their impacts to the tested rice varieties on lowland rainfed alluvial in Aceh Jaya

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Abstract

This research was aimed to determine the effect of tillage and varieties on rice growth and yield. This research used a Split Plot Design (SPD) where the land was cultivated (T) as the main plot and rice varieties as subplots (V) repeated three times. The main factors as the main plot consist of three levels, namely: without soil tillage (T0), minimum soil tillage (T1), and perfect soil tillage (T2). The second factor is 5 level varieties, namely: Tinggong (V1), Ciherang (V2), Cibogo (V3), Inpari-13 (V4), and Situ Bagendit (V5). Data were also projected onto principal component analysis (PCA) to observe differences and affected factors related to the soil tillage system. The results showed that the system of tillage had a very significant effect on the yield per hectare. There was no significant difference in yield between the minimum tillage and the perfect tillage. Variety had a very significant effect on plant height at eight weeks after planting (WAP), the number of tillers at 8 WAP, panicle length per clump, the amount of grains, percentage of full grain per clump, percentage of empty grain per hill, the weight of grain per panicle, weight 1,000 grain and yield per hectare. The Cibogo variety gave the highest yield, namely 4.86 ton/ha. Based on PCA analysis, plant height, the total amount of grain, and filled grain are highly affected by the soil tillage system.

1. Introduction

Rice (*Oryza sativa* L.) is one of the most important food crops as it is consumed by more than half of the world's population (Khush, 2005). In Indonesia, rice plants have a significant role as a staple food for most of the population. The need for rice in Indonesia is always increasing from year to year due to population growth. Indonesia is still importing, although including the largest rice producer's country in the world, to meet the national demand. The rate of population growth is a little higher, 0.53%, than the rate of domestic rice consumption. However, the rapid demographic growth pressuring in the rice sector recommends increasing rice production to avoid a national food crisis (FAO, 2018).

According to Anggraeni (2020), national rice production was 79.14 million tons in 2016, but the amount has not been able to meet national consumption needs. The government has to import 1.3 million tons of rice in 2016 to cover the shortage of rice needs and less productivity in Indonesia. To achieve national production, the government implemented an intensification and extensification policy, including planting rainfed rice fields with superior rice varieties, more convenient access to capital and farm inputs, and support market integration as well as agriculture technologies (Lopulisa *et al*., 2018).

Therefore, meeting these needs is always prioritized by the government. Rice production can be increased by good cultivation, planting superior varieties, and proper soil tillage system to get perfect results. The soil tillage system is directly influenced rice productivity, and tillage impact can reduce the availability of nutrients and microbes in the soil (Sari *et al*., 2017). On the other case, the selection of rice varieties that have higher adaptability to various farming environments is essential, before making a recommendation in which variety is comfortable to a specific land in gain a high rate of variety adaptation, especially in developing countries (De Abeysiriwardena, 2001).

The soil tillage system in rice planting aims to

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change the soil's physical properties so that the initially hard layer becomes flat and muddy. The soil tillage system dramatically affects the soil structure naturally, which is formed due to root penetration; when the cultivation is too intensive, the soil structure will be damaged. How soil tillage is treated can improve soil density, soil structure, soil temperature, water availability, soil microbiological activity, and soil respiration to crop productivity and agriculture sustainability (Moraru and Rusu, 2013).

The method for tillage land T0 (without soil tillage) is to leave the land without being disturbed at all. The remaining plants were previously cleared and used to cover the soil surface or last season's crop residues, and the weeds in the area were sprayed with herbicides after dry or dead weeds were planted (Atika *et al*., 1997). The results of Sembiring (2009) research on upland rice obtained dry weight of grain per plot in perfect tillage (1.82 kg), minimum tillage (2.13 kg), and without soil tillage (1.80 kg). The yield of upland rice under perfect tillage and without soil tillage gives the same results, while the minimum tillage yields high yields.

Apart from cultivating the land, varieties that seed is also a determinant factor to increase rice yields. Rice farmers in Pasie Raya Subdistrict, Aceh Jaya Regency, Province of Aceh generally still use local varieties so that their productivity is still low. There are a lot of superior varieties that have been released by the government, but there is no information about which varieties are suitable for cultivation in Pasie Raya District, Aceh Jaya Regency. In correlation to the above conditions, we tried to research the effect of the tillage system and test some rice varieties in rainfed rice fields clearly.

2. Materials and methods

This research was carried out in the lowland alluvial rainfed rice fields, Pasie Raya Sub-district, Aceh Jaya Regency Province of Aceh, Indonesia. The materials used in this research were high rice seeds (local varieties), Ciherang, Cibogo, Inpari-13, and Situ-Bagendit. The experimental design used was Split Plot Design (SPD), where the tillage (T) was the main plot, and the variety was the subplot (V) with three replications. The main factor (T) consists of three levels, namely: without soil tillage (T0), minimum tillage (T1), and perfect tillage (T2). The second factor is the varieties (V) of 5 levels, namely: Tinggong (V1), Ciherang (V2), Cibogo (V3), Inpari-13 (V4), and Situ Bagendit (V5). Data were processed by using ANOVA and LSD 0.05 testing methods.

Research implementation includes soil cultivation before soil tillage is carried out, first the land is divided into three main plots with a size of 16 m x 17 m. Each plot is processed according to the treatment, in the T0 treatment, only spraying with herbicides are evenly distributed on the soil surface. T1 treatment; the soil was cleared of weeds by cutting, the weeds were moved to another place, then the soil was digested or harrowed, and in the T2 treatment, the soil was cultivated completely, namely by ploughing twice and harrowing once. The first tillage was carried out using a tractor to a depth of 30 cm ploughshares. After the first tillage, the soil is left for one week. Subsequently, the second tillage was carried out to destroy a large chunk of soil. The third soil tillage was carried out three days later using a plough or rake, aiming to slather the soil and level the soil. Then in each main plot is divided by five sub-plots with a size of 3 m × 5 m, each with three replications, so that each main plot has 15 sub-plots.

Observations included plant height at 8 WAP, number of tillers per hill at 8 WAP, number of panicles per clump, average panicle length per clump, the total number of grains, percentage of filled grains per clump, percentage of empty grain per clump, the weight of filled grains panicle, the weight of grains containing per clump, the weight of 1,000 grains filled per plot, and yields of tons per hectare. Moreover, Data were also projected onto principal component analysis (PCA) to observe differences and affected factors related to the soil tillage system.

3. Results

3.1 Effect of soil tillage

The results analysis of variance (ANOVA) showed that soil tillage system had a very significant effect on yield per hectare, had a significant effect on plant height and number of tillers at 8 WAP, but had no significant effect on the number of panicles, panicle length, total grain volume, percentage of filled grains per clump, percentage of dry grain. The average plant height and number of tillers at 8 WAP, number of panicles, panicle length, total grain number, percentage of full grain per clump, percentage of un-hulled grain per hill, grain weight per panicle, grain weight per hill, weight 1,000 grains and yield per hectares in various tillage cars are presented in Table 1.

3.2 Varieties impact

The analysis of variance showed varieties of rice had a very significant effect on plant height at 8 WAP, the number of tillers 8 WAP, panicle length per clump, the total number of grains, percentage of full grain per hill, percentage of un-hulled grain per hill, the weight of grain contained per panicle, 1,000-grain weight and yield per

Table 1. Average plant height and number of tillers at 8 WAP

Observed Variables	Soil tillage system			LSD
	T0	T1	T2	0.05
Plant height (cm) at 8 WAP	73.25[a]	74.87[ab]	84.18[b]	2.55
Number of tillers at 8 WAP	21.07[a]	23.82[ab]	26.67[b]	3.29
Number of panicles	17.23	15.7	15.95	-
Panicle length (cm)	22.37	22.53	23.05	-
The total amount of grain (grain)	135.43	139.94	150.19	-
(%) filled grain/clump	71.90	73.06	75.84	-
(%) empty grain / clump	28.10	26.94	24.16	-
Grain weight per panicle (g)	2.19	2.43	2.76	-
Grain weight per hill (g)	31.22	31.26	35.16	-
Weight 1000 grains (g)	23.75[a]	24.08[a]	25.09[b]	0.68
Yield (ton/ha)	3.29[a]	4.00[ab]	5.49[b]	1.02

T0 (without soil tillage), T1 (minimum tillage), T2 (perfect tillage). Values with the same superscript within the same column are not significantly different at the 5% chance level (LSD test).

hectare, significantly affected the number of panicles per hill. However, varieties treatment had no significant effect on the weight of grain contained per hill, plant height and number of tillers at 8 WAP, number of panicles, length of panicles, the total number of grains, percentage of full grain per clump, percentage of un-hulled grain per hill, grain weight per panicle, grain weight per hill, the weight of 1,000 grains and yield are presented in Table 2.

4. Discussion

Table 1 shows that the best growth and yield of rice plants were found in the perfect tillage treatment (P2) but not significantly different from the minimum tillage treatment (P1). This is in line with the research conducted by Moraru and Rusu (2013) on the impact of tillage on wheat crops. The yield of wheat at maximum tillage and minimum tillage was better than that without soil tillage. This is thought to be because perfect soil cultivation can create better soil conditions and aeration, resulting in better plant growth. Furthermore, Simanihuruk *et al*. (2007) explained that soil cultivation plays a role in preserving groundwater and soil aeration so that it can affect plant growth. The observations in this study indicate that the soil cultivation system has a significant effect on plant growth. The effect of the T0 to T2 tillage system has different impacts due to the different environmental characteristics as shown in Figure 1.

Proper tillage can suppress weed growth and create good soil aeration. On land where the number of weed populations can be suppressed and soil aeration is not a problem, soil cultivation is no longer needed because it can result in increased water loss in the root zone which disrupts plant growth (Prasetyo, 2006). In this study, the highest yield of rice production due to the soil cultivation system was found in the perfect tillage treatment but not significantly different from the minimum tillage treatment (Table 1). Tomar *et al*. (2005) explained that in perfect soil cultivation, the soil has high moisture which can provide optimal water and nutrient absorption so that rice yields can increase compared to the untreated

Table 2. Average plant height and number of tillers aged 8 WAP

Observed Variables	Variety of Rice					LSD
	Tinggong (V1)	Ciherang (V2)	Cibogo (V3)	Inpari (V4)	Situ-bagendit (V5)	0.05
Plant Height (cm) 8 WAP	73.87[b]	70.15[ab]	69.58[a]	92.44[d]	81.12[c]	3.30
Number of tillers 8 WAP	29.19[c]	23.56[b]	26.78[c]	18.82[a]	20.92[ab]	2.68
Number of panicles	17.47[b]	15.82[ab]	18.25[b]	13.55[a]	16.36[b]	2.78
Panicle length (cm)	23.71[b]	22.07[ab]	21.95[a]	23.44[b]	22.07[ab]	0.58
The total amount of grain (grain)	225.31[c]	115.93[ab]	108.16[a]	147.63[b]	112.26[a]	12.60
(%) filled grain/clump	51.76[a]	81.28[c]	77.26[bc]	74.14[b]	83.56[c]	5.84
(%) empty grain/clump	48.24[c]	18.72[a]	22.74[ab]	25.86[b]	16.44[a]	5.84
Grain weight per panicle (g)	2.19[a]	2.56[b]	2.22a	2.85c	2.48[ab]	0.29
Grain weight per hill (g)	30.40	35.85	37.01	30.34	29.14	-
Weight 1,000 grains (g)	17.67[a]	26.03[b]	25.75[b]	25.82[b]	26.26[b]	0.58
Yield (ton/ha)	4.29[ab]	4.61[b]	4.86b	3.90[a]	3.64[a]	0.67

Values with the same superscript within the same column are not significantly different at the 5% chance level (LSD test).

treatment. Besides, Zhang *et al*. (2019) found that tillage practices greatly affect the resilience and multifunctionality of the soil against the dry-wet cycle, which may have important consequences for the ecosystem remains provided by agricultural soils under recent global climate change. Wulanningtyas *et al*. (2021) explained that agriculture with a system without soil tillage and the use of ground cover crops can increase soil organic carbon (SOC), total N, available P, exchangeable K and Mg, Cation Exchange Capacity, bulk density, soil penetration resistance, and substrate-induced respiration which can improve soil conditions in soybean cultivation.

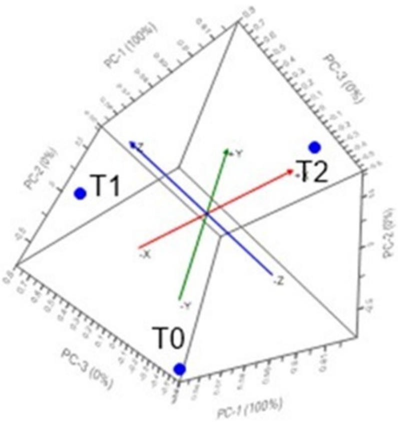

Figure 1. Score plot of PCA analysis to observe differences among soil tillage system

The yield of rice plants in the minimum tillage treatment was not significantly different from the yield of rice plants in the complete processing treatment (Table 1). Thus, based on this study, farmers do not need to cultivate perfect soil to grow rice in rainfed rice fields. Minimum tillage techniques can also reduce the cost of using labour for tillage and reduce the impact of soil structure damage due to tillage (Rayyandini *et al*., 2017); minimum tillage can also increase the activity of microorganisms in the soil to encourage a sustainable agricultural system (Moraru and Rusu, 2013). In line with this, Karlen (1990) explains that conservation soil cultivation is all soil cultivation methods and a planting system that maintains at least 30 per cent of the land surface is covered with residues or with cover crops to reduce soil erosion from rainwater collisions. In this study, the growth and yield of rice plants had a significant effect on the soil cultivation system. Judging from the results of the PCA analysis as shown in Figure 2, the total amount of grain, plant height, and pithy grain are the three main factors that are strongly influenced by the soil cultivation system. Rutkowska *et al*. (2018) explain that the reduction in tillage significantly reduces CO_2 gas emissions into the atmosphere 7-35% lower than conventional tillage systems. On the other hand, in the untreated treatment, most of the organic matter is concentrated on the surface of the soil so that the level of weathering is low and the resulting nutrients are also low, especially phosphorus, which functions to reduce the amount of un-hulled grain as shown in Figure 3.

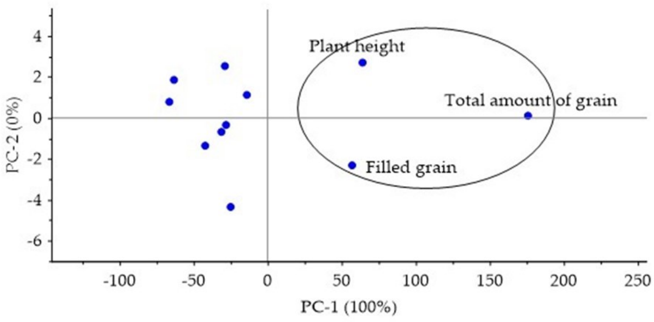

Figure 2. Dominant plant growth and yield affected by the soil tillage system

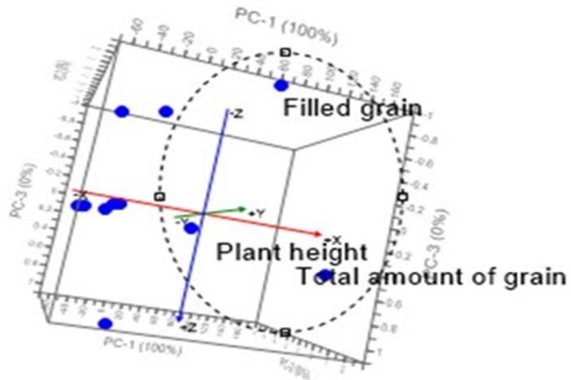

Figure 3. PCA score plot of plant growth and yield affected by the soil tillage system

Table 2 shows the growth and yield of rice from the various varieties tested in this study. The best growth was found in Situ-Bagendit variety, this is thought to be caused by differences in genetic traits of the varieties used where the Situ-bagendit variety has compatibility with the local environment and the adaptation factor to the environment greatly determines the growth and development of a plant. The difference in growth and production of rice varieties is thought to be due to differences in internal and external factors. Internal factors are the genetic characteristics of rice, while external factors are environmental conditions where rice is grown, such as soil, water, and climate conditions. Gardner *et al*. (1991) and Anhar *et al*. (2016) explained that differences in genetic characteristics of each variety such as plant age, plant morphology, yield potential, disease resistance, nutrient reserve capacity, and differences in external factors such as climate, soil, and biotics, factors causing differences in yields of plant height and number of tillers. Meanwhile, the number of un-hulled rice and the percentage of dry un-hulled rice was found in Tinggong varieties which were significantly different from other varieties.

The highest percentage of grain was found in Situ Bagendit varieties, which were significantly different from the Tinggong and Inpari-13 varieties but not significantly different from the Ciherang and Cibogo varieties. The heaviest grain weight per panicle was found in Inpari-13 which was significantly different from other varieties. The heaviest grain weight per hill was found in the Cibogo variety, although it was not statistically significant from other varieties. The heaviest weight of 1,000 grains was found in Situ Bagendit varieties, which were significantly different from the Tinggong varieties but not significantly different from the Ciherang, Cibogo, Inpari-13 varieties. Abdullah (2009) explained that the characteristics of superior rice varieties are having stronger stems, greener leaves, and thicker, medium tillers, heavier and dense panicles. The amount of grain is determined by the genetic characteristics of the plant, especially the panicle length, panicle branch, and grain differentiation (Setiobudi *et al*., 2008). Garside *et al*. (1992), stated that each variety is different in completing the generative phase, which is the filling of grain grains to influence grain weight.

5. Conclusion

The tillage system significantly affected the rice yield per hectare, significantly affected the plant height and the number of tillers at 8 WAPs. Best growth and yields are found in perfect tillage. The minimum tillage system provides results equivalent to perfect tillage and is a conservation tillage system that can maintain environmental balance. Variety had a very significant effect on plant height at 8 WAP, number of tillers of 8 WAP, number of panicles per hill, panicle length per hill, number of grains, percentage of full grain per hill, percentage of empty grain per hill, the weight of unhulled grain per hill, weight 1,000 grain and yield per hectare. Cibogo variety gave the highest yield, namely 4.86 ton/ha. The minimum tillage system can be applied to rice cultivation in rainfed rice fields in Aceh Jaya District using the Cibogo variety.

Conflict of interest

The authors declare no conflict of interest.

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References

Abdullah, B. (2009). Progress of Rice Improvement through Recurrent Selection. *Journal Agronomy Indonesia,* 37(3), 188-197.

Anhar, R., Erita, H. and Efendi. (2016). The Effect of Urea Fertilizer on Growth and Production of Plasma Nutfic of Aceh Local Rice. *Journal of Kawista*, 1(1), 30-36.

Anggraeni, T. (2020). A Comparative Study of Indonesian Estimated Rice Production and Consumption. *Journal of Policy Analysis and Public Services*, 6(2), 101-112. https://doi.org/10.31947/jakpp.vi.9279

Atika, P., Utomo, S.M. and Affandi. (1997). Effect of Various Soil Cultivation Systems and N Fertilizer Treatment on Stability of Soil Aggregate and Production of Upland Rice (*Oryza sativa* L.) Season in Ultisol Hajimena. Bandar Lampung, Indonesia: University of Lampung, MSc. Thesis.

De Abeysiriwardena, D.S. (2001). Statistical Analysis of On-Farm Yield Trials for Testing Adaptability of Rice. *International Journal of Plant Breeding (Euphytica)*, 121, 215-222. https://doi.org/10.1023/A:1012007906425

FAO. (2018). FAOSTAT Rice Production and Consumption in Indonesia, Rome. Retrieved on September 12, 2020 from FAO Website: http://www.fao.org/faostat

Gardner, F.P., Pearce, R.B. and Mitchell, R.L. (1991). Cultivated Plant Physiology: Translation by Herawati Susilo. Jakarta: University of Indonesia Press.

Garside, A.L., Lawn, R.J. and Byth, D.E. (1992). Irrigation management of soybean (Glycine max L., Merrill) in a semi-arid tropical environment. I. Effect of Irrigation frequency on growth, development, and yield. *Australian Journal of Agriculture Research*, 43(5), 1003-1017. https://doi.org/10.1071/AR9921003

Karlen, D.L. (1990). Conservation tillage research needs. *Journal of Soil and Water Conservation*, 45(3), 365-369.

Khush, G.S. (2005). What it will take to feed 5.0 billion rice consumers in 2030. *Journal of Plant Molecular Biology*, 59(1), 1–6. https://doi.org/10.1007/s11103-005-2159-5

Lopulisa, C., Rismaneswati, Ramlan, A. and Suryani, I. (2018). The Emerging Roles of Agricultural Insurance and Farmers Cooperatives on Sustainable Rice Productions in Indonesia. Presented at 1st International Conference on Food Security and Sustainable Agriculture in the Tropics (ICFSSAT), Sulawesi Selatan 24-25 October 2017, IOP Conference Presiding. https://doi.org/10.1088/1755-1315/157/1/012070

Moraru, P.I. and Rusu, T. (2013). Effect of Different Tillage Systems on Soil Properties and Production on Wheat, Maize, and Soybean Crop. *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering,* 7(11), 689-692.

Prasetyo, Y.T. (2006). Planting upland rice without cultivating the land (Revised Edition). Jakarta, Indonesia: Penebar Swadaya.

Rayyandini, K., Banuwa I.S. and Afandi. (2017). Effect of Soil Tillage system and Application of Herbicide Against Run-Off and Erosion on Generative Phase of Cassava (*Manihot utilissima*) in Secondary Planting Season. *Journal Agrotek Tropika,* 5(1), 57 – 62.

Sari, N.Y., Ete, A. and Made, U. (2017). Growth Response of Rainfed Lowland Rice Applied with Organic Matter in the Various Condition of Water Availability. *e-Journal Agrotekbis,* 5(1), 53 -57.

Sembiring, S. (2009). Growth and Production of Several Upland Rice Varieties (*Oryza Sativa* L.) at Different Spacing and Soil Preparation. Medan, Indonesia: University of North Sumatra, MSc. Thesis.

Setiobudi, D., Abdullah, B., Sembiring, H. and Wardana, I.P. (2008). Increasing Yield of New Types of Rice Through Nutrient Management of Nitrogen Fertilizers. Presented at *Symposium V on Food Crops, Food Crop Development Innovation, Agricultural Research, and Development Agency*, Jakarta 2008. Book-2 Symposium Presiding.

Simanihuruk, B.W., Kasli, Husin, E.F. and Syarif, A. (2007). The Response of Upland Rice Plants to The Effect of Inorganic Nitrogen Substituted with Tithonia Divesifolia. *Agrosia Deed Journal*, 10(2), 100-107.

Tomar, P.K., Ganwar, S., Grag, R.N., Deiwde, B.S., Gupta, V.K., Sahoo, R.N., Chakraborty D. and Moharir A.V. (2005). Effect of Tillage Systems and Moisture Regimes on Weed Growth and Productivity of Rice-Wheat Sequence in Inceptisol of Indo-Gigantic Plains. *Journal of Annals Plant Protection Sciences,* 13(1), 205-211.

Rutkowska, B., Szulc, W., Sosulski, T., Skowronska, M. and Jan, S. (2018). Impact of Reduced Tillage on CO_2 Emission From Soil Under Maize Cultivation. *Soil and Tillage Research*, 180, 21-28. https://doi.org/10.1016/j.still.2018.02.012

Wulanningtyas, H.S., Gong, Y., Li, P., Sakagami, N., Nishiwaki, J. and Masakazu, K. (2020). A Cover Crop and Without Soil Tillage System for Enhancing Soil Health by Increasing Soil Organic Matter in Soybean Cultivation. *Soil and Tillage Research*, 205, 104749. https://doi.org/10.1016/j.still.2020.104749

Zhang, B., Liang, A., Wei, Z. and Ding, X. (2019). No-tillage Leads to a Higher Resistance But a Lower Resilience of Soil Multifunctionality Than Ridge Tillage in Response to Dry-Wet Disturbances. *Soil and Tillage Research*, 195, 104376. https://doi.org/10.1016/j.still.2019.104376

