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Effect of Various High Puddles on the Growth of Aerenchyma and the Growth of Rice Plants (*Oryza sativa L*) in Pot

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Abstract: Long-term goal of the research is to improve the productivity of paddy crop which is a modification of the SRI (the System of Rice Intensification) of environmentally sound, reducing water use effectively and efficiently (saving water). In that case, the cultivation of which will be applied in the future is that paddy cultivation requires no much water (less than SRI and PTT) and the land from the beginning until the harvest is not stagnant but still moist (because the aeration of soil is pretty good) and oxidation of the soil layer becomes thicker as needed for rice productivity. While the specific objectives of this research is to study the growth of *Aerenchyma* tissue as a pathway where the release of methane gas from the soil and the growth of rice in the rice fields. This study wanted to obtain an optimal soil conditions, using Complete Randomized Design through vary of water depth level treatment (levels of soil water in pot) in the pot varies. The obtained results of this research are the latest results as different from previous research results. Finally the research obtained some conclusions; 1.) The growth of *Aerenchyma* in roots of rice plant *Batang Piaman* was not affected by high of inundation and soil water content in the potting media, 2.) The best rate of assimilation is treatment D (inundation of 10cm from the ground); 3.) the highest total number of seedlings obtained in treatment D (high pool of 10cm from the ground) which is 64.26 rods, far more than the other treatments and descriptions of varieties of rice *Batang Piaman* itself ie from 14 to 19.4; 4.) Base on the number of seedling growth parameters, high-tech farming with an inundation of 10cm below the soil surface (treatment D) can produce 180% better than conventional cultivation techniques (treatment A) 5.) We applied the latest rice cultivation technology with a high inundation of ±10 cm below the ground surface will provide an optimal effect on the growth of rice plants in field.

Key words: SRI (the system of rice intensification), *aerenchyma*, water saving, aeration of ground, the oxidation layer

INTRODUCTION

The strategy of agricultural development in Indonesia is to increase the production of environmentally sound. The study is in line with Indonesia's development strategy that is raising rice productivity with efficient use of water and methane gas emission reduction in rice fields.

Some of the factors causing the low yield of rice paddies that are conventionally performed with anaerobic soil conditions (flooded soil), among others: 1.) A large amount of energy is used for the synthesis of ethylene and for the development of aerenchyma tissue that supplies air to the roots; 2.) Rice root development is not optimal; 3.) inhibited the development of aerobic bacteria. According Venkateswarlu and Visperas (1987), a technique that has not been done optimally cultivation by farmers' causes rice plants have demonstrated the potential ability to optimally match the genetic capability. The System Rice Intensification (SRI) is one method that is applied to the intensification of crop genetic ability optimally expressed. SRI cultivation in Indonesia has begun to be applied to increase the yield of rice plant per unit area, but it is still necessary to be improved to achieve an optimal results. Of the five factors that are applied in SRI cultivation, there is some major factor that has not been clear and unequivocal in its application in field used, one of which that is not waterlogged soil conditions or the right moisture level. This factor has been no report, so it needs to be studied in depth. In addition, soil conditions in SRI methods, Integrated Crop Management (ICM) of rice plant and conventional wet rice cultivation highly correlated with the development of *Aerenchyma* as a pathway out of the soil gas methane into the atmosphere.

In terms of environment, the SRI is a method that is used in rice cultivation with highly efficient water use. According to Budi (2001), cultivation of paddy rice with wet soil can save over 40% less water than conventional methods. Conventional farming is a technical contributor to methane gas as one of the greenhouse gases that cause global warming increase. There is approximately 90% methane gas that is produced from conventional rice fields through *Aerenchyma* tissue during the

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reproductive phase (Cicerune and Shetter, 1981). Therefore, a way to reduce methane production in rice fields need to be a technical rationale for the change from conventional farming to be more technical. In addition to the environment, is no less important is the increased productivity of rice.

According to Uphoff *et al*. (2002), the SRI method was first applied in Madagascar, about the condition of the soil moist until the soil is characterized by cleavage. In line with Uphoff, Las (2004) also added that Balitpa Sukamandi developed technology ICM (Integrated Crop Management) which is a modification of the SRI to increase the yield of rice paddies. One of its components is the management of intermittent irrigation, where the muddy ground is left until the cracks. Further, according to Kasim (2000), a component of water management in SRI cultivation is characterized by muddy ground until the soil cracks. Nevertheless, it is not clear how the soil water content, soil pF value, or what percentage of the level of saturation. Differences in soil moisture content affect the development of *Aerenchyma* tissue, which in turn also correlated with the growth, production of components and productivity of rice plants. There has been no report that describes in precise and explicit about the muddy soil conditions and yet there are also reports on the development of *Aerenchyma* tissue and its correlation to the growth and productivity of rice plants. Therefore, it needs to be studied in detail the optimal conditions of muddy ground of clear and measurable at every stage of the growth of rice plants.

Based on the explanation above, the research is aimed at improving productivity outcomes of rice plant with SRI through manipulation of the environment to grow into a better direction. Optimizing the growing environment is approached with rice cultivation technology through the provision of water management and water provision and management of environmental management to grow roots. Then will be able to fix the growth of rice plants and reduce the emissions of methane gas produced from the wetland.

MATERIALS AND METHODS

Materials used in the experiment are a type of rice varieties namely *Batang Piaman*, compost, fertilizer (urea), *SP36* and *KCl*, *Currater 3-G* and 2, 4 *dimethyl amine*. Meanwhile, the equipment used was a small pail (30 cm diameter), large pail, (60 cm diameter), sprayer, bar, pH meter, analytical balance and so forth.

Research was conducted in the greenhouse which aims to assess the pool of water high in the outer pot on the growth of rice plants. High puddle outside the pot (soil moisture) is how to *aerenchyma* tissue does not grow but the growth of rice to be optimal. k out the optimal pot. Then, moisture is how the planting medium is suitable to support the growth of rice after high puddle outside the optimal pot found in this study.

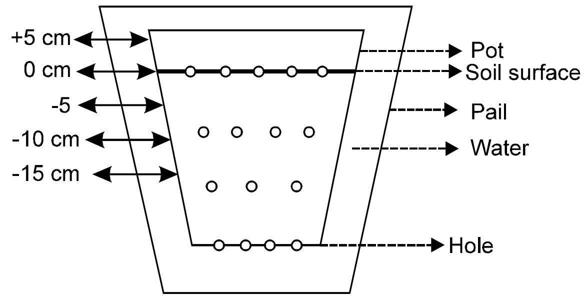

Fig. 1: Experiment tools.

Pot: As a growing medium containing soil

Pail: Filled with water, place pot into water levels in accordance with the treatment that is +5 cm, 0cm, -5 cm and -10 cm

Hole: The entry of water into the pot, made 4 rows and rows equal to the height of the top surface of the water outside the pot according to the treatment, each line number 8 hole, while the number of holes in the bottom of the pot plants have 9 holes.

Water: Outside of pot or inside of pail is filled with water.

A = +5 cm, water depth level in pail, 5 cm above ground level in the pot

B = 0 cm, water depth level in pail, the same as the soil surface in the pot)

C = -5 cm, water depth level in pail, 5 cm below the soil surface in the pot)

D = -10 cm, water depth level in pail, 10 cm below the soil surface in the pot)

E = -15 cm, water depth level in pail, 15 cm below the soil surface in the pot)

Rice grown in soil media in the pot holes are given (way for the incoming water), while the pot is submerged in a bucket under a larger and high surface puddles outside the pot, higher or lower than the surface soil in the pot (in accordance with their each treatment). Soil in the pot is not given water, but water is obtained or derived from infiltration of water from the catchment that lies outside the pot (the water in the bucket). High pool of the bucket is the treatment that will give different values of water content in the pot as a growing medium. This study tested the high pool of five treatment differences in the bucket to the ground surface in the pot (Fig. 1).

The treatment in this experiment of high pool of five treatment differences in the bucket are as follows:

A = +5 cm (5 cm above ground level in the pot)

B = 0 cm (the same as the soil surface in the pot)

C = -5 cm (5 cm below the soil surface in the pot)

D = -10 cm (10 cm below the soil surface in the pot)

E = -15 cm (15 cm below the soil surface in the pot)

We use a completely randomized design with three replications, so we get 15 experimental units. Each experimental unit contained seven potted plants, in order

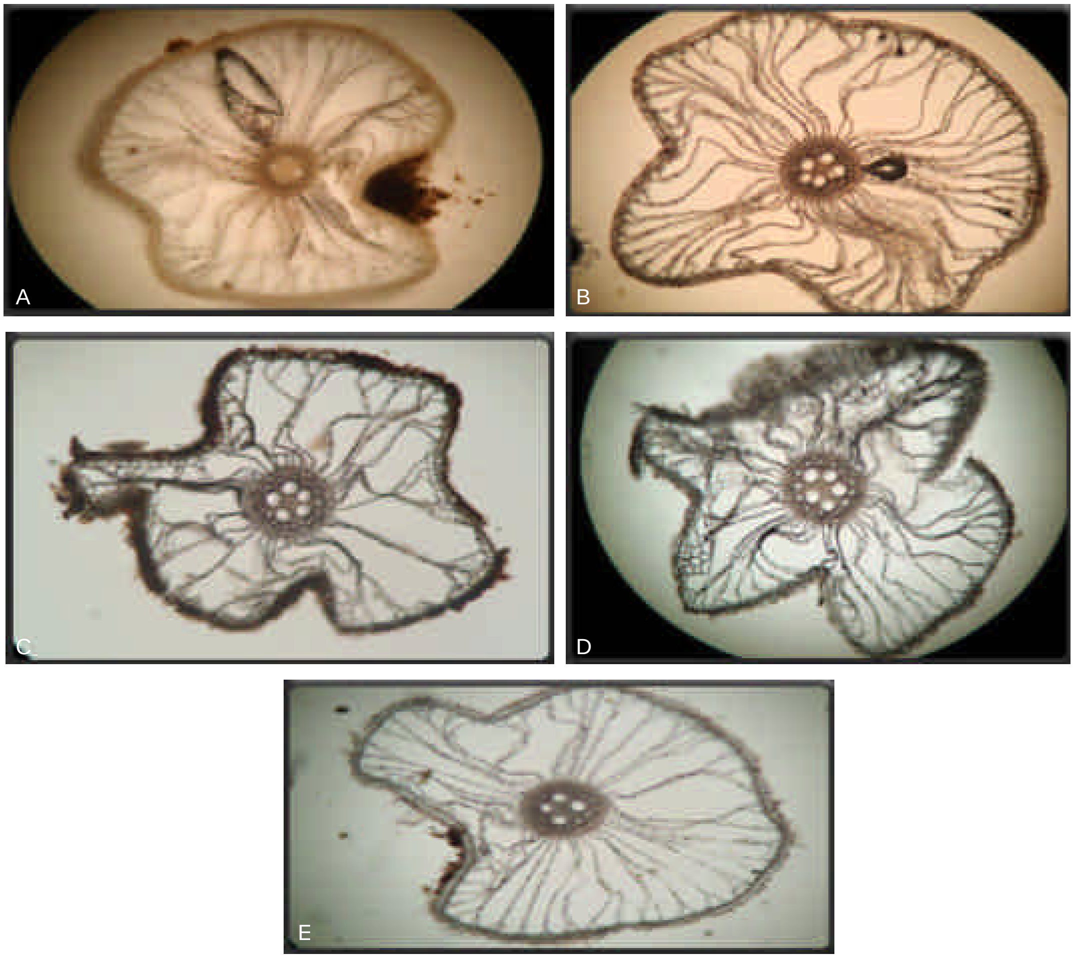

Fig. 2: *Aerenchyma* in each treatment A, B, C, D and E formed the larger cavities are scattered throughout the cortical tissue with a score of 3

to obtain 105 the number of pot plants. Seven clumps of plants in each experimental unit used for the observation of *Aerenchyma* tissue development and growth characteristics (vegetative) by 5 clumps of plants, while two more clumps of plants used for the observation of other parameters.

RESULTS AND DISCUSSION

Aerenchyma: Observation to *Aerenchyma* tissue shows that all treated base, center and tip of the root results a score of 3. Mano *et al.* (2005) said that within the growth of *Aerenchyma* tissue there are 5 types namely score 0 describes the *Aerenchyma* is formed, a score of 0.5 described the *aerenchyma* formed in part, a score of 1 represents the radial *aerenchyma* and a score 2 illustrates that aerenchyma well or perfectly formed (Fig. 2).

Results of *Aerenchyma* observation that were subjected to various height differences in a puddle of water outside the pot showed that the growth of *aerenchyma* is not affected by the high difference in the puddles outside the pot. In Fig. 2, it can be seen that large *aerenchyma* in the cortex tissue was relatively similar in each treatment.

Table 1: The average score of the development of *aerenchyma* tissue of various types of high inundation in lowland rice varieties *Batang Piaman*

Treatments	Average
A (+5)	3.00a
B (0)	3.00a
C (-5)	3.00a
D (-10)	3.00a
E (-15)	3.00a

Figures followed by same letter in the same column means it does not differ according to the test at the level of 5% DMNRT

Results of statistical analysis as shown in Table 1, shows no difference, although given a different treatment; water saturated soil or hypoxia (treatments A and B) and unsaturated soil (treatment C, D and E). The results of this study differed with Smirnoff and Crawford (1983) and Justin and Amstrong (1987) which states hypoxia induces *aerenchyma* in roots and increased the number of *aerenchyma* in species that have constitutive *aerenchyma*. Furthermore, the results of this study also differed with Yoshita (1981) and Webster and Gunnell (1996) which states that the rice fields have the power of a good adaptation to aerobic environments, where lies the *aerenchyma* serves as an internal air system to provide oxygen diffusion into the root system. Instead, the results of this study show that rice varieties of *Batang Piaman* do not have adaptation ability to different environmental conditions due to the treatment given. At different conditions (aerobic and anaerobic soil), the growth of *aerenchyma* remain the same.

Aerenchyma tissue development in rice is largely determined by genetic factors, because the cultivation of the soil is not waterlogged or flooded will show a large network of fixed *aerenchyma* in the study were given a score of 3. Relationship of genetic and environmental factors has been studied by various experts. By Crowder (1986) if it remains stable despite the growth of plants grown in a very different place, it indicates that the growth of these plants is largely determined by genetic factors. As Zimmermann *et al.* (2000) say, that the development of different rice *aerenchyma* in maize. *Aerenchyma* in maize tissues are very sensitive to water logging.

Net assimilation rate: Net assimilation rate is defined as an increase in plant dry weight per unit time per leaf area. Net assimilation rate can be viewed as a measure of the efficiency of each unit area of leaf photosynthesis for plants to accumulate dry matter. Net assimilation rate of leaf area is affected by the ongoing capture of solar radiation and light intensity and temperature. Temperature directly affects the activity of photosynthesis and respiration processes that substrate is dry material that accumulated during the process of photosynthesis. The development of net assimilation rate of rice varieties with the provision of treatment *Batang Piaman* high puddles looks range from age 5 weeks to 9 weeks. In Figure 3 can be seen 5-7 weeks of age of the plant net assimilation rate (LAB) is flat at both increasing. LAB then decreased at the age of 8 weeks for the treatment plant B (high inundation or equal to 0 m ground level). Whereas the other treatments showed LAB remained elevated, but a sharp increase in LAB occurs in treatment D (high pool of 10 cm below the surface). Generally, the development of LAB decreased at 8 weeks of age of the plant, it is in accordance with the opinion of Goldsworthy and Fisher (1996) which states that the development of LAB decreased at *anthesis*.

The average value of LAB during the 5-9 week old plants shows the LAB developmental differences after treatment were given a different pool can be seen in Table 2.

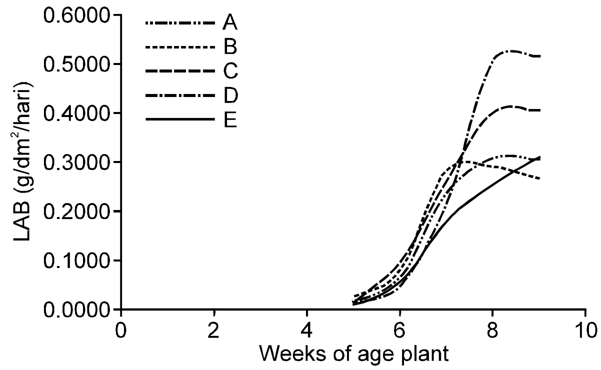

Fig. 3: LAB growth (net assimilation rate) from the age of 5-9 weeks of treatment by administering a pool of different height

Table 2: LAB average value as results of treatment application by administering a pool of different height to rice variety *Batang Piaman* ($g/dm^2/week$)

Treatments	Average
D (-10)	0.44a
A (+5)	0.36ab
C (-5)	0.34ab
E (-15)	0.32ab
B (0)	0.26b

Figures are not followed by same letter within a column means significantly different according to the test at the level of 5% DNMRT

In Table 2, it can be seen that the height of a pool for each treatment were significantly different. LAB in the treatment of high pool of 10cm below ground level (treatment D) is the best treatment and significantly different from a pool of equal height with the ground surface (treatment B). This is in accordance with the opinion of Patrick *et al.* (1985) who said that the flooding will alter the physical properties of soil (air balance, aeration, aggregation and temperature) and physico chemical (pH, ion concentrations and changes in *redox* potential and nutrient availability). PAD stagnant conditions, loss of N occur through evaporation, de-nitrification and leaching. This causes the efficiency of rice to absorb N is lower than the dry land rice.

Compared to the growth of *Aerenchyma* (Table 1) with a value of LAB (Table 2), there was no relationship with LAB *Aerenchyma* growth in *Batang Piaman* rice varieties, for different soil conditions do not provide a real influence on the development of *aerenchyma*. On the contrary, different soil conditions to give the real effect of the LAB, LAB values at Diman D treatment compares favorably with other treatments. These results contradict the opinion Bakelaar (2001) which states that the condition of waterlogged or saturated ground water occurs in a state of hypoxia, where the roots are not well developed so that the roots take nutrients coverage will be limited and there is adaptation to anaerobic environments so that the rice crop will form *aerenchyma* to supply oxygen from the atmosphere; presence of aerenchyma took place approximately 30%-40% of the root cortex, thus potentially interfere with the transport of nutrients and water from the soil into the xylem tissue.

The number of total tillers: Number of tillers related to environmental conditions such as availability of sufficient water, nutrient availability, aeration and irradiation. by providing a pool of media treatment of high ground, then place the soil media is full of water or the relative thickness of oxidation layer does not exist (treatments A and B), the thickness of oxidation layer 5 cm (treatment C), the thickness of oxidation layer 10 cm (treatment D) and thickness oxidation layer of 15 cm (treatment E). This difference in the thickness of oxidation layer in fact lead to the growth of a varied number of tillers, as can be seen in Fig. 4.

Observation of the number of seedlings planted starting from the age of 4-9 weeks. Relatively equal number of suckers on the plant age of 4 weeks then increased until the age of the plant 9 weeks. However, treatment of D is much higher increase compared with other treatments. Whereas treatment of C, B, A and E tends to increase relatively the same and rather flat. This indicates that the soil conditions that have oxidation layer thickness 10 cm is the optimal soil conditions and the availability of water and nutrients are optimal. Compared to Figure 3 the development of LAB, the LAB visible improvement in the treatment of D is relatively the same with an increase in the number of tillers. It is because LAB is a source for the growth of the tillers.

Furthermore, the number of sampling can be seen at higher D treatment and significantly different from other treatments as shown in Table 3.

In Table 3 above, it can be seen that the average total chicks on treatment D significantly different from other treatments. The treatment D had a significant total number of suckers. This is caused by good condition of aeration and increased activity of microorganisms that overhaul C-organic growing fast for the formation of the puppies. Availability of appropriate water also affects the growth medium. Whereas in the other treatments can suppress the growth of the maximum number of tillers caused by the drawing of energy to supply air into the soil and root development are not optimal due to poor aeration thereby reducing vegetative growth phase induced inhibition of photosynthesis, as a result of photosynthesis and the allocation for the establishment of seedlings also reduced, so the number of puppies produced is also declining. While the E although the treatment of aerobic soil layer, the availability of sufficient water is not thought to be optimal for the growth of rice seedlings so that the total number is smaller than the treatment D. Gardner *et al*. (1991) states that the number of suckers would be maximized if the plants have a genetic trait with favorable environmental conditions or in accordance with plant growth. it is also in accordance with the Ismunadji *et al*. (1988) opinion which states that the maximum number of seedlings is determined by solar radiation, mineral nutrients, soil and environmental conditions of the technical cultivation itself. Therefore, the maximum number of tillers will increase when the condition is fulfilled by a good crop in the vegetative phase to the generative phase.

Fig. 4: Growth of tillers from the age of 4-9 weeks of treatment by administering a different pool of water high

Table 3: Average total number of seedling from the various applications of high inundation in toward rice varieties *Batang Piaman*

Treatments	Average
D (-10)	64.16A
C (-5)	36.50b
A (+5)	35.50b
E (-15)	33.00b
B (0)	32.83b

The figures are not followed by same letter within a column means significantly different according to the degree of test DNMRT 5%

The number of the growth of tillers in treatment D is much better than other treatments. This indicates that the vegetative growth phase needs sufficient water for crop and soil environmental conditions to aerobic oxidation of the soil layer is thicker than the others, except for treatment of E. According Arraudeau and Vergara (1992), the water acts as a major limiting factor is absolutely required by the plant as a carrier of nutrients to the plants and plant temperature control. Furthermore Doorenbos and Pruit (1975) also confirm that the rice plants with optimal productivity does not require excessive water, rice plant requires much water in the vegetative phase of 320 mm over 60 days, similar to soybean plants that require the most water in the flowering phase which is 292 mm (in contrast to 10%) for 45 days, corn requires most water on the grain filling phase of 250 mm (unlike 28%) for 40 days.

Conclusion:

a. The growth of *aerenchyma* in roots of rice plant variety of *Batang Piaman* was not affected by depth of inundation, soil water content in the potting media.

b. The rate of assimilation is best to treatment d (high pool-10 cm of the soil surface or ground water at levels of 37.60%.
c. The highest total number of tillers obtained in treatment D (high-puddle-10 cm of soil surface) which is 64.16 rods, far more than the other treatments and descriptions of the varieties Trunk Piaman 14-19.
d. In term of the parameters of the growing number of tillers, cultivation technology with high-puddle-10 cm below the soil surface (treatment D) resulted in the number of pups 180% better than conventional cultivation techniques (treatment A).
e. We applied new rice cultivation technology with a high pool of approximately 10 cm below the soil surface will provide an optimal effect on the growth of rice plants.

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