Application of pumping and rice planting patterns to improve the productivity of fresh water swampy rice fields in South Sumatra, Indonesia

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Abstract. Productivity of the fresh water rice fields is currently relatively low due to various factors such as cropping patterns and water factors. This study aimed to compare four cropping patterns in cultivation of swampy fresh water rice. The four cropping patterns consisted of the cropping patterns of Farmer Entrepreneurs, Conventional Farmers, Fostered Farmers of *Jajar Legowo Super*, and Fostered Farmers of *Tegel Diairi*. The study used descriptive method by collecting primary data presented in tabular forms. The primary data were the plant height (cm), maximum number of tillers (stems/clumps), productive tillers (stems/clumps), panicle length (cm), number of grains/panicles, dry weight of biomass and grains of rice, weight of 1000 grains (g), and land productivity (tons/ha). The study was conducted in Pemulutan Subdistrict, Ogan Ilir District of South Sumatra. The cropping pattern of Fostered Farmers of *Jajar Legowo Super* with the pumping was the best treatment viewed from the agronomic performance, namely the highest number of grains per panicle of 115.72, the number of pithed grains per panicle of 110.53, weight of 1,000 grains (g) of 22.07 and grain productivity of dry harvest of 7.33 tons/ha. The treatment of conventional farmers' cropping pattern was the lowest one in terms of the lowest number of grains per panicle which was 72.24, the number of pithed grains per panicle which was 67.43, the weight of 1,000 grains (g) which was 18.55, and the productivity of dry grains which was 1, 69 tons/ha.

1. Introduction

Fresh water swamps are lands that are always saturated with water or waterlogged. The area of swamps in Indonesia is ± 33.4 million ha, consisting of about 20 million ha of tidal swamps and 13.4 million ha of swampy lands [1]. The area of fresh water swampy rice fields in South Sumatra is 285,941 ha with an area of 166,908 ha planted with rice once a year, 29,966 ha is planted with rice twice a year, 8,982 ha is planted other than rice, and 80,085 ha is abandoned or idle land [2]. If the idle land is managed, the productivity of fresh water swampy rice fields in South Sumatra could increase significantly.

The risk of crop failure for farmers of fresh water swampy rice fields is relatively high with relatively low productivity. The main obstacle in developing rice farming in the fresh water swampy area is highly dependent on natural factors. The most influential factor is the weather; in the wet season the rice fields are flooded, whereas in the dry season droughts occur. These two factors

continue to recur every year that the life of farmers in the area is difficult to develop in terms of economics.

The current low productivity of fresh water swampy rice fields is due to various factors, one of which is the use of inappropriate planting distance, farmers tend to assume that the narrower the spacing, the more yield will be because more and more plant populations are planted. The planting distancing is a pattern of spacing between plants in farming including spacing between lines and rows. Plant spacing will affect agricultural productivity because it is related to the availability of nutrients, sunlight, and space for plants. Plant spacing arrangement is important for plants because it can influence the capture of sunlight for photosynthesis, the effectiveness of nutrient absorption by roots, water requirements, air circulation, microclimate (temperature and humidity), and weed populations and PDO (plant-disrupting organisms). The next dominant factor is water management.

According to [3], the cropping pattern of *Jajar Legowo Super* can also increase production. The advantages of *Jajar Legowo* cropping pattern when compared to transplanting planting are (1) more number of broad unity plants means more productivity; (2) intermittent planting distance causes more air circulation and sunlight to enter, thereby reducing pest and disease, and (3) fertilization and weeding become easier to save labor costs.

The *legowo jajar* system is one that aims to manipulate the layout of plants so that each rice grove becomes a side crop. The rice plants that are on the edge will get sunlight. The right cropping pattern determines productivity. Rice planting methods need to be improved so that productivity and quality increase [4]. There are some things to consider such as rice varieties, planting methods, and also pump irrigation. According to [5], water management is one of the keys to the success of increasing rice production in rice fields. This causes the production of lowland rice will decrease if the rice plants lack water. Common symptoms due to lack of water include rolling rice, leaf scorching, reduced tillers, dwarf plants, delays flowering, and the seeds become hollow [6]. This study aimed to compare the agronomic performance of fresh water swampy rice with different planting patterns planted with different cultivation systems.

2. Materials and Method

2.1. Land preparation

First, the rice fields were cleared of grass and shrubs using parangs or sickles. After clearing rice fields, the soil is processed. The land preparation was conducted in two stages, well-known as plowing and puddling. After plowing, the soil was usually left for 10-15 days, and it was then followed by puddling.

2.2. Rice seeding

The seedings were carried out on the lands of *Jajar Legowo* Fostered Farmers, *Tegel* Fostered Farmers, and Conventional Farmers. The rice seeding was carried out in a plastic tray of 30 cm wide, 40 cm long and 8 cm high. The tray was filled with soil taken from the rice fields. The seedlings in the seedbed took about 15 to 20 days.

2.3. Rice planting

The age of seeds that could be moved was around 15 to 20 days with the characteristics of having about 5 – 6 leaves, 22 – 25 cm high, large and hard lower stems, and free from attack by pests. On the land of *Jajar Legowo Super* Fostered Farmers, the rice was planted with the 2:1 "*Jajar Legowo Super*" system having planting spacing of 12.5 x 25 x 50 cm. The number of seedlings planted was 2-3 stems each hole. The *Tegel Diairi* Fostered Farmers and Conventional Farmers used a spacing of 25 cm x 25 cm, while the Farmer Enterpreneur used the Direct Seed Planting (*Tabela*) by spreading the seeds and this required relatively a lot of seeds of around 50 kg per hectare.

2.4. Maintenance

The maintenance phase consisted of weeding, watering, fertilizing, and controlling pests and diseases. The weeding was carried out by controlling weeds that grew to reduce the level of competition with the rice. The watering was conducted to meet the needs of rice water both in terms of quantity and quality. If there is a shortage, irrigation can be done, and if there is an excess, drainage can be constructed.

2.5. Sample collection

This study was conducted using survey methods. The 1 hectare observation area was divided into three plots having five observing points. On the four fields, they had differences in each of the four rice crop patterns (Table 1). The observations covered the plant height (cm), maximum number of tillers (stems/clumps), productive tillers (stems/clumps), panicle length (cm), number of grains/panicles, dry weight of biomass and grains of rice, weight of 1000 grains (g) weighed using analytical balance, and land productivity (ton/ha).

Table 1. Differences in Rice Cropping Patterns in Fresh Water Swampy Land of Pemulutan Subdistrict

Characteristics	Enterpreneur Farmer	Conventional Farmer	Fostered Farmer of *Jajar Legowo Super*	*Tegel Diairi* Fostered Farmer
IP Land	IP 200 (Main)	IP 100 (Main)	IP 200 (Main and Ratoon)	IP 200 (Main and Ratoon)
Planting System	*Tabela*	*Tegel Diairi*	*Jajar Legowo Super*	*Tegel Diairi*
Watering	Pumping	-	Pumping	Pumping
Time of Plant	April, December	May - September	May - September	May - September
Seed treatment	Seeds soaked with folicur fungicide + ZPT	-	Seeds soaked in biophytes	Seeds soaked in biophytes
Variety	Hybrid	*Ciherang*	*Mekongga*	*Mekongga*

2.6. Data analysis

The research method used descriptive methods by collecting primary data and presented in tabular forms.

3. Results and Discussion

Agronomic performance referred to plant height, maximum number of tillers, productive tillers, panicle length, number of grains/panicles, dry weight of biomass and grains of rice, weight of 1000 grains, and land productivity in the four cropping patterns of fresh water swampy rice presented in Table 2. The height of the rice plant showed that the highest value was obtained by the Farmer Enterpreneur cropping pattern which was 104.86 cm, and the Fostered farmers of *Tegel Diari* which was 100.87 cm, and the Fostered farmers of *Jajar Legowo Super* which was 92.67 cm, while the lowest one was the Conventional Farmer which was 76.53 cm.

The highest number of tillers was the Farmer Enterpreneur which was 23, then the Fostered Farmer of *Jajar Legowo Supe*r which was 19.2, and Fostered Farmer of *Tegel Diari* was the same as Conventional Farmer which was 15.73. The number of productive tillers could be the ones that developed further and produced panicles. The highest number of productive tillers was 15.8 for Farmer Enterpreneur, followed by the Fostered Farmer of *Jajar Legowo Super* which was 13.67 and the Fostered Farmer of *Tegel Diari* which was 12.07, while the lowest one was the Conventional

Farmer (Figure 1). The highest dry weight of biomass in the *Jajar Legowo Super* Farmer cropping pattern was 31.41 g, while the lowest one obtained in the Conventional Farmer cropping pattern which was 8.13 g. The dry weight of rice biomass of Conventional Farmer was significantly different from that of other cropping pattern farmers.

Table 2. The average of growth and yield components of rice with four cropping patterns and three replication

Components of Growth and Yields	Enterpreneur Farmer	*Tegel Diairi* Fostered Farmer	Fostered Farmer of *Jajar Legowo Super*	Conventional Farmer
Plant Height (cm)	104,86	100,87	92,67	76,53
Number of tillers per clump	23	15,73	19,2	15,73
Number of productive tillers	15,8	12,07	13,67	8,13
Dry weight of biomass (g)	28,63	31,23	31,41	13,77
Panicle length (cm)	23,45	21,52	22,79	19,64
Number of heads per panicle	105,88	91,95	115,72	72,24
Number of pithy ears per panicle	91,027	83,19	110,53	67,43
Number of hollow ears per panicle	14,85	8,76	5,19	4,68
Weight of 1,000 ears (g)	19,77	20,86	22,07	18,55
Panicle weight/clump (g)	32,44	23,61	34,37	10,58
Panicle weight g/m^2	444,60	377,91	732,77	169,25
Productivity tons/ha	4,44	3,78	7,33	1,69

The highest panicle length was the Enterpreneur Farmer cropping pattern of 23.45 cm, the Fostered Farmer of *Jajar Legowo Super's* cropping pattern of 22.79 cm, and then the Fostered Farmer of *Tegel Diairi's* cropping pattern of 21.52 cm, while the lowest panicle length was the Conventional Farmers' cropping pattern which was 19.64 cm. The highest number of grains per panicle in the cropping pattern of *Jajar Legowo Super* was 115.72, followed by the cropping pattern of Enterpreneur Farmer which was 105.88 and the Fostered Farmer of *Tegel Diari* which was 91.95, while the least number of grains per panicle was in the Conventional Farmer's cropping pattern which was 72.24.

The highest number of rice grains per panicle in the cropping pattern of Fostered Farmer of *Jajar Legowo Super* was 110.53, then the Enterpreneur Farmers which was 91.03 and the Fostered Farmers of *Tegel Diari* which was 83.19, while the least number of rice grains per panicle was that of Conventional Farmer which was 67.43. The least number of hollow grains per panicle was that of Conventional Farmer's cropping pattern which was 4.68, then that of Fostered Farmer of *Jajar Legowo Super* which was 5.19, and that of the Fostered Farmer of *Tegel Diairi* which was 8.76, while the highest hollow grains per panicle was in the Enterpreneur Farmer's cropping patterns which was 14, 85 (Table 2).

The weight of 1,000 grain of rice showed that the cropping pattern of Fostered Farmer of *Jajar Legowo Super* was the most weighted which was 22.07 g, that of Fostered Farmer of *Tegel Diairi* which was 20.86 g, and that of the Enterpreneur Farmer Company which was 19.77 g, while the least heavy was that of the Conventional Farmer which was 18.55 g. Each weight of 1000 seeds in the Enterpreneur Farmer's cropping pattern was 19.7 g, in the Conventional Farmer it was 18.55 g, and in the cropping pattern of the Fostered Farmer of *Tegel Diairi* it was 20.86 g, and that of Fostered Farmer of *Jajar Legowo Super* it was 22.07 g. The panicle weight per clump of cropping pattern of the Fostered Famer of *Jajar Legowo Super* was 34.37 g, followed by that of the Enterpreneur Farmer which was 32.44 g, and the Fostered Farmer of *Tegel Diairi* which was 23.61 g, while the least weighted one was that of the Conventional Farmer which was 10.58 g.

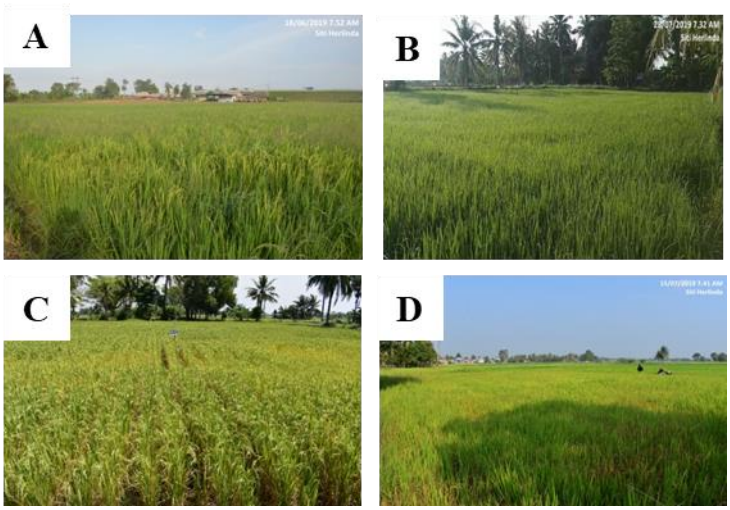

Figure 1. The characteristics of four fresh water swampy rice fields which were 56 days old after planting: Company Farmers (a), Fostered Farmer of *Tegel Diairi* (b), Fostered Farmer of *Jajar Legowo Super* (c), and Conventional Farmers

The panicle weight per m^2 cropping pattern of the Fostered Farmer of *Jajar Legowo Super* was 732.77 g, then that of the Enterpreneur Farmer which was 444.60 g, and that of the Fostered Farmer of *Tegel Diairi* which was 377.91 g, while the least weighted was that of the conventional Farmer which was 169.25 g. The highest crop productivity of the Fostered Farmer of *Jajar Legowo Super* was 7.33 tons/ha of harvested dry rice, then that of the Enterprise Farmer which was 4.44 tons/ha, and the Fostered Farmer of *Tegel Diairi* which was 3.78 tons/ha. The lowest crop productivity was the Conventional Farmer which was 1.69 tons.

Planting spacing is a pattern of spacing between plants in farming which includes spaces between lines and rows. The plant spacing will affect agricultural production because it is related to the availability of nutrients, sunlight and space for plants. Wide spacing provides opportunities for plant varieties to express their growth potential. The closer the plant population is, the smaller the number of tillers and panicle length per clump [7] will be. The wide spacing gives plants the freedom to get nutrients and sunlight so that the plants with a wide spacing will be more optimal in metabolizing and producing growth in the number of tillers [8].

According to [9], increase in plant height due to plant canopy getting denser will result in the decrease of the quality of light received by the plants. The closer the plant spacing is used, the higher plant growth will be faster because each plant tries to get more sunlight. The cropping pattern of the Enterpreneur Farmer used *Tabela* (direct seed planting) system so that the plant spacing was very tight. The sunlight and plant population density affected the plant height growth; the high plant density gave rise to competition of sunlight absorption that the leaves did not expand but the stem segments got much longer.

The number of tillers per clump showed that the cropping pattern of the Enterpreneur Farmer was the most, 23 tillers per clump. It was presumed that the plant spacing was different; if the plant spacing got tighter, more number of tillers would be produced. The cropping pattern of *Jajar Legowo Super* (2:1) could produce high grain production and got quality grains because the spacing system could reduce the hollow ones due to the effects of peripheral plants. This is consistent with the statement [10] stating that higher yields are achieved with the *Legowo* row planting system compared to the 25 cm x 25 cm tile system. The closer the plant spacing that produces more tillers is, the better the root growth will be.

The results of the study [11] showed that the *Jajar Legowo* of 2:1 cropping pattern with spacing of 25 x 12.5 x 50 cm could increase yields between 9.63 to 15.44% compared to that of *Tegel Diairi* cropping pattern. The greater the distance of the tillers to produce more is, the better the root growth is compared to the narrower spacing. However, to get better quality seeds, the *Jajar Legowo Super* of 2:1 cropping pattern should be used. It is able to reduce the emptiness resulted from the effects of peripheral plants [10]. According to [12], the cropping pattern of *Jajar Legowo Super* is the basic principle of making all rows of the plants and peripheral plants. And among the groups of rice plant plots there are wide aisles and longways along the rows causing more sunlight to enter the rice fields and open the opportunities for border effect to each plant that the plants grow better and the resulted grains are fuller (pithy) which ultimately the plants have higher productivity.

Jajar Legowo Super system is the one aiming to manipulate the layout of plants so that each clump of rice becomes the peripheral plants. The peripheral rice plants will get optimum sunlight. On the land of Enterpreneur Farmers' cropping pattern the farmers used an electricity pumping system. On land with a Fostered Farmer's cropping pattern when the seedlings are 15 to 20 days old, the seeds are ready to be sown or planted according to the spacing of each treatment [13]. After transplanting land was divided into two, namely the lands using *Jajar Legowo Super* and *Tegel Diairi*, the two lands used a pumping system to prevent the land from getting drought. The constraint that could not be managed but was needed by smallholder farmers in intensifying food production was technology solution for uncertain and uncontrollable natural flooding and drought occurrence in fresh water swampy rice fields. Government intervention is expected for constructing infrastructure for water management in fresh water swampy rice fields., i.e. polder system[14].

The results of the study [15] showed that the use of irrigation was more appropriate to increase the planting index of 2 to 3 times a year. Farmers can enjoy the results with two or three harvests a year. In order to better support the program, related parties can provide various types of training and guidance so that the farmers can increase their productivity in accordance with the expected results. The automatic irrigation process in order to develop properly must have requirements, namely the user easily adjusts the water level needed for planting and uses the system for the proper irrigation process. This long-term irrigation will help reduce water waste and time [16]. The photovoltaic (PV) irrigation system is the best technological solution for agricultural use such as irrigating crops. The photovoltaic-powered water pumping system assists water pumping consisting of solar panel arrangement and AC / DC water pump [17].

4. Conclusions

Based on the results of the study, it is concluded that cropping pattern of Fostered Farmer of *Jajar Legowo Super* with pumping was the best treatment viewed from the highest number of grains per panicle which was 15.72, the number of pithed grains per panicle which was 110.53, weight of 1,000 rice grains (g) which was 22.07 and productivity of harvested dried rice which was 7.33 tons/ha. The treatment of Conventional Farmer's cropping pattern was the lowest treatment in terms of the lowest number of grains per panicle which was 72.24, the number of piths per panicle which was 67.43, the weight of 1,000 grains (g) which was 18.55, and the productivity of dried grains which was 1.69 tons/Ha.

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