Field Adaptation for Watermelon Cultivation under Shallow Ground Water Table in Tidal Lowland Reclamation Area

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Field Adaptation for Watermelon Cultivation under Shallow Ground Water Table in Tidal Lowland Reclamation Area

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ABSTRACT

Agriculture productivity of tidal lowland reclamation areas in South Sumatra is still low. It leads to the increasing of agricultural land conversion into plantation areas. Controlling the water table is the main factor in the tidal lowlands; this research aimed to develop micro drainage system in tertiary block for controlling water table under wet condition. Watermelon was used as a crop indicator and planted in mid-March 2015. The location of the research was in a tidal lowland agriculture with land typology B, a land where the tide can only be as irrigation during the rainy season. The method of this research was surveying and monitoring. Groundwater observation, measurement value hydraulic conductivity and land drainage applications were included in the field activities. The design of land drainage used an intensive shallow drainage concept; the effect of the depth of the water table to water status was evaluated by the UPFLOW model. A micro drainage on tertiary block was used by 8 m drain spacing, with channel depth of 20 cm. The results showed that the tertiary gate operation was maximum drainage option. The water table depth was 25 cm in soil depth. The watermelon crops grew well and production reached 20 t ha^{-1}.

Key words: *drainage; tidal lowland; water table; watermelon*

INTRODUCTION

Increaseing food production becomes essential to meet the population growth. Rice production in Indonesia has so far been supplied by swampland areas, including outside of Java island like Sumatera island (Shultz, 2016). A problem occurs when there is a decrease in soil quality and more over there are many lands change their function to plantation (Aswandi *et al*., 2017). Such land conversion caused negative impacts to the soil, like decreasing biophysical soil conditions for paddy production and damaging infrastructure network of water system. Currently only 45 % of the tidal lowland in Telang II Banyuasin (South Sumatera) is cultivated to food crops (Imanudin *et al*., 2010). Therefore, the agricultural development in tidal lowland reclamation areas should take into account the physical and environmental conditions, so the value of the investment is proportional to the profit earned and the sustainability of food agriculture is maintained (Zhu *et al*., 2017).

In other places in Sumatera, oil palm profits are able to be overcome by intensive farming models of food crops if tidal lowland is equipped with infrastructure network of water system. This tidal lowland is able to be planted three times per year with the pattern of paddy-corn-corn. This condition can generate higher income than oil palm cultivations (Imanuddin & Bakri, 2014). This report suggests that economic values is considered as crop diversification effort.Watermelon is one of the potential crops for crop diversification. This crop has a high economic value because of the high demands for domestic consumption. Watermelon cultivation in upland can double the income compare to paddy crops. While watermelon cultivation in Iran under full irrigation water requirement got high production of 37.45 t ha^{-1} per year (Barzegar *et al*., 2017). It is also reported that the condition is very potential in tidal lowland after paddy. Watermelon cultivation on 0.5 ha of lowland gave Benefit Cost Ratio (B/C) of 3.76 while for paddy crops showed B/C just

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1.57. The same research on watermelon in Iran showed the average yield value of B/C of 2.61 (Nosetto *et al*., 2009; Asri *et al*., 2012).

Watermelon is commonly planted in upland. Second crop cultivation of tidal lowland needs some efforts to reduce soil wetness level in the rooting zone for reducing groundwater table. This main problem in watermelon cultivation on tidal lowlands is a shallow groundwater table condition. The production can fall upto 20-50 % when the ground water level is too shallow (about 10-20 cm under the soil surface). The very shallow water level can decline production because it disturbs plant growth and root respiration (Nosetto *et al*., 2009). However, the depth of the ground water level should not be deeper than 100 cm. These conditions contributed sufficient capillary water to meet the needs of crop evapotranspiration. A research on sandy loam soil showed a significant contribution of groundwater capillary in 70 cm depth below the soil surface. In this condition 80% of the crop water requirement can be supplied from groundwater capillarity (Udom *et al*., 2013). China is the largest watermelon producer in the world; approximately 68 % of total world production. However, the highest watermelon production reached 76.3 t ha^{-1} in Turkey with irrigation level of 342 mm and the water needs for evapotranspiration was 412 mm (Erdem *et al*., 2005).

The design of land drainage in South Sumatera was done with intensive shallow drainage methods (Imanudin at al., 2010). Shallow drainage system was also capable to reduce nitrogen loss due to leached up to 35 % (Helmers, Christianson, Brenneman, Lockett, & Pederson, 2012). The applications of water table control in the shallow drainage and sub irrigation system could reduce nitrate-nitrogen losses by 71 % (Bonaiti & Borin, 2010). In general, maintaining water table under 30 cm is commonly suitable for food crop except for paddy. However, the controlled drainage is also important to plush out the toxics element under root zone in tidal lowland areas.

This research aimed to determine the water melon respond under shallow water table condition. The information is useful for farmer to manage the land regarding the time planting and how to reduce the excess water in the field. Gate operation in tertiary canal also will determine to develop the model operation for field water management.

METHODOLOGY

The research was done in the tidal lowlands of Telang II Primer 17, Mulya Sari village, Banyuasin District, South Sumatra (Indonesia) at the end of rainy season 2015. A field experiment was conducted on tertiary blocks in an area of 0.5 ha. The water system network was completed by water gates at both secondary and tertiary blocks. The condition of water gates properly worked to retain and drain out water. The watermelon was planted from the middle of March to May 2015. Watermelon cultivation (*Citrullus vulgaris* Schard) uses varieties of Red Top 2.12. Plants Characterized by round fruit and age at harvest is 60 days after planting. The planting system is by planting a dual system that uses a spacing of 90-100 cm x 8 m.

The methodology of the research is field experiment. Watermelon was planted in beds with around 8 m spacing between the channels. The water in channel were between 20 cm and 30 cm. The shallow drainage system was used for water control model in tertiary channel. The drainage system did not stimulate pyrite oxidation because the pyrite (FeS_2) was found in the depths ranged from 70-90 cm below the soil surface. The scheme of this research was presented in Fig. 1. The observed parameters were soil texture, soil hydraulic conductivity, pH values as well as the growth and production parameters of watermelon. Soil fractions (clay, silt and sand) were determined by using hydrometer method. The saturated soil hydraulic conductivity (Ksat) was determined by auger hole method

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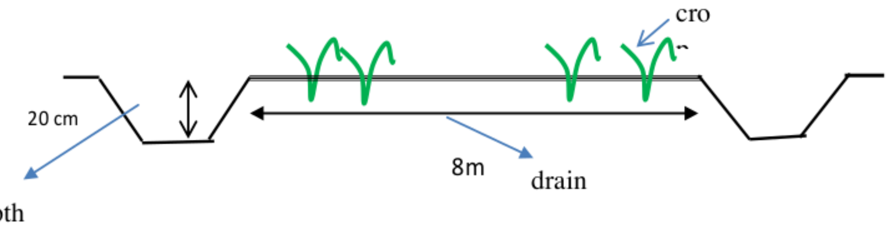

Figure 1. Micro drainage design scheme in the fields

within nine replication (T1 to T9), soil reaction (pH) was measured directly in the field by using pH paper.

Reclamation of tidal lowlands area in South Sumatra begins by making the navigation channel (primary channel) which connects the river that flows in the reclaimed delta. Perpendicular to the primary channel, secondary channel was built, this channel as a secondary plot boundary area of 270 ha. From the secondary channel, the water was carried out through tertiary channels. Two tertiary channels were bordered the area of 16 ha tertiary block. In tertiary and secondary channels were equipped with water gates. The water table was controlled by operating the tertiary water gates as drainage option.

Land drainage system was an open system, the water in the channel was maintained with water gates operating both in the secondary and tertiary levels (Fig. 2 and Fig. 3). Water gates in secondary channels were screw types (sliding gate), so they were operated occasionally. The main goal of secondary water gate operation was to remove excess water during floods (water gates open 60 cm) and hold back the tide in case of saltwater intrusion. In the field experiment, there were no water gate operations at the secondary level. It meant that no excess water in the secondary channel, due to the water supply from tide and rain was lower than the maximum capacity of water storage in channel. Free water flow through the gate during high and low tide in the canal was maintained by opening the gate at 60 cm depth.

A. primary canal B. Secondary canal

Figure 2. Macro system drainage canal in tidal lowland of Telang II reclamation areas

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A. Tertiary gate B. Secondary gate

Fig. 3. Secondary hydraulic structure for water control in the field

Controlling water levels was done at the tertiary level. This condition occurred mainly in the rainy season. Tertiary water gate (Fig 4) was a valve type in which the water gate opened and closed automatically as a function of height difference of water levels. When the gate installed in the front (facing to secondary channel), the water from tide was protected automatically, and water in tertiary canal was only drained during low tide.

Water level control was done by operating of the tertiary water gate. The operating gate in tertiary canal had two operating systems; open or close. In this case the water gate was operated for drainage, which was placed in front of the water gate position (estuary). This water gate will open when the water flowing from the tertiary channels (low tide), so the water in the tertiary canal flows into the secondary channel (Fig. 4). When there is a high tide, the water enters the secondary channel, then the water will be held back by the flow of the tide against the water gate so it closes automatically. As a result, if the tide does not come in, so the water supply in the land only from rainfall and the land will not flood although there is a rain.

A. Water supply position B. Water drainage position

Figure 4. Tertiary hydraulic structure for water table control in tertiary

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The water contribution from capillary rise was estimated using UPFLOW model which was developed to estimate water depth for the capillary rise under land use, soil types and some environmental conditions. The software was able to be adapted with modification in local climatic requirements (Raes, de Nys, & Deproost, 2002). It was successfully used under tropical wetland condition (Imanudin *et al*., 2010).

Table 3 shows that the tertiary water gate operatees during plant growth. In the initial stage when the rain was high, the water management objective was to maintenance the dryness. However for the next growing stage, water supply from rain was not much, then gate did not operate (gate could be removed). Free operation meant that the water could enter to the tertiary canal during the tide and drain at low tide. By this operating, it is possible to maintain the constant water level in the root zone. The potential of land drainage in tertiary block was identified by the hourly observation of water level in the secondary and tertiary channels for 2 x 24 hours, on 22 to 24 November 2014.

Table 3. Monthly operation of tertiary gate for watermelon cultivation in tidal lowland

Growing stage	Time Period	Gate Operation/Position
Initial stage	April-May	Drainage/In front site
Vegetative stage	May-June	Free operation
Generative stage	June	Free Operation

RESULTS AND DISCUSSION

Soil Characteristics

The study area has land typology of B characteristics and the land only receives tide during rainy season and relatively poor in soil drainage. However, it is never stagnant with water for a long time. Only at the time of high tide and heavy rain, the land will be inundated for 3-5 hours. An improvement of drainage system has succeeded in creating an un-flooded land, but the ground water level is still relatively shallow. The measurement of soil hydraulic conductivity in the field shows that classes are in range from 4.1- 5.8 m per day or 5,800 cm per day (Table 1).

The soil texture is dominated by loam texture, just a few points in first layer have dusty loam, sandy loam and clayey loam textures. Loam ttexture is a transition between sand and clay texture. It is regarded as optimal for crop growth and agricultural production, because it is able to hold water and nutrients better than sand soil texture, whereas the drainage, aeration and soil properties of the top soils better than clay soils. The ability of capillary water on three types of soil texture is calculated by using the model UPLOW (Table 2).

Table 2 shows the value of soil moisture in different depths of soil. For loam texture, soil saturated water content is about 45 %, 32 % from field capacity and permanent wilting point was 10.3 %. From the field condition, the crop should be irrigated when the groundwater was at 60.0 cm depth below the soil surface and for the sandy loam, moisture content should be 42 % and for saturated condition, moisture content was 21.7 % at the field capacity and the permanent wilting point of around 10 %. The crops need irrigation when soil water depth exceeds 50 cm. For the clay loam texture, the soil has water retention characteristics of 51 % for saturated water content, water content of 40 % for field capacity, and 21 % for moisture content of permanent wilting point. Contribution of groundwater shows that the crop still needs to be watered when the soil

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was in water depths of 70 cm. Contribution of groundwater decreases as the shallow groundwater to the surface position (Table 2).

Water table under the silty clay loam soil texture contributed 90.0; 41.0, and 7.0 % to Evapotranspiration (ET) for water table depths of 50 cm; 100 cm and 150 cm respectively, and 92.0; 31.0; 9.0 % for fine sandy loam. A shallow water table caused negative effects on crops. The main problem in the cultivation of such tidal lowlands is the condition of shallow groundwater. Production could fall into range of 20-50 % if the ground water was too shallow at level of 10-20 cm under the soil surface (Rizzo et al, 2018).

Table 1. Field measurement of hydraulic conductivity using auger hole method

Nr	Replications	K (Saturated Hydraulic Conductivity) Values (m day^{-1})								
		T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**
1	U1	5.64	5.32	5.46	5.67	5.71	5.81	6.02	5.93	5.84
2	U2	4.40	4.75	4.43	4.65	5.46	4.53	5.46	5.04	5.07
3	U3	4.16	4.73	4.46	4.44	4.55	4.57	4.44	5.13	5.20
	Average	4.73	4.93	4.78	4.92	5.24	4.97	5.31	5.37	3.37

Remarks: T1-T9: Treatment 1-9; source: Field measurement (2015)

Table 2. Contributions of capillary water to soil water content on the root zone

Water depth (cm)	Contributions of capillary water and soil water content on the root zone for some texture classes (%)		
	Loam	**Sandy loam**	**Clay loam**
10	0.0 mm day^{-1} (44.8 %)	0.0 mm day^{-1} (41.7 %)	0.0 mm day^{-1} (50.8 %)
20	0.0 mm day^{-1} (44.2 %)	0.0 mm day^{-1} (40.8 %)	0.1 mm day^{-1} (49.8 %)
30	0.1 mm day^{-1} (43.4 %)	1.0 mm day^{-1} (39.6 %)	0.2 mm day^{-1} (49.0 %)
40	0.3 mm day^{-1} (42.7 %)	2.8 mm day^{-1} (37.9 %)	0.3 mm day^{-1} (48.4 %)
50	0.5 mm day^{-1} (41.9 %)	4.8 mm day^{-1} (36.4 %)	0.5 mm day^{-1} (47.6 %)
60	2.2 mm day^{-1} (23.9 %)	5.0 mm day^{-1} (15.9 %)	1.4 mm day^{-1} (33.4 %)
70	4.2 mm day^{-1} (23.9 %)	4.0 mm day^{-1} (15.9 %)	1.1 mm day^{-1} (33.4 %)

Source: Secondary data by Simulation of UPLOW model (2015)

The ideal level of water table is at 50-100 cm and this depends on the type of crops, and soil texture. In this case, water table data was found at 20 cm below soil surface during the initial stage. At this level, the capillary water movement is sufficient to fulfill crop evapotranspiration. Generally, at development stage crops can be grown on soil water depth of 1.5-2.0 m. However, if the ground water level at 50.0 cm depth under soil surface, all the crop water needs can be met by ground water through capillary rise. The field experiment was conducted during wet condition and the water level during vegetative stage was 50 cm below soil surface and continued till generative stage in May 2015. Most of crop water requirements could be achieved by ground water through capillary rise when the ground water level at a depth of 0.5 m (Antonelli *et al.,* 2015). In sunflower case, when it was grown under clay soil texture, crop water requirement was enough from capillary rise at soil water depth of 150 to 200 cm under soil surface. In this condition, water requirement of sunflower could extract 92 % of the available water.

The planting period of watermelon was after paddy harvest time (from Mid-March to May). It did not need irrigation because there was a lot of rain. The tertiary gate was operated maximum drainage during growing

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period. Thus, the water management objective in this season was maximum drainage.

Micro water management in tertiary block is developed in a quarter channels. This channel is perpendicular to the tertiary channels, and at the mouth of the channel quarter makes water valve gate. This channel is immediately supply and or drain water from the tertiary block. In a land plot of the water system consists of a collector and a quarter channels (channel worms). Collectors around the land that store temporarily accommodate drain water from the worm channel. Worms channels were created by the inter channels with spacing of 6-8 m; the depth was 15-20 cm and the width of 50 cm (Fig. 4).

Harvesting time of water melon in May, could promote the third crop cultivation. The third crop was planted in June. However, the crop in the generative period (July-August) will get water deficiency and the farmer should apply pump irrigation to water the crop.

Water Management for Watermelon Cultivations under Wet Condition

The watermelon was planted in March 2015, it was still raining and the land was waterlogged. The water table was reduced by making micro drainage system with the inter-channel spacing of 8 m and a depth of 20 cm. This drainage concept was a shallow drainage method since it was easy, economical and the depth of the channel would not create a layer of pyrite oxidation. It can also be applied for paddy cultivation.

Based on the observations made, it indicated that the condition of the tide occurred at 10:00 AM until 02:00 PM, its height was 130 cm and 165 cm. It caused a lot of water entering the field, especially if there was a high rainfall. Fig. 5 shows the duration of water level decreases during the low tide within 6 hours. The maximum receding water conditions in the secondary channel occurred at 6:00 to 08:00 AM and lasted for only 3 hours with a water height of 60 cm. The discharge of water in the soil was not sufficient to be drained (Fig. 5).

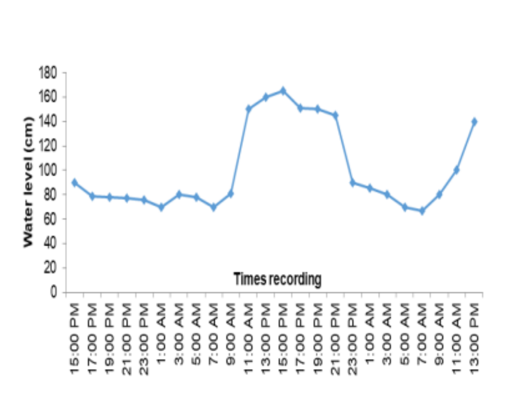

Figure 5. Fluctuations of surface water in secondary channel in the Mulyasari village

Watermelon crops were planted on an area of 0.5 ha in mid-March 2015. Ponska (dose of 400 kg) and Mutiara fertilizers (dose of 150 kg) were divided into 5 times application during growing period. The fertilizers were mixed with the water to make them easily absorbed by the crop and then five time sprayed on the land of watermelon. Harvesting time was done in mid-May. The productivity was reached in average 20 t ha^{-1} (Fig 6.). The profit obtained in one hectare ranged 25-30 million rupiah.

Figure 6. The performance of water melon growth in tidal lowland under wet condition

The productivity was lower than the maximum national productivity that can reach around 30-40 t ha^{-1}. It was caused by the excessive water status and the water table depth on average of groundwater table was in

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15-20 cm below the soil surface. It induced that the soil was too wet for crop growth. Micro drainage in tertiary block was not working properly to reduce the water table, because the macro drainage system (secondary canal) did not have enough time to drain water during low tide. Thus, the modified planting time is the best way to avoid excess water due to very shallow ground water table. Based on the water table fluctuation data (Fig 7) showed that in the beginning of dry seasons (April-May) was good possibility to start planting. The groundwater table level was 25 cm in average. It was very suitable for water melon growth in the initial stage (Imanudin et al., 2019). Since the stress water could be done during the generative period (July), and then the pumping irrigation would be required. It was also that the water table should be maintained under 50-70 cm below soil surface to avoid pyrite oxidation.

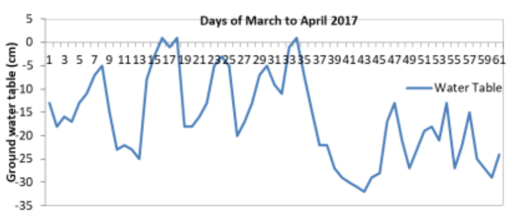

Figure 7. The daily water table fluctuation in the field

The decreasing production of watermelon was caused by the excess water and also followed by other crops such as corn. Imanudin *et al*. (2010) reported that the corn planted in wet conditions (March to May) had around 30 % of result reduction compared to normal production. The range values in the optimum water table depth were ca. 100-150 cm, where corn yields reached the highest yield and stable. A corn yield with deep water level of > 400 cm was highly reduced to a quarter and half of results in comparison to those in areas with optimal water table conditions. The number of days for a full root growth to total growth period should be < 0.5. This condition is able to provide enough crop opportunity to take water from the shallow water table. The maximum root depth to water was an average water depth of > 50 cm (Ayars *et al*., 2006).

CONCLUSION

Developing drainage system in micro level of tertiary plot is very important to implement second crop cultivation under shallow water table condition on tidal lowland reclamations area. Water table at initial stage can be maintained at 25 cm below soil surface. The water melon planted at mid-March was successfully growth and harvested in May with 20 t ha^{-1} production. This production is still low due to the excess water in the generative stage. The best planting time is in April to avoid excess water during the initial and generative phase.

Tertiary gate of valve gate fiberglass type was suitable to maintain ground water table in tertiary canal. The gate should be installed in awhole area when the second crop was planted after rice at one secondary areas (250 ha). Gate operation model in the tertiary canal was as drainage option during vegetative period (April-May) and supply during the generative phase (July to June).

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