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Production of Soybean Varieties under Saturated Soil Culture on Tidal Swamps

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ABSTRACT

Saturated soil culture (SSC) is a cultivation technology that gives continuous irrigation and maintains water depth constantly and makes soil layer in saturated condition. By keeping the water-table constantly, soybean will be avoided from negative effect of inundation on soybean growth because soybean will acclimatize and improve its growth. The objective of the research was to study the response of soybean varieties under saturated soil culture on tidal swamps. The research was conducted at Banyu Urip of Tanjung Lago Sub District, Banyuasin District, South Sumatera Province, Indonesia from April to August 2009. The experiment was arranged in a split plot design with three replications. The main plot was water depth in the furrow consisted of without watering, 10, 20, 30, 40 cm under soil surface (uss). The subplot was soybean variety consisted of Tanggamus, Slamet, Willis, and Anjasmoro. The result showed that the interaction between varieties and water depth significantly affected growth and seed production, except pod numbers/plant. The values of all variables were higher under SSC compared to those cultivated without watering (control), but varieties responded to SSC differently. The highest seed production was obtained from Tanggamus with 40 cm uss, i.e. 4.83 ton/ha but it was not significantly different from those at water depth 20 (4.63 ton/ha) and 30 cm uss (4.71 ton/ha). However, technically and economically, 20 cm uss was the most appropriate water depth for soybean production on tidal swamps.

Key words: *Glycine max* L. (Merr.), water management, water table

INTRODUCTION

National production of soybean in Indonesia is low and can only fullfill about 35–40% of the national demand, therefore the government imports soybean about 1.3 million ton/year (Balitbangtan, 2005). Increasing soybean planting area in order to increase soybean production is hampered by land use change. One of the alternatives is to optimize the use of marginal land, and tidal swamp is one of the potential ecosystems for future soybean production. There is about 20 million ha tidal swamps in Indonesia (Suryana, 2006), and about 9 million ha is appropriate for agriculture (Nugroho *et al*., 1992 *in* Noor and Sabur, 2007).

The major constrain of producing soybean in tidal swamp is high pyrite content. When pyrite is oxidized, soil pH decreases. Djayusman *et al*. (2001) reported that high pyrite content suppressed the productivity of soybean on tidal swamps to only about 800 kg/ha.

SSC is a technology in cultivation that gives water permanently, maintains and keeps its depth constantly (± 5 cm under soil surface/uss). This makes soil layer in saturated condition. In saturated soil culture, watering is started from the beginning of plant growth to maturity stage (Hunter *et al.*, 1980). By keeping the water-table constantly, soybean will be avoided from negative effect of inundation on soybean growth, because soybean will acclimatize and improve its growth (Troedson *et al*., 1983).

Soil water management can be applied to reduce pyrite content where the soil is in reductive condition and able to support soybean growth. SSC technology is one of soil water managements that has been studied in highland and succeeds to increase soybean production (Ghulamahdi *et al*., 1991; Indradewa *et al*., 2004; Ghulamahdi and Nirmala, 2008). This offers the chance to reduce the pyrite hence increase soybean production on tidal swamps.

Response of soybean to saturated condition varied between varieties and the later-maturing soybean was better than the earlier one (CSIRO, 1983; Ghulamahdi *et al*., 1991; Ghulamahdi, 2008; Ghulamahdi and Nirmala, 2008). Many varieties of soybean have been studied in their response on acid soil, e.g. Alihamsyah and Ar-Riza (2006) found that Tanggamus, Wilis, and Slamet were varieties that could adapt well on inland.

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The objective of the research was to study the response of soybean varieties under saturated soil culture on tidal swamps.

MATERIALS AND METHODS

The research was conducted on tidal swamps land in Banyu Urip Village of Tanjung Lago Sub District, Banyuasin District, South Sumatera Province, Indonesia from April to August 2009. The experiment was arranged in split plot design with three replications. The main-plot was water depth in the furrow consisted of without watering, 10, 20, 30, 40 cm under soil surface (uss). The subplot was soybean varieties consisted of Tanggamus, Slamet, Wilis, and Anjasmoro. Each main-plot was surrounded by 30 cm wide and 50 cm height furrows. Water was given at the planting time and kept until the maturity stage and made plots in wet condition.

Two weeks before planting, plots were applied with 2 ton dolomite/ha, 2.5 ton animal manure/ha, 400 kg SP18/ha and 100 kg KCl/ha. N fertilizer was not added as the root nodules were expected to supply N for the plant. However, the plants were sprayed with 7.5 g urea/l at 2 and 4 weeks after planting to support the acclimatization.

At planting date, seeds were inoculated with *Rhizobium* sp. and treated with insecticide with active agent Carbosulphan 25,53%. Seeds were planted in 2 m x 5 m plot size, 20 cm x 25 cm planting distance, 2 seeds/hole. The observed variables were flowering and harvesting time, plant height, numbers of trifoliate leaves, branches, pods, and seed production per ha.

RESULTS AND DISCUSSION

Plants cultivated under saturated soil culture showed better growth and higher production than those without watering (control) (Table 1 – 5). This indicated that soybean explored adaptation mechanism to saturated condition in tidal swamp as well as in highland. In highland, Ghulamahdi (1999) found that soybean growth under SSC showed an adaptation mechanism to saturated condition, where plants in saturated condition increased roots 1-aminocyclopropane-1-carboxylic acid (ACC) and followed by the increase of roots ethylene content. Root ethylene would promote formation of aerenchyma and new roots. Indradewa *et al*., (2004) showed that these new roots would increase the formation of root nodules, and Ghulamahdi *et al*., (2006) reported that the increase of root nodule formation increased nitrogenase activity and nutrient absorption. Increased soybean production agreed with the findings from Indradewa *et al*., (2004) that showed SSC significantly increased the production of soybean up to 20-80% compared to that of conventional watering because SSC gave field capacity condition to the soil. On the contrary, conventional watering technique (without water management), like as farmer applied, makes soil water condition is unstable.

Plant height of varieties cultivated under SSC were above 50 cm, while those cultivated without watering were less than 40 cm height. Plant height of Slamet was higher than those of other varieties at all water depths, but it was not significantly different between water depths (Table 1). It seems that plant height was not positively correlated to the leaf and branch numbers as shown that the highest plant was Slamet (Table 1) but the highest number of leaves and branches were obtained from Tanggamus. Table 2 and 3 showed that leaf and branch numbers of soybean cultivated under SSC were different among varieties and water depths. Tanggamus was the most responsive variety to water condition as the leaf and branch numbers under SSC were more than double the leaf and branch numbers of control. High number of leaves and branches were benefit for soybean to produce pod and fill it. Botanically, the flower of soybean emerges from nodes in the stem/branch. The more soybean produces branch, the more it has node.

Table 1. Plant height of soybean varieties on water-table treatments

Water depth (cm uss)	Varieties				Means
	Tanggamus	Slamet	Wilis	Anjasmoro	
	………..............………… cm ………………….............……………				
Control	34.78 d	37.22 d	38.11 d	36.89 d	36.75
10	63.54 c	79.24 ab	61.39 c	67.55 bc	67.93
20	66.71 bc	84.01 a	66.77 bc	67.43 bc	71.23
30	65.46 bc	85.90 a	65.53 bc	55.47 c	68.09
40	62.05 c	91.19 a	59.88 c	53.62 c	66.68
Means	64.44	85.09	63.39	61.02	

Note: values followed by different letters in the rows and columns are significantly different at 5% DMRT
USS: Under Soil Surface

Table 2. Leaf numbers of soybean varieties and water-table treatments

Water depth (cm uss)	Varieties				Means
	Tanggamus	Slamet	Wilis	Anjasmoro	
Control	12.11 g	19.00 ef	16.44 fg	21.67 cdef	17.31
10	27.50 ab	22.53 bcde	20.43 def	18.90 ef	22.34
20	28.60 a	22.17 cde	18.77 ef	19.30 ef	22.21
30	29.90 a	26.00 abc	19.43 ef	16.23 fg	22.89
40	29.67 a	25.57 abcd	18.20 ef	17.73 ef	22.79
Means	25.56	23.05	18.65	18.77	

Note: values followed by different letters in the rows and columns are significantly different at 5% DMRT test

Table 3. Branch numbers of soybean varieties and water-table treatments

Water depth (cm uss)	Varieties				Means
	Tanggamus	Slamet	Wilis	Anjasmoro	
Control	2.00 f	2.44 f	2.44 f	3.00 ef	2.47
10	4.94 cde	4.96 cde	3.95 def	4.02 def	4.47
20	6.42 abc	5.44 abcd	3.98 def	3.78 def	4.91
30	6.98 ab	5.46 abcd	3.88 def	3.06 ef	4.84
40	7.37 a	5.17 bcd	3.57 def	2.91 ef	4.76
Means	5.54	4.70	3.56	3.36	

Note: values followed by different letters in the rows and columns are significantly different at 5% DMRT test

Pod numbers of soybean cultivated under SSC was significantly greater from those of control (Table 4). Water depth of 10 cm uss resulted in 8 fold pod numbers compared to that of control. Based on pod numbers, tanggamus and Slamet adapted well to tidal swamps under SSC technique. This experiment also found that pod numbers/plant were higher than those from highland. On tidal swamps, Tanggamus, Slamet, Wilis, and Anjasmoro produced 105.4, 96.4, 39.9, and 42.1 pods/plant, respectively, at 20 cm uss water depth. On the contrary, Ghulamahdi *et al*. (2009) found that soybean under SSC technique in highland (Bogor, Indonesia) produced only 38 (Tanggamus), 49 (Slamet), 27 (Wilis), and 18 (Anjasmoro) pods/plant at the same water depth.

Table 4. Pod numbers of soybean varieties and water-table treatments

Water depth (cm uss)	Varietas				Means
	Tanggamus	Slamet	Wilis	Anjasmoro	
Control	20.56	4.78	6.56	1.33	8.31 b
10	94.12	68.16	46.87	46.09	63.81 a
20	105.36	96.39	39.87	42.06	70.92 a
30	107.72	75.10	47.18	38.59	67.15 a
40	94.54	72.48	32.26	30.92	57.55 a
Means	84.46 a	63.38 b	34.55 c	31.80 c	

Note: values followed by different letters in the same rows and same columns are significantly different at 5% DMRT test

Seed production of all varieties significantly increased with the application of water on tidal swamp area. Twenty until forty centimeters uss water depth resulted in 8-9 folds of seed production compared to that of control (Table 5). Stability of water under soil surface from the beginning growth to the maturity stage (Fehr *et al*., 1971; Nathanson *et al*., 1984) and high day temperature on tidal swamps area (27.7-34.4^{o}C) induce the plant to produce more flowers. Flower formation was affected by temperature and humidity. Irwan (2006) reported that at high temperature and low air humidity, solar radiation stimulated floral bud to emerge. Arifin (2008) also found that at low temperature, lateral bud would be a vegetative bud and not a flower bud.

Table 5. Seed production of soybean varieties and water table treatments

Water depth (cm uss)	Varieties				Means
	Tanggamus	Slamet	Wilis	Anjasmoro	
	……….............……….. ton/ha ……………..............……………..				
Control	0.85 g	0.16 g	0.30 g	0.09 g	0.35
10	3.85 b	2.35 def	2.59 cde	2.61 cde	2.85
20	4.63 a	2.85 cd	2.47 cdef	2.62 cde	3.14
30	4.71 a	3.20 bc	1.97 ef	2.64 cde	3.13
40	4.83 a	2.61 cde	1.72 f	2.15 def	2.83
Means	3.78	2.23	1.81	2.02	

Note: values followed by different letters in the rows and columns are significantly different at 5% DMRT test

Seed production of Tanggamus at 40 cm water depth was 4.83 ton/ha but it was not significantly different from those at water depth 20 (4.63 ton/ha) and 30 cm uss (4.71 ton/ha). However, it was easier and cheaper to make furrow with 20 cm uss water depth than 30 and 40 cm uss. So that, technically and economically, 20 cm uss was the most appropriate water depth for soybean production at tidal swamps

This experiment also found that compared to those without water, the availability of water under SSC technique made longer vegetative stage of soybean growth and leaves were still greener until pod filling stage. Soybean cultivated in SSC was harvested later (89.50- 90.58 days after planting/DAP) than control (86.42 DAP) (Table 6). Longer maturing days probably prolonged the photosynthesis activity hence produced more assimilates for plant growth, pods formation and filling.

Table 6. Flowering and harvesting time of soybean under water table treatments

Water Depth (cm uss)	50% Flowering (DAP)	Harvesting Time (DAP)
Control	33.75a	86.42a
10	38.17b	90.58b
20	37.58b	89.83b
30	37.58b	90.00b
40	37.33b	89.50b

Note: values followed by different letters in the rows and columns are significantly different at 5% DMRT test

Tanggamus (90.13 DAP) and Slamet (89.80 DAP) were harvested later than Wilis (88.53) and Anjasmoro (88.60 DAP) (Table 7). Seed production of Tanggamus was the highest at 20 – 40 cm uss. Later-maturing variety will be better than the earlier one because soybean would have longer period for acclimation (CSIRO, 1983; Ghulamahdi *et al*., 1991; Ghulamahdi, 2008; Ghulamahdi and Nirmala, 2008), and resulted high nutrient absorption. Tanggamus absorbs higher nutrients (1.10 g N, 0.10 g P_2O_5, and 0.46 g K_2O/plant) than Slamet (0.81 g N, 0.08 g P_2O_5, and 0.31 g K_2O /plant), Wilis (0.64 g N, 0.0 g P_2O_5, and 0.29 g K_2O/plant), and Anjasmoro (0.86 g N, 0.09 g P_2O_5, and 0.42 g K_2O /plant). The findings confirmed that Tanggamus was the most adaptable variety in tidal swamp as shown by the highest seed production at all water depths even in control treatment. This agreed with Alihamsyah and Ar-Riza (2006) that Tanggamus, Wilis, and Slamet were varieties that could adapt well on inland. However, this experiment found that Tanggamus was more responsive to SSC on tidal swamps.

Table 7. Flowering and harvesting time of soybean varieties

Varieties	50% Flowering (DAP)	Harvesting Time (DAP)
Tanggamus	37.00a	90.13a
Slamet	37.67a	89.80a
Wilis	36.53b	88.53b
Anjasmoro	36.33b	88.60b

Note: values followed by different letters in the rows and columns are significantly different at 5% DMRT test

Tanggamus

Slamet

Wilis

Anjasmoro

Figure 1. Growth of soybean varieties at 20 cm uss at 6 WAP

Figure 2. Pod numbers of Tanggamus at control (left) and 20 cm uss (right) at 8 WAP

Soil analysis data (pH 3.8-4.4, 21.4 ppm P_2O_5 (Bray 1), 117 ppm K_2O (Morgan), and 0.47% (4700 ppm) pyrite) indicated that the soil fertility is low according to CSR/FAO (1983). Application of lime and fertilizers, however, could increase soil pH and nutrients, while the stability of water under soil surface made the soil in reductive condition and pyrite oxidation could be prevented or decreased.

The experiment showed that water management and variety were important in tidal swamps and proved that saturated soil culture technique increased the production of soybean on tidal swamps. Growth of soybean under SSC can be seen in Figures 1 and 2.

CONCLUSSION

The result showed that the interaction between variety and water depth significantly affected plant performance and seed production, but insignificantly affected pod numbers/plant. The values of all variables under SSC were higher than those cultivated without watering (control), but response of each variety to SSC was different as shown by different growth and production of those varieties. Slamet at 40 cm uss water depth produced the highest plant (91.19 cm), but insignificantly different from 10, 20, and 30 cm uss (79.24 – 85.90 cm). Tanggamus produced the highest number of leaves, branches, pod, and seed production at all water depths. Seed production of Tanggamus at 40 cm water depth was 4.83 ton/ha but it was not significantly different from those at water depth 20 (4.63 ton/ha) and 30 cm uss (4.71 ton/ha). However, technically and economically, 20 cm uss was the most appropriate water depth for soybean production at tidal swamps.

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