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Research Article

Growth and production of soybean on different inoculant sources of arbuscular mycorrhizal fungi and water saturation periods

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ABSTRACT

Production expansion to suboptimal areas such as tidal land through the application of integrated land management technology is an effort to increase soybean production in Indonesia. The study aimed to evaluate the morphophysiological response of soybean treated with arbuscular mycorrhizal fungi (AMF) inoculation and duration of water saturation in tidal land. The study was conducted in April-October 2021 in the plastic house of the Research Field of the Faculty of Agriculture, Sriwijaya University, Palembang. The experiment used a randomized complete block design with two factors and 3 replications. The first factor was the source of AMF propagations (without inoculations, corn inoculants, soybean inoculants, sugarcane inoculants, and soybean-sugarcane inoculants). The second factor was the water saturation periods (0, 2, and 3 months since planting), so there are 15 treatments. The results showed that the interaction between the inoculant sources and the duration of water saturation had no significant effect on all parameters. The inoculant propagated in the media of sugarcane produced the highest effect as compared to other treatments. The water saturation for 2 or 3 months since planting gave soybean plants a better morphophysiological response and yield than conventional cultivation.

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INTRODUCTION

Soybean (*Glycine max* (L.) Merill) is the third most important food crop commodity after rice and corn in Indonesia, which is high in protein content. Soybean is used for food, feed and industry, therefore soybean demand continues to grow along with the increasing need for raw materials for the processed food industry and population growth (BPS, 2020). Soybean for the food processing industry in Indonesia is widely used as raw materials for making tofu, *tempe*, and soy sauce. Annual soybean consumption in Indonesia is about 2.24-2.5 million tons.

However, soybean import is still high in Indonesia, about 45% of domestic demand. Soybean harvesting area in Indonesia was still fluctuating; in 2016 reached 589.42

thousand ha, decreased by 4.02% as compared to 2015. The balance of soybean supply and demand in Indonesia for 2016-2020 experienced an increase in the average deficit by 36.95% per year (Riniarsi, 2016). Soybean productivity in Indonesia in 2018 decreased by 4.62% when compared to 2017 (BPS, 2018). Several factors, including land suitability, land fertility, nutrient and water management, pest control, maintenance, and post-harvest, influence the increase in soybean production. Therefore, improving soybean production is important.

Efforts to increase soybean production can be through land intensification and intensification. Extensification through opening new production areas is difficult due to the limited availability of optimal land (Sudary et al., 2007). From the total land 188.2 million ha, around 94.1 million ha is suitable for agriculture, while the rest areas are classified as suboptimal indicated by acidic soils and low nutrient content (Mulyani et al., 2009). According to Mulyani et al., (2009), suboptimal land could be utilized by implementing integrated land management techniques such as balanced fertilizer application, water supply in the dry season, and control of plant-disturbing organisms.

Low soil fertility of suboptimal fields especially related to the low availability of phosphates, and low pH causes high levels of Al-dd and Fe which are toxic to plants and bind macronutrients such as phosphates (Mulyani et al., 2009). One of the efforts to overcome this problem is using local microorganisms in the plant rhizosphere, such as arbuscular mycorrhizal fungi (AMF).

AMF is a living microorganism with adaptation power to the host and specific environment (Miska et al., 2016). The use of AMF can increase the availability of P for plants (Rahman et al., 2019). In shallots, adding mycorrhiza at a phosphate dose of 100 kg SP-36 per ha increases the total P uptake by 74%; while at a phosphate dose of 200 kg SP-36 per ha and 250 kg SP-36 per ha, a mycorrhizal application increases total P uptake by 49% and 102%, respectively (Rahman et al., 2019). Using natural AMF isolation from local plants will be more effective than isolates from outside the plant growing place. In soybean, the application of mycorrhiza stimulates plant growth as indicated by the number of productive branches, the weight of 100 seeds, the dry weight of biomass, and yield per hectare (Muktiyanta et al., 2018).

AMF can be symbiotic in all plants but has a different level of colonization in each host plant, affecting the number of AMF spores produced (Nurhayati, 2012). Host plants of the monocotyledonous group have a high percentage of root infections and a greater number of spores when compared to dicotyledonous plants (Rini & Rozalinda, 2010). Maize (*Zea mays*) is the best host plant with the highest spores, colonization rate, inoculum weight, wet weight, and root dry weight as compared to the host plants of *Pueraria javanica*, sorghum (*Sorghum bicolor*), and some soybean varieties (Muis et al., 2016a). Host plant types show different influences on the percentage of infection and P uptake of plants (Nurhayati, 2012). However, the application of AMF to overcome problems in cultivation on marginal land is still rarely evaluated.

Saturated soil culture (SSC) is a cultivation technology that irrigates continuously and maintains the depth of the water in the channel to make the soil layer saturated (Ghulamahdi et al., 2016; Maulana et al., 2019). The SSC is a cultivation system that can be applied to tidal marshlands and marginal soils with moderate or poor drainage (Aziz et al., 2016). SSC provides better conditions for root growth because water availability is sufficient, so the plant forms more roots and root nodules. Water-saturated cultivation in tidal land for 2 months increases soybean production, as seen from the production of stuffed pods (Toyip et al., 2019).

Based on this consideration, it is necessary to study the influence of the use of inoculant sources of local arbuscular mycorrhizal fungi (AMF) of tidal soil origin and the duration of saturation with water-saturated cultivation systems on the growth of soybean plants. The study aimed to evaluate the morphophysiological response of soybean treated with arbuscular mycorrhizal fungi (AMF) inoculation and duration of water saturation in tidal land.

MATERIALS AND METHODS

The research was conducted in April-October 2021 at the plastic house of the Research field of the Faculty of Agriculture, Sriwijaya University, Palembang. The materials used tidal soil media, Arbuscular Mycorrhizal Fungi inoculants produced from trapping hosts: corn, soybeans, sugarcane (*Saccharum officinarum* Linn), and soybean-sugarcane combinations. Other materials were inorganic fertilizers in the form of urea, SP 36, and KCl, soybean seeds of the Tanggamus variety, manure, $CaCO_3$, and pesticides. Polybags 35 cm x 50 cm, plastic tubs measuring 46 cm x 36 cm x 15 cm, and stationery were also used in the experiment.

The experiment used a factorial randomized complete block design with 2 (two) factors and 3 replicates. The first factor was the source of inoculants AMF propagations (without inoculations, corn inoculants, soybean inoculants, sugarcane inoculants, and soybean-sugarcane inoculants). The second factor was the water saturation periods (0, 2, and 3 months since planting), so there are 15 treatments; each treatment unit consists of 3 plants (2 non-destructive sample plants and 1 destructive sample plant). In total, there were 135 experimental units.

Polybags measuring 35 cm x 50 cm were filled with tidal soil that has been dried as much as 10 kg per polybag. One week before planting, $CaCO_3$ and manure of 2 tons ha^{-1} each were added to the soil. Three soybean seeds were planted and maintained as many as 2 plants per planting hole. The application of AMF 5 g per polybag was given at planting. The polybag was placed on a plastic tub filled with water with a height of 5 cm and maintained the water level according to the treatment.

Irrigation for dry cultivation begins with calculating the amount of water to be added by weighing 300 g of soil samples that have been dried at a temperature of 105 ^{o}C for 24 hours. The soil sample was wet with 250 mL, then weighed again to obtain a weight of 463.69 g. The final weight of the soil sample was then reduced by the initial soil weight of 300 g equal to 163.69 g or 163.69 mL which is the value of the field capacity. Furthermore, it was converted to 10 kg of soil to add as much as 5.5 L water to achieve field capacity (Table 1).

Table 1. Water treatment for soybeans in a plastic house.

Time	No saturation (0 months)	Saturation of 0-2 months	Saturation of 0-3 months
0-15 DAP	FC	SSC	SSC
16-30 DAP	80% FC	SSC	SSC
31-45 DAP	70% FC	SSC	SSC
46-60 DAP	60% FC	SSC	SSC
61-75 DAP	50% FC	FC	SSC
76-90 DAP	40% FC	80% FC	SSC

Note: Normal harvest age of soybeans Var. Tanggamus is 88 days after planting (DAP); FC-field capacity; SSC-saturation soil culture.

Application of urea (N) solution was carried out 4 times at the age of 3, 4, 5, and 6 weeks after planting (WAP) by spraying through leaves with a concentration of 10 g L^{-1}, while other fertilizers: 200 kg SP-36 ha^{-1}, and 100 kg KCl ha^{-1} were applied at planting. Weeding was done manually. Control of plant pests was carried out by spraying insecticides according to field conditions.

Harvesting was carried out after entering the physiological ripening phase when most of the soybean leaves begin to dry out, and the whole pod has been filled, the seed coat was thin, the skin of the pods was quite hard, the fibers were very noticeable and blackish-brown in color. The morphological and agronomic characteristics were observed including plant height, number of trifoliate leaves, number of fill pods at harvest, the weight of 100 seeds, wet weight, and dry weight of the plant (shoot, root and root nodules), the number of root nodules and percentage of AMF colonization.

The physiological characteristics were observed including leaf pigment content (chlorophyll-a and -b), number of stomata, nutrient concentration and absorption N, P, K. The data were subjected to analysis of variance; then, means were compared using the Least Significance Different (LSD) test. All tests were considered significant at $p < 0.05$. The observational data was processed using the STAR (Statistical Tool for Agricultural Research) application software, then Microsoft Excel version 2021.

RESULTS AND DISCUSSION

The interaction between the AMF inoculant source's treatment and the saturation duration has no significant effect on all parameters. Factors of inoculant sources and saturation duration significantly affected chlorophyll-a, b, total contents, and percentage of AMF colonization (Table 2). The treatment of inoculant sources from *Saccharum officinarum* showed marked differences in chlorophyll-a, b, and total contents compared to non-inoculation treatments. The highest chlorophyll-a, b, and total content were found in the inoculant source treatment from *Saccharum officinarum*, and the lowest was found in the non-inoculation treatment. This may be because AMF colonization can expand the area of absorption of nutrients plants need as chlorophyll-forming nutrients, one of which is nitrogen. This is also in line with the study of Muis et al., (2016b) where the application of AMF from corn rhizosphere with water-saturated cultivation increases the uptake of N, P, and K. In the present experiment, the treatment of inoculant sources of *Saccharum officinarum* origin was not significantly different from that of inoculant sources from *Zea mays, Glycine max*, and *Saccharum-Glycine max* combination on chlorophyll-a, -b and total.

Table 2. Chlorophyll a, chlorophyll b, total chlorophyll, and AMF colonization percentage.

Treatment	Chlorophyll content (mg L^{-1})			Percentage of AMF colonization (%)
	a	b	Total	
Inoculant source				
No inoculant	16.989±3.60b	6.00±1.29c	22.97±4.89d	20.56±3.34c
Zea mays	18.80±1.31ab	7.25±1.32ab	26.04±2.56cd	26.00±5.00bc
Glycine max	19.94±0.73ab	7.28±0.70ab	27.21±1.43bc	34.00±5.29a
Saccharum officinarum	21.08±0.33a	10.49±2.55ab	31.55±2.35a	31.33±12.01ab
Saccharum-Glycine max	20.3±0.92a	10.83±1.88a	31.16±2.00ab	24.33±2.08c
Water saturation periods				
Conventional culture	18.18±3.10b	7.03±1.96	25.19±4.88b	21.47±4.07b
2 months since planting	19.45±1.42ab	8.60±2.66	28.02±3.62ab	31.67±9.08a
3 months since planting	20.67±0.51a	9.50±2.49	30.15±2.79a	28.60±5.18a

Note: Numbers followed by the same letter in the same column are not significantly different based on the LSD test at α = 5%. The mean value is followed by the standard error (SE) value.

Saturation duration had a significant effect on chlorophyll-a and total chlorophyll but had no significant effect on chlorophyll-b (Table 2). At the change in chlorophyll-a and total chlorophyll, the comprehensive treatment of the saturation duration for 3 months since planting (MSP) differed markedly from conventional cultivation. However, it did not differ markedly from the saturation duration of 2 MSP. Saturation periods of 2 and 3 MSP increase the total chlorophyll content of the leaves by around 10-17% when compared to conventional cultivation.

Chlorophyll-a and b play a role in the process of plant photosynthesis. Chlorophyll-b serves as a photosynthetic antenna to collect light which is then passed on to the reaction center composed of chlorophyll-a. The physiological response of plants that arises due to lack of water is a decrease in leaf chlorophyll concentration which can be caused by inhibited chlorophyll formation, reduced rubisco enzyme, and inhibition of nutrient absorption, especially nitrogen, and magnesium, which play an important role in chlorophyll synthesis (Nio Song & Banyo, 2011). Water shortage conditions caused by adding PEG 8000 with the potential of water media (WP) -0.25 and -0.5 MPa reduces the total chlorophyll content of local rice in North Sulawesi (Nio et al., 2019).

The treatment of single-factor inoculant sources and the duration of saturation had a noticeable effect on P nutrient levels, K levels, and N, P, and K nutrient absorption. However, it did not affect N nutrient levels (Table 3). In the change in nutrient levels of N, P, and K, the highest values were found in inoculant sources from *Saccharum officinarum*, which were 5.07% N, 0.33% P, and 1.86% K. In contrast, the lowest was found in the treatment without inoculants, namely 3.81% N, 0.27% P, and 1.12% K. In the change of nutrient levels, P and K treatment *Saccharum officinarum* inoculant sources are not significantly different from *Zea mays* inoculant sources, *Glycine max* and *Saccharum-Glycine max* combination. In the change in nutrient content N, P, K, the highest value is found in the old 3 MSP saturation treatment, namely 5.17%N, 0.32% P, 1.66% K, and the lowest is found in conventional cultivation treatment. In the N nutrient absorption change, the treatment of inoculant sources from *Saccharum officinarum* was not significantly different from the administration of *Zea mays, Glycine max*, and *Saccharum-Glycine max* inoculant sources. According to Bücking and Kafle (2015), external hyphae of mycorrhiza absorb N from the soil and transport it to the internal hyphae inside the roots of the host plant and further exchanged for carbon passing through the peri arbuscular membrane connecting the host plant and the fungus.

Table 3. Total N, P, K concentration and N, P, K absorption.

Treatment	Nutrient concentration (%)			Nutrient absorption (g per plant)		
	N	P	K	N	P	K
Inoculant source						
No inoculant	3.81±0.88	0.27±0.04c	1.12±0.18c	0.068±0.02b	0.013±0.00b	0.086±0.03c
Zea mays	4.75±0.42	0.30±0.02ab	1.39±0.13b	0.118±0.02a	0.024±0.00a	0.172±0.04a
Glycine max	5.14±0.23	0.30±0.02ab	1.64±0.27ab	0.094±0.02ab	0.019±0.00ab	0.132±0.03b
Saccharum officinarum	5.07±0.16	0.33±0.01a	1.86±0.10a	0.121±0.04a	0.024±0.01a	0.166±0.06ab
Saccharum-Glycine max	4.95±0.21	0.30±0.01ab	1.73±0.17a	0.106±0.04a	0.020±0.01a	0.143±0.05ab
Saturation periods						
Conventional culture	4.44±0.78	0.29±0.03b	1.37±0.33b	0.14±0.03b	0.02±0.00b	0.19±0.05b
2 months since planting	4.63±0.64	0.30±0.02b	1.62±0.30a	0.22±0.06a	0.04±0.01a	0.32±0.10a
3 months since planting	5.17±0.22	0.32±0.01a	1.66±0.28a	0.23±0.04a	0.04±0.00a	0.31±0.06a

Note: Numbers followed by the same letter in the same column are not significantly different based on the LSD test at α = 5%. The mean value is followed by the standard error (SE) value.

Inoculants from corn rhizosphere and water-saturated cultivation increase P uptake (Muis et al., 2016b). In general, soybeans inoculated with inoculant sources from *Saccharum officinarum* and *Zea mays* with a saturation duration of 2 MSP and 3 MSP absorbed more N, P, and K than no inoculation. Arbuscular mycorrhiza will symbiose with the responsive host plant with multiple roots with an extensive root system (Muis et al., 2016a). In the present experiment, mycorrhiza is very influential in increasing plant P uptake (Table 3). The increase in P available is presumably due to the influence of mycorrhiza is caused because P is free from Al and Fe fixation. The phosphatase enzyme produced by arbuscular mycorrhiza can release P, which is influenced by the presence of phosphatase acids present in AMF hyphae so that inorganic P is released from organic P sources in the area near the surface of root cells and can then be absorbed through the nutrient absorption process (Nurhayati, 2012). Mycorrhiza also increases the K uptake by plants, especially at low soil K levels (Garcia and Zimmermann, 2014).

The inoculant source treatment markedly affected the plant height of 6 WAP but had no noticeable effect on the height of 2 WAP and 4 WAP plants (Table 4). In comparison, the old saturation treatment had a noticeable effect on the plant height of 2 WAP and had no significant effect on the plant height of 4 WAP and 6 WAP. In the inoculant source treatment, the number of leaves of 2 WAP did not have a noticeable effect on all inoculant source treatments, but a noticeable effect on the number of leaves of 4 WAP and 6 WAP. The highest number of leaves of 4 WAP and 6 WAP was found in the inoculant source treatment from *Saccharum officinarum*, while the lowest was in the non-inoculant treatment. The old treatment of saturation of 2 MSP and 3 MSP did not differ significantly in leaf changes of 2 WAP, 4 WAP, and 6 WAP but differed significantly from conventional cultivation treatments.

Table 4. Plant height and number of leaves.

Treatment	Plant height (cm)			Number of trifoliate leaves		
	2 WAP	4 WAP	6 WAP	2 WAP	4 WAP	6 WAP
Inoculant source						
No inoculant	14.30±0.53	22.77±0.63	44.33±1.19c	1.0±0.08	6.3±0.49b	12.5±1.28b
Zea mays	14.73±0.47	23.17±0.34	46.91±2.17bc	1.0±0.08	6.9±0.68ab	15.6±2.45a
Glycine max	15.37±0.92	24.05±0.65	49.82±1.31ab	1.1±0.14	7.0±0.28ab	17.0±2.64a
Saccharum officinarum	15.95±1.26	24.96±1.52	51.39±3.66a	1.2±0.25	7.7±0.73a	17.1±2.47a
Saccharum-Glycine max	15.26±0.83	24.48±1.13	48.40±1.52ab	1.1±0.08	7.3±0.37a	17.4±0.69a
Saturation periods						
Conventional culture	14.36±0.40b	23.03±0.66	46.20±2.29	1.0±0.07b	6.6±0.39b	14.0±1.98b
2 months since planting	15.60±1.07a	24.59±1.33	49.47±2.90	1.2±0.14a	7.4±0.55a	17.1±1.96a
3 months since planting	15.40±0.76a	24.04±0.98	48.84±3.57	1.1±0.11a	7.1±0.71ab	16.6±2.89a

Note: Numbers followed by the same letter in the same column are not significantly different based on the LSD test at α = 5%. The mean value is followed by the standard error (SE) value.

The source of the inoculant showed a marked influence on the number of pods and root nodules but had no noticeable effect on the number of stomata (Table 5). Whereas the single factor of the duration of saturation shows a marked influence on the number of pods, the number of root nodules, and the number of stomata. Mycorrhizal inoculation increases leaf number, leaf area index, chlorophyll levels, and photosynthesis rate of soybean plants (Misbahulzanah et al., 2014). Giving several doses of mycorrhiza has no noticeable effect on the number of leaves of *Mucuna bracteata* but has a greater number of leaves when compared to without mycorrhiza (Wahyuni et al., 2020). Clove seedlings fed with arbuscular mycorrhizal fungus shows a noticeable effect on the number of leaves compared to those without inoculation (Putri et al., 2016).

The number of pods, the number of root nodules, and the highest number of stomata values were found in the provision of inoculant sources from the *Saccharum- Glycine max* combination, while the lowest was found in the treatment without inoculants (Table 5). The number of pods, the number of nodules, and the number of stomata, the treatment of 2 MSP saturation duration was not significantly different from the saturation duration of 3 MSP but it was significantly different from conventional cultivation. Root nodules found in the roots of legume plants are a symbiosis between the roots and the bacterium *Rhizobium japonicum*. Root nodules bind free nitrogen, and in addition to being able to fertilize the soil, root nodules can also provide nitrogen elements to the soil. The application of biofertilizers has a noticeable effect on the number of root nodules of the Davros variety soybean plants (Melissa Syamsiah and Bachaerul, 2013). The mycorrhizal application increases plant ability to absorb N, P, and K and also increases the number of root nodules of *Calliandra calothyrsus* (Laksmi Hendrati and Husna Nurrohmah, 2016). In addition, dry conditions fail N-bacterial infections so that nodules do not form on the roots of soybean plants. The presence of external hyphae AMF, in addition to helping to absorb P, also helps the formation of root nodules on the roots of soybean plants (Oktaviani et al., 2014). AMF 80% can form endosymbiotic relationships with land crop types, including food crops such as corn, sorghum, and rice (Xue et al., 2015).

Table 5. Number of pods, number of nodules, and number of stomata at 8 WAP.

Treatment	Number of pods	Number of roots nodules	Number of Stomata
Inoculant source			
No inoculant	43.7±10.45b	27.3±13.95c	64.7±5.89
Zea mays	84.8±9.64a	59.3±25.14b	68.8±5.31
Glycine max	82.7±18.10a	63.0±35.93b	67.1±4.47
Saccharum officinarum	104.1±25.47a	67.9±41.39b	66.4±2.52
Saccharum-Glycine max	97.5±37.64a	90.3±40.71a	69.7±4.14
Saturation periods			
Conventional culture	60.0±18.34b	27.8±9.75b	62.5±2.81b
2 months since planting	95.3±29.12a	76.7±37.07a	69.6±3.12a
3 months since planting	92.4±28.32a	80.2±25.71a	70.0±1.69a

Note: Numbers followed by the same letter in the same column are not significantly different based on the LSD test at α = 5%. The mean value is followed by the standard error (SE) value.

In a single-factor treatment, the inoculant source showed a marked influence on the dry weight of the header and the dry weight of the shell but had no noticeable effect on the dry weight of the roots, the number of filled pods, the weight of 100 seeds and the weight of seeds per polybag (Table 6). It is probable that the roots of soybean undergo colonization so that soybean plants can absorb nutrients well and they have an impact on production. It is estimated that inoculants increased the dry weight of plants by 18-32% when compared to those without inoculants.

The application of the old saturation treatment showed a noticeable effect on the change in the dry weight of the header, roots, plant space, number of filled pods, and seed weight per polybag but did not have a noticeable effect on the weight of 100 seeds. In the dry weight change of the header, root, and cropping, it can be seen that the old treatment of saturation of 2 and 3 MSP is not significantly different but is significantly different from conventional cultivation treatment. Saturation periods of 2 MSP and 3 MSP increased plant dry weight by around 31-41% compared to conventional cultivation. The dry weight of the plant is an accumulation of photosynthesis from the process of photosynthesis. The plant growth response in the form of the dry weight of the plant and the length of the roots treated with mycorrhizal inoculation showed the best treatment when compared to those without mycorrhiza (Samanhudi et al., 2017).

Table 6. The dry weight of the shoot, roots, stem, and production.

Treatment	Dry weight (g per plant)			Production per plant		
	Shoot	Root	Stem	Number of filled pods	Weight of 100 seeds (g)	Seed weight (g)
Inoculant source						
No inoculant	18.07±3.31c	4.82±2.67	22.89±5.91c	61.1±8.80	8.54±0.37	10.44±3.35
Zea mays	25.99±3.26ab	6.73±3.34	32.72±6.50ab	80.5±26.13	9.27±0.42	13.33±3.88
Glycine max	21.93±2.14bc	5.86±2.97	27.79±5.11bc	86.1±36.17	8.80±0.07	12.52±3.99
Saccharum officinarum	27.46±7.89a	6.04±3.19	33.50±11.00a	75.1±12.04	9.25±0.14	14.57±4.44
Saccharum-Glycine max	27.03±8.09ab	5.08±2.81	32.11±10.66ab	89.9±20.19	8.86±0.16	14.50±3.69
Saturation periods						
Conventional culture	18.77±3.03b	2.31±0.44b	21.08±3.45b	56.1±7.93b	8.70±0.36	9.42±1.54b
2 months since planting	28.27±6.49a	7.37±1.46a	35.64±7.20a	85.1±12.27a	9.09±0.30	16.85±2.16a
3 months since planting	25.26±3.89a	7.44±0.59a	32.70±4.07a	94.2±22.05a	9.05±0.36	12.94±2.23b

Note: Numbers followed by the same letter in the same column are not significantly different based on the LSD test at α = 5%. The mean value is followed by the standard error (SE) value.

CONCLUSIONS

The interaction between inoculant sources and saturation periods did not significantly affect all parameters. The inoculant propagated in the media of *Saccharum officinarum* gives the highest effect as compared to those from other treatments. The water saturation for 2 or 3 months since planting gave soybean plants a better morphophysiological response and yield than conventional cultivation.

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