Universal Journal of Agricultural Research 12(4): 539-545, 2024 http://www.hrpub.org
DOI: 10.13189/ujar.2024.120401

Effect of Planting Distance and Foliar Fertilizer on Soybean Growth and Yield in Saturated Soil Culture in Tidal Swamp

Munif Ghulamahdi[1,*], Sandra Arifin Aziz[1], Iskandar Lubis[1], Bagus Abimanyu[1], Tatsuhiko Shiraiwa[2], Paul Taylor[3]

[1]Department of Agronomy and Horticulture, IPB University, Indonesia
[2]Graduate School of Agriculture, Laboratory of Crop Science, Kyoto University, Japan
[3]Faculty of Science, University of Melbourne, Australia

Received March 11, 2024; Revised June 6, 2024; Accepted June 26, 2024

Cite This Paper in the Following Citation Styles

(a): *[1] Munif Ghulamahdi, Sandra Arifin Aziz, Iskandar Lubis, Bagus Abimanyu, Tatsuhiko Shiraiwa, Paul Taylor , "Effect of Planting Distance and Foliar Fertilizer on Soybean Growth and Yield in Saturated Soil Culture in Tidal Swamp," Universal Journal of Agricultural Research, Vol. 12, No. 4, pp. 539 - 545, 2024. DOI: 10.13189/ujar.2024.120401.*

(b): *Munif Ghulamahdi, Sandra Arifin Aziz, Iskandar Lubis, Bagus Abimanyu, Tatsuhiko Shiraiwa, Paul Taylor (2024). Effect of Planting Distance and Foliar Fertilizer on Soybean Growth and Yield in Saturated Soil Culture in Tidal Swamp. Universal Journal of Agricultural Research, 12(4), 539 - 545. DOI: 10.13189/ujar.2024.120401.*

Abstract This experiment aims to find the optimal foliar fertilizer type, planting distance, or combination of both to increase the productivity and growth of soybeans. This experiment was conducted in Mulyasari Village, Banyuasin District, South Sumatra Province, eleven feet above sea level, 2°38'42.35" South Latitude, and 104°45'5.92" East Longitude. An overflow-type experiment took place in 2017 between April and August. For the trial, we used a randomized complete block design consisting of two components, each with three replications. The first factor was foliar fertilizer; in the absence of foliar fertilizer, nitrogen was included in (Nitrogen + Cu), (Nitrogen + Cu+ Zn), and (Nitrogen + Cu + Zn + Mg). The second factor was the planting distance, which came in two sizes, 25 cm by 20 cm and 40 cm by 12.5 cm, with two seeds in each hole. Six weeks after planting, the foliar fertilizer impacted the quantity of leaves and plant height (WAP). The productivity was 3.170 tons/ha without foliar fertilizer and 3.785 tons/ha with N + Cu, respectively. This means that foliar fertilization can increase yields by 615 kg ha^{-1} compared to without foliar fertilization. The planting distance had an impact on the number of leaves at 6 and 10 WAP; plant fill pod count, 100 seed dry weight, plant dry weight, seed dry weight per plot, and production: 3. tons/ha at 25 cm × 20 cm and 3.278 tons/ha at 40 cm × 12.5 cm were the results.

Keywords Soybean, Pyrite, Foliar Fertilizer, Population, Tidal Swamps

1. Introduction

The Indonesian population consumed 2.8 million tons of soybeans in 2022. Just 10.7%, or ±0.3 million tons, of the total national production was sustained by the national production. In 1992, Indonesia's largest soybean planting area was recorded at 1.6 million hectares, with a productivity of 1.12 tons per hectare. However, by 2023, the same area had shrunk to 0.554 million hectares with a productivity of 1.45 tons per hectare [1]. The low price and low productivity of soybeans contributed to the decrease in planting area [2]. To meet the country's demand for soybeans, extra effort must be made, either by expanding the number of production sites or increasing crop output.

Making the best use of marginal land outside Java Island is one option for expanding soybean farming in Indonesia.

The tidal swamp is one possible environment for the cultivation of soybeans in the future. Of Indonesia's approximately 20 million hectares of tidal wetlands, 9 million are suitable for agriculture, and 2 million are good for soybean cultivation [3]. High pyrite content is the main barrier to soybean cultivation in tidal swamps. The area of tidal swamp with pyrite content > 9 % is grouped as very high, between 4-8 % as high, between 2-4 % as medium, and < 1 % as lower [4].

The pH of the soil will drop when the pyrite oxidizes. Soybean productivity on tidal marshes was suppressed by high pyrite content by about 800 kg/ha when using a dry culture technique [5]. Tidal swamp soil fertility was indicated by low pH, high Al, high pyrite, medium P availability, and low K availability [6]. Using Saturated Soil Culture (SSC) technology, soybean productivity may increase while pyrite oxidation on tidal wetlands can decrease. In tidal wetlands on the C overflow type of Tanggamus, Slamet, Anjasmoro, and Wilis, the soybean productivity under saturated soil culture was 4.63, 2.85, 2.62, and 2.47 tons/ha, whereas during dry culture, it was only 0.85, 016, 0.09, and 0.30 tons/ha [6]. Drought reduced seed yield by 19.1 % to 32.9% on grain legumes [7].

The production method known as saturated soil culture (SSC) was created in semi-arid tropical Australia and is said to boost soybean output over traditional irrigation. Water is kept in the furrows between beds with SSC from the beginning of vegetative stages till maturity. SSC was done with continuous irrigation 5 cm under soil surface from 15 days after planting until harvesting time [8]. Constant water table will decrease water inundation negative effect [9]. On tidal swamp, SSC was made with ditch width of 30 cm, ditch depth of 25 cm, water depth of 20 cm from the soil surface, and bed width of 400 cm. The continuous irrigation was given from planting time until harvesting time [6].

Tidal swamps can be classified as type A, B, C, or D depending on the type of overflow they have. High tides constantly overwhelm Type A during both the rainy and dry seasons. Type C is not affected by high tide but is affected by groundwater levels that are deeper than 50 cm, while Type B is only covered by high tide during the wet season. Similar to type C, type D also has groundwater levels below 50 cm [10].

The B overflow type will see saturated soil culture technology development expand. The B overflow type has better water availability than the C overflow type, but it also has a higher frequency of transient flooding, pyrite concentration, and Fe and Al content [11]. The application of ameliorant, minimum tillage, fertilization, water management, and genotype adaptability can all be used to tackle this issue [6].

The criteria of soybeans with high adaptation in a tidal swamp, under wet soil culture were: 1) high tolerance to Al and Fe, 2) high tolerance to temporary flooding, 3) high root hair development, and 4) high root compatibility to *Rhizobium*, sp and *Mycorrhiza* [12]. The tolerant variety had a higher root Al content than the sensitive variety to the Al stress [13]. The Anjasmoro variety is more tolerant than the Tanggamus Variety on the double stress Al and Fe [14].

Different types of soybeans responded differently to saturated conditions, with later maturing soybeans performing better than earlier ones [8]. The sensitivity index from the productivity variable was used to determine the variety's sensitivity to the brief flooding under saturated soil culture. Because the sensitivity indexes of Variety Tanggamus, Variety Anjasmoro and Variety Detam-2 range from 1.067 to 1.226, they were categorized as sensitive varieties. Still, Wilis and Malika were classified as moderate-tolerant because their sensitivity index ranges from 0.680 to 0.857 [15].

The root and nodule beneath the water's surface will die, the leaf's N content will drop, and the soybean leaf will develop chlorosis during the early stages of acclimation under saturated soil culture [9]. Foliar fertilizer can be applied to address the low N content in leaves. When compared to foliar application, the application of N fertilizer through the soil proved to be ineffective.

After planting, the acclimation phase lasted two to four weeks [16]. Under these circumstances, the amount of ethylene and ACC (1-aminocyclopropane-1-carboxylic acid) in the roots will rise [17], which will have an impact on the development of roots, nitrogenase activity in the nodule, and the creation of root aerenchyma [16]. Compared to a dry culture system, the nodule dry weight rose four times in non-tidal swamps [18] and the nitrogenase activity rose nine times in tidal swamps [16] under saturated soil culture. In comparison to a dry culture system, saturated soil culture resulted in greater nutrient uptake. The continuous irrigation increased N, P, and K nutrient uptake, respectively [19]. Application of nodule inoculant in combination with P led to increased nodulation, and contributed to higher yields of soybeans [20]. This physiological process will boost soybean output, fill pods per plant, and grow. This is the adaptability of soybeans grown in saturated soil.

The application of N foliar fertilizer with enrichment Cu, Zn, and Mg will increase leaf nutrients and decrease leaf Al toxicity. The optimal population of soybean cultivation in a tidal swamp, under wet soil culture was 400.000 plants/ha [6]. The number of branches and fill pods per plant will rise with the proper planting distance. This experiment aims to determine the best foliar fertilizer type, planting distance, or combination of both to boost soybean growth and yield.

2. Materials and Methods

The study was performed in Mulyasari Village, eleven feet above sea level, 2°38'42.35" South Latitude, and 104°45'5.92" East Longitude in Banyuasin District, South

Sumatra Province. An overflow-type experiment took place in 2017 between April and August. The research used a randomized complete block design with two factors, and three replications were used for the experiment. The first factor is the planting distance, which is separated into two categories. Each hole is 40 by 12.5 cm and each hole measures 25 by 20 cm. The second element is foliar application, which comprises 1) Without foliar fertilizer, 2) N, 3) N + Cu, 4) N + Cu + Zn, and 5) N + Cu + Zn + Mg. Foliar fertilizer was given 3, 4, 5 and 6 weeks after planting. The concentration of N is 10 g Urea l^{-1} water, Cu is 0.1 g $CuSO_4$ l^{-1} water, Zn is 0.1 g ZnSO4 l^{-1} water, and $MgSO_4$ is 0.2 g l^{-1} water with a spray volume of 400 liters of water ha^{-1}. This experiment used the Anjasmoro Variety. As seen in Fig. 1, a trench with 30 cm in width and 25 cm in depth surrounds each plot with a bed width of 4 meters. When planting, water was applied 20 cm below the soil's surface and maintained until the plots reached maturity, keeping them moist.

Before doing the DMRT (Duncan Multiple Range Test) with a 95% confidence interval, the data were analyzed using Analysis of Variance (ANOVA). SAS version 9.0, Minitab, and Microsoft Excel 2016 were used to analyze variance.

Plots with size 4 m x 3 m were applied one week before planting, along with 200 kg of SP-36 18 kg ha^{-1}, 100 kg of KCl ha^{-1}, and 2 tons of dolomite/ha. On the day of sowing, seeds were treated with an insecticide containing the active ingredient carbosulfan (25.53%) and inoculated with Rhizobium sp. Two seeds per hole were sown at planting distances of 25 cm by 20 cm and 40 cm by 12.5 cm. The observed variables are: plant height, leaf number, leaf nutrient content, branch number, fill pod, empty pod per plant, seed dry weight per plot, and 100-seed dry weight.

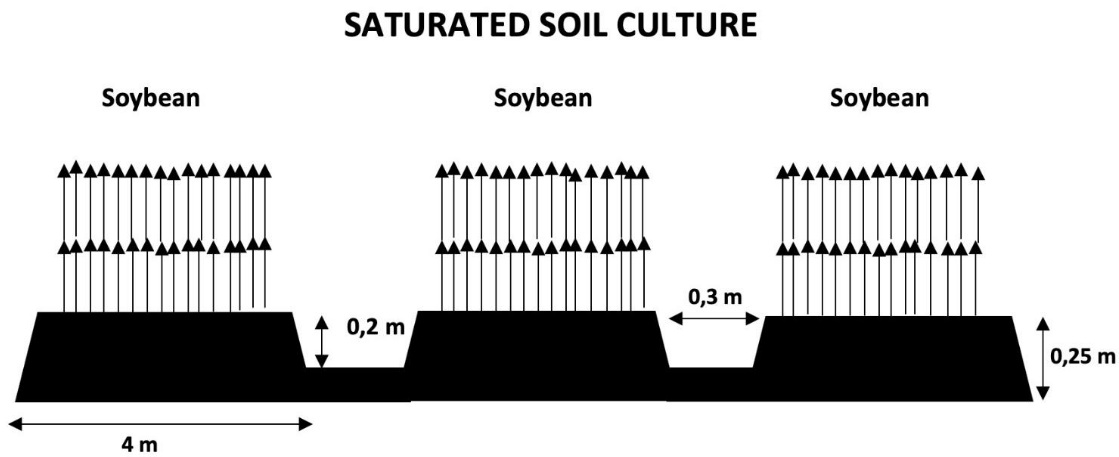

Figure 1. The size of the trench and bed width in saturated soil culture

3. Result and Discussions

3.1. The Impact of Single Elements Planting Distance and Foliar Application

The single planting distance factor unaffected plant height at 2–10 WAP, although it did alter; there are six leaves and 10 WAP. A planting distance of 25 cm × 20 cm produced more leaves than a planting distance of 40 cm × 12.5 cm (Tables 1 and 2).

Table 1. How far a plant is planted affects its height (cm)

Age (Week After Planting)	Planting distance	
	25 x 20	40 x 12.5
2	11.28	11.6
4	17.64	17.68
6	37.23	37.14
8	40.12	40.24
10	40.31	40.14

Note: There is no discernible difference between numbers in a sequence that is followed by the same letter, according to the Duncan multiple range test α = 5%.

Table 2. Planting distance's impact on the quantity of leaves

Age (Week After Planting)	Planting distance	
	25 x 20	40 x 12.5
2	1.35	1.39
4	4.07	4.01
6	17.05a	15.55b
8	20.64	18.73
10	20.64a	18.73b

Note: There is no discernible difference between numbers in a sequence that is followed by the same letter, α = 5% based on the Duncan multiple range test results.

The planting distance did not affect the number of branches per plant. However, it did impact the fill pod number per plant, 100 seed dry weight, seed dry weight per plant, seed dry weight per plot, and productivity. The productivity on the planting distance of 25 cm × 20 cm, fill pod number per plant, 100 seed dry weight, seed dry weight per plant, seed dry weight per plot, and so on were greater than 40 cm × 12.5 cm (Table 3).

Table 3. The impact of planting distance on productivity, branch number, fill pod number, plant and seed dry weight, 100 dry weight, and seed dry weight/plot

Variable	Planting distance	
	25 x 20	40 x 12.5
Branch number per plant	3.54	3.22
Fill pod number per plant	41.80a	36.96b
Seed dry weight per plant (g)	13.65a	12.17b
100-seed-dry weight	15.10a	16.00b
Seed dry weight per 6.0 m^2 (g)	2 104.8a	1 966.8b
Productivity (ton ha^{-1})	3.508a	3.278b

Note: There is no discernible difference between numbers in a sequence that is followed by the same letter, according to the Duncan multiple range test α = 5%.

In Indonesia, the lowland tidal marsh area had higher levels of solar radiation intensity than the country's highlands. In August, the sun radiation intensity was 1,063 Wm^{-2} in the tidal swamp at Mulyasari, South Sumatra Province, and only 434 Wm^{-2} in the highland of Bogor, West Java [21]. High productivity will be supported by the intensity of the sun's rays when planting distance and fertilizer are suitable. With a planting distance of 25 cm by 20 cm, the productivity of the soybean was 3.50 tons/ha, and it was classified as high productivity in Indonesia. The productivity of soybeans in the country was only 1.45 tons ha^{-1} [1].

At 6 WAP, the foliar fertilizer alone impacted plant height and leaf count; however, similar effects were not observed at subsequent ages. The most remarkable plant and leaf count was achieved by applying foliar fertilizer N + Cu. The shortest plant and the fewest leaves were observed with the application of foliar fertilizer N + Cu + Zn (Tables 4 and 5).

Table 4. Foliar fertilizer's impact on plant height

Age (WAP)	Foliar Fertilizer				
	Without fertilizer	Nitrogen	Nitrogen + Cu	Nitrogen + Cu + Zn	Nitrogen + Cu + Zn + Mg
2	11.53	11.50	11.34	11.07	11.77
4	17.3	17.6	18.33	17.27	17.8
6	35.38b	38.40a	38.13a	34.42b	39.59a
8	38.37	42.04	38.57	39.8	42.13
10	37.84	42.24	39.3	39.4	42.34

Note: There is no discernible difference between numbers in a sequence that is followed by the same letter, according to the Duncan multiple range test α = 5%.

Table 5. Foliar fertilizer's impact on leaf number

Age (WAP)	Foliar Fertilizer				
	Without fertilizer	Nitrogen	Nitrogen + Cu	Nitrogen + Cu + Zn	Nitrogen + Cu + Zn + Mg
2	1.34	1.64	1.37	1.14	1.37
4	3.87	4.07	4.5	3.9	3.87
6	15.43bc	16.64b	18.60a	14.25c	16.60b
8	18.3	20.84	19.84	20.2	19.27
10	18.3	20.84	19.84	20.2	19.27

Note: There is no discernible difference between numbers in a sequence that is followed by the same letter, according to the Duncan multiple range test α = 5%.

Table 6. The impact of foliar fertilizer on productivity, branch number, fill pod number, plant seed dry weight, 100 dry weight, and seed dry weight/plot

Variable	Foliar Fertilizer				
	Without fertilizer	Nitrogen	Nitrogen + Cu	Nitrogen + Cu + Zn	Nitrogen + Cu + Zn + Mg
Branch number per plant	3.30	3.60	3.55	3.15	3.30
Fill pod number per plant	39.05	40.50	42.20	34.50	40.65
Seed dry weight per plant (g)	13.41	13.29	13.81	11.39	12.65
100-seed-dry weight	15.10	16.00	16.00	16.00	15.75
Seed dry weight per 6.0 m^2 (g)	1902	1977	2271	1941	2088
Productivity (ton ha^{-1})	3.170	3.295	3.785	3.235	3.480

Note: There is no discernible difference between numbers in a sequence that is followed by the same letter, according to the Duncan multiple range test α = 5%.

The foliar fertilizer did not affect the number of fill pods and branches on each plant, the quantity of seed dry weight per plant, the quantity of seed dry weight per plot, and productivity. Table 6 shows that the productivity range for all foliar fertilizer treatments was 3.170-3.785 tons ha^{-1}. There are indications from the trend of the seed dry weight per plot that the foliar application will tend to increase soybean productivity, although the statically was no different. The leaf N content was predicted to be still low, i.e. < 4 %.

To achieve the soybean productivity of 4 ton ha^{-1}, the leaf N content is minimal at 4 % [22]. In this experiment, the leaf N content was in the range of 3.0–3.5 %. Therefore, the N leaf fertilizer concentration will be increased to 15-20 g Urea l^{-1} water under saturated soil culture in the high pyrite location. The pyrite content in the B overflow type was more elevated than in the C overflow type [11]. Applying N leaf fertilizer with a concentration of 30 g Urea l^{-1} water will cause the soybean leaf to be burnt [23].

The application of foliar fertilizer of Nitrogen, Nitrogen + Cu, Nitrogen + Cu + Zn, Nitrogen + Cu + Zn + Mg increased productivity of soybeans as much as: 125 kg (3.94 %), 615 kg (19.4 %), 65 kg (2.05 %), and 310 kg (9.7 %) than without fertilizer, respectively. The highest productivity of soybeans was obtained on Nitrogen + Cu. Nitrogen + Cu foliar fertilizer ha^{-1} need Urea 16 kg ha^{-1} with price U$ 0.657 (U$ 10.512), $CuSO_4$ 0.6 kg with price U$ 3.757 (U$ 2.254), and spraying 8 mans with price U$ 6.262 (U$ 50.096), or total cost ha^{-1} as much as U$ 62.862. The income of Nitrogen + Cu from the increasing productivity ha^{-1} compared without fertilizer was obtained 615 kg with price U$ 0.626 (U$ 384.990), and the benefit ha^{-1} was obtained U$ 322.128.

3.2. The Impact of Foliar Fertilizer and Planting Distance Interaction

The interplay between foliar fertilizer and planting distance impacted plant height at 2 WAP. On the planting, the tallest plant was found distance of 40x12.5 cm, and on the foliar fertilizer Nitrogen + Cu + Zn + Mg. The shortest plant was obtained on the planting distance of 40 × 12.5 cm, and on the foliar fertilizer N + Cu + Zn; and on the planting distance of 25 cm × 20 cm, and on the foliar fertilizer N (Table 7).

Based on the data presented in Table 7, it appears to be examining the effect of the interaction between planting distance and the application of various foliar fertilizers on development of plants two weeks following planting

(WAP). The table displays the mean values of a measured variable (possibly plant height, leaf area, or biomass) for different combinations of planting distances and foliar fertilizer treatments. The planting distances evaluated were 25 cm × 20 cm and 40 cm × 12.5 cm, which likely represent different plant densities or spacing configurations. The foliar fertilizer treatments included no fertilizer (Without), nitrogen (N), nitrogen + copper (N + Cu), nitrogen + copper + zinc (N + Cu + Zn), and nitrogen + copper + zinc + magnesium (N + Cu + Zn + Mg).

At the 25 cm × 20 cm planting distance, the highest mean value was observed for the Without treatment (11.73), followed by N + Cu (11.27), N + Cu + Zn (11.27), N + Cu + Zn + Mg (11.20), and the lowest mean value was for the N treatment (10.93). At the 40 cm × 12.5 cm planting distance, the highest mean value was observed for the N + Cu + Zn + Mg treatment (12.33), followed by the N treatment (12.07), N + Cu (11.40), Without (11.33), and the lowest mean value was for the N + Cu + Zn treatment (10.87).

The significance of the differences between the means was determined using Duncan's multiple range test at a 5% level, as indicated by the letters following the numerical values. This means that the same letters within the same row are not significantly different from each other.

Table 7. The result of interactions between planting distance and Foliar Fertilizer on the plant height at 2 WAP

Foliar Fertilizer	Planting distance	
	25 x 20	40 x 12.5
Without Fertilizer	11.73bc	11.33cd
N	10.93d	12.07ab
N + Cu	11.27cd	11.40cd
N + Cu+ Zn	11.27cd	10.87d
N + Cu+ Zn + Mg	11.20cd	12.33a

Note: There is no discernible difference between numbers in a sequence that is followed by the same letter, according to the Duncan multiple range test α = 5%.

4. Conclusions

The leaf number at 6 and 10 WAP, productivity, pod count/plant, seed dry weight per plant, seed dry weight/plot, and 100 seed dry weight were all impacted by planting distance. Soybeans produced more when planted at a 25 cm × 20 cm spacing than 40 cm × 12.5 cm. At a planting distance of 25 cm by 20 cm, the productivity was 3.508 tons/ha, and at 40 cm by 12.5 cm, it was 3.278 tons/ha. Foliar fertilizer affected plant height and number of leaves at 6 WAP but not other parameters. Production was 3.170 tons/ha without foliar fertilizer and 3.785 tons/ha with nitrogen + copper. This means that foliar fertilization can increase yields by 615 kg ha^{-1} compared to without foliar fertilization. Plant height was the sole criterion affected by the planting distance at 2 WAP and foliar fertilizer mix.

Acknowledgements

We thank IPB University's International Collaboration Research and the General Directorate of Higher Education, Research and Technology of the Ministry of Education, Culture, and Technology for funding this research.

REFERENCES

[1] Statistic Central Agency. (2023). Production, Harvesting Area, and Productivity of Palawija (Non Pady) in Indonesia.

[2] Azizah, M. A., Syafrial, S., & Suhartini, S. (2015). Analysis import policy of soybean on economics performance of Indonesian soybean. *Habitat*, 26(1), 47-56. https://doi.org/10.21776/ub.habitat.2015.026.1.6

[3] Yasin, M., Noor, A., & Ningsih, R. D. (2020, April). Opportunities for improving rice production in sub-obtimal lands South Kalimantan. In *IOP Conference Series: Earth and Environmental Science* (Vol. 484, No. 1, p. 012063). IOP Publishing. https://doi.org/10.1088/1755-1315/484/1/012063

[4] Widyatmanti W, Sammut J. (2017). Hydro-geomorphic controls on the development and distribution of acid sulfate soils in Central Java, Indonesia. *Journal of Geoderma*, 308, 321-332. https://doi.org/10.1016/j.geoderma.2017.08.024

[5] Raharjo, B., & Herwenita, H. (2019). Relationship between Farmers Knowledge Level and Technologies Implementation in Tidal Swamp Land in South Sumatra. *Sriwijaya Journal of Environment*, 4(3), 165-170. https://doi.org/10.22135/sje.2019.4.3.165-170

[6] Ghulamahdi, M., Melati, M., & Sagala, D. (2009). Production of soybean varieties under saturated soil culture on tidal swamps. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, 37(3). https://doi.org/10.24831/jai.v37i3.1301

[7] Gusmao, M., & Sitorus, L.T. (2021). Adaptation of grain legumes in transient water deficit in Timor-Leste. *Universal Journal of Agricultural Research*, 9(6), 235-247. https://doi.org/10.13189/ujar.2021.090602

[8] Hunter, M.N, De Fabrun P.L.M., & Byth D.E. (1980). Response of nine soybean lines to soil moisture conditions close to soil saturation. Austral. *J. Exp. Agric. Anim. Husb*, 20, 339–345. https://www.publish.csiro.au/an/EA9800339

[9] Troedson, R.J., Garside, A.L., Lawn R.J., Byth D.W., & Wilson D.L. (1983) *Saturated soil culture in innovated water management option for soybean in the tropics and sub tropics*. pp. 171-180. *In* S. Shanmugasundaran and E. W. Sulzberger (eds.). Tsukuba, Japan. Soybean in Tropical and Subtropical System. Proc. Symp. https://worldveg.tind.io/record/5199

[10] Hidayanto, M., & Fiana, Y. (2021). Optimization of Newly Opened Rice Fields on Tidal Swamp Through Superior Rice Varieties in Bulungan District. *Agromet*, 35(2), 89-97. https://doi.org/10.29244/j.agromet.35.2.89-97

[11] Fahmi, A., Alwi, M., & Nursyamsi D. (2018). The role of inundation types of tidal swamp land on the chemical properties of potentially acid sulphate soils under fertilizer and lime application. *Journal of Tropical Soil*, 23, 55-64. https://journal.unila.ac.id/index.php/tropicalsoil/article/view/270/267

[12] Harsono, A., Harnowo, D., Ginting, E., & Elisabeth, D. A. A. (2021). *Soybean in Indonesia: Current status, challenges and opportunities to achieve self-sufficiency*. IntechOpen. https://doi.org/10.5772/intechopen.101264

[13] Prameswari, W., Silitonga, E.B., & Setyowati, N. (2023). Soybean (*Glycine max* L.) response to aliminum stress in the vegetative phase. In *IOP Conference Series:* BIO Web of Conferences 69, 01014 *2nd ICAFE (International Conference on Agriculture. Food, and Environment.* https://doi.org/10.1051/bioconf/20236901014

[14] Noya, A.I., Ghulamahdi, M., Sopandie. D., Sutandi, A., & Melati, M. (2014). Interactive effects of aluminum and iron on several soybean genotypes grown in nutrient solution. *Asian J Plant Sci*, 13, 18-25. https://scialert.net/abstract/?doi=ajps.2014.18.25

[15] Ghulamahdi, M., Charunisa, S.R., Lubis, I., & Taylor, P. (2016). Response of five soybean varieties under saturated soil culture and temporary flooding on tidal swamp. *Procedia Environmental Sciences*. 33, 87-93. https://www.researchgate.net/publication/301317670

[16] Lawn, R.J. 2004. Contribution to crop improvement and sustainable agriculture in tropical an subtropical Australia. Queensland. Submitted for degree of doctor of agricultural science at the University of Queensland. https://www.researchgate.net/publication/43467272_Contributions_to_crop_improvement_and_sustainable_agriculture_in_tropical_and_subtropical_Australia

[17] Arguesto, C.T., Hansen, M., & Kieber, J.J. (2007). Regulation of ethylene biosynthesis. J. Plant Growth Regul, 26, 92-105. https://doi.org/10.1007/s00344-007-0013-5

[18] Guafa, W., Peoples, D.F. Herridge, D.F, & Rerkasem, B. (1993). Nitrogen fixation, growth and yield of soybean grown under saturated soil culture and conventional irrigation. Field Crops Research, 32, 257-268. https://doi.org/10.1016/0378-4290(93)90035-L

[19] Kanade, S.M., Kale, K.D., Pawar, D.D., & Hasure, R.R. (2017). Yield of soybean, nutrient uptake and nutrient availability in an inceptisol as influenced by irrigation at critical growth stages. Agropedology, 27, 71-75. https://doi.org/10.47114/j.agroped.2017.jun10

[20] Savala, C.E.N., & Kye-Boahen, S. (2020). Potential pf inoculant and phosphorus application on soybean production in Mozambique. *Universal Journal of Agricultural Research*, 8(2), 46-57. https://doi.org/10.13189/ujar.2020.080204

[21] Sagala. D. (2015). Adaptation of Soybean Genotypes from Various Countries on Tidal Swamps in The Wet Tropical. Report of Collaboration Between Bogor Agricultural University and Kyoto University. Bogor. 25 June 2015.

[22] Small, H.G., & Ohlroggee, A.J. (1973). Plant Analysis as an Aid in Fertilizing Soybean and peanuts. P: 315-327. In. L. M. Wals and J.D. Beaton (ed.). Soil Testing and Plant Analysis. Soil Sci. Soc. of Amer., Inc. Madison, Wisconsin. USA.

[23] Matcham, Emma G., et al. (2021). Foliar fertilizers rarely increase yield in United States soybean. *Agronomy Journal*, 113(6), 5246-5253. https://doi.org/10.1002/agj2.20889