Indonesian Journal of Agronomy

ISSN 2085-2916 | e-ISSN 2337-3652
Indonesian J. Agron., *51*(1), 27-36, April 2023
DOI: https://dx.doi.org/10.24831/ija.v51i1.45811

Research Article

Growth, yield, and land use efficiency of soybean-maize relay cropping under saturated soil culture on tidal swamps

Sahuri [1], Munif Ghulamahdi [2,*], and Suwarto [2]

[1] Graduate School of Agronomy and Horticulture Study Program, Faculty of Agriculture, IPB University, Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, INDONESIA
[2] Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University, Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, INDONESIA
* Corresponding author (✉ mghulamahdi@yahoo.com)

ABSTRACT

More than 75 percent of households growing maize and soybean adopts the monoculture method. The relay cropping of soybean-maize is a strategic choice to increase the planted area and productivity of these two commodities' sustainability in tidal swamps. The research aimed to study the land equivalent ratio (LER), determine the best planting spacing and soybean varieties, and the best relay cropping of maize on saturated soil culture in tidal swamps. The experiment was on mineral soils with type B tidal swamps, in Banyuasin, South Sumatra, from July to December 2022. The experiment used a three-factor randomized complete block design with three replications. The first factor was soybean varieties: Argomulyo, Gepak Kuning, Detap 1, and Demas 1, the second factor was soybean planting spacing: 78 cm x 15 cm x 12.5 cm and 60 cm x 40 cm x 10 cm, and the third factor was the relay cropping of maize: 30 and 45 days after planting (DAP) of soybeans. Results showed that plant height, number of leaves, number of branches, filled pods, 100 seeds weight, and seed yield were influenced significantly by varieties. Demas 1 variety produced a higher seed yield, with relay cropping and monoculture, i.e., 4.2 tons ha^{-1} and 4.1 tons ha^{-1}, respectively. Plant height, stem diameters, number of leaves, 100 grains weight, and grain yield in maize were significantly higher at soybean planting spacing of 78 cm x 15 cm x 12.5 cm and relay cropping at 30 DAP. The LER values > 1, indicated that relay cropping increased land productivity as compared to monoculture cultivation. The LER at relay cropping of 30 DAP was significantly highest for Argomulyo and Detap 1 varieties, i.e., 1.8 and 1.8, respectively.

Keywords: *Land equivalent ratio*, *planting spacing*, *relay cropping*, *saturated soil culture*, *tidal swamps*

Edited by:
Arya Widura Ritonga

Received:
28 January 2023
Accepted:
30 March 2023
Published online:
19 April 2023

Citation:
Sahuri, Ghulamahdi, M., & Suwarto. (2023). Growth, yield, and land use efficiency of soybean-maize relay cropping under saturated soil culture on tidal swamps. *Indonesian Journal of Agronomy*, *51*(1) 27-36.

INTRODUCTION

More than 75 percent of households planting maize and soybean crops adopt the monoculture cultivation method (BPS, 2020). Monoculture means only a single crop exists on the farm. The tidal swamp becomes a food production area in Banyuasin Regency with a total area of 0.23 million ha with a single planting index (planted once a year), i.e., between November-March (BAPPEDA of Banyuasin Regency, 2019). Such a situation is an opportunity to increase maize and soybean yields through relay cropping in tidal swamps. Relay cropping is one way to increase the planting index of soybean and maize in tidal swamps (Ghulamahdi et al., 2017). Relay cropping is a double-cropping pattern in which a second crop is planted among the first crop when the first crop enters the reproductive period before harvest. This pattern increases the land equivalent ratio (LER) and improves soil fertility through nitrogen fixation by soybean (Zaeem et al., 2019).

The maize+soybean relay cropping is possible because these two crops can have beneficial complementary effects. Soybean leaves spread horizontally, allowing for sufficient light (Ghulamahdi et al., 2017). Soybean has low light use efficiency (LUE) and radiation use efficiency (RUE) due to the deep shade created by the maize canopy (Blessing et al., 2022). Maize requires high nitrogen, and some nitrogen can be obtained from nitrogen fixation by soybean with the help of *Rhizobium japonicum* bacteria. The relay cropping has an average LER of 1.32 and a Fertilizer N Equivalent Ratio of 1.44, meaning that the same results in the same unit area a monoculture requires 44% more nitrogen fertilizer than that of relay cropping (Xu et al., 2020).

The time of planting is important in the relay cropping system because it determines the success of maize+soybeans production. Soybeans planted 21 days before planting maize produce the highest number of pods as compared to those planted 21 days after planting maize (Aziz and El-rack, 2012). Soybean planted 30 days before maize resulted in soybean nodule dry weight, and nitrogenase activity, respectively 34.2% and 12.5% higher than monoculture. The amount and ratio of N_2 fixation in relay cropping are significantly higher than in monoculture, which reduced N application (Du et al., 2020). Planting maize 30 days after soybeans planting can keep the stomata open longer than monoculture (320 mmol $m^{-2}s^{-1}$ vs 100 mmol $m^{-2}s^{-1}$) because maize in relay cropping experiences less water stress ($\delta^{13}C$: -10.12%) than monoculture (Khongdee et al., 2021).

The soybean-maize relay cropping in a tidal swamp is carried out with saturated soil culture. This culture technique is providing continuous irrigation and ensures a constant water level so that the subsoil layer is saturated with water and can eliminate the negative effects of excess water. Furthermore, the plants acclimatize and improve their growth by allocating photosynthate to the lower part of the plant for root growth and root nodule, thereby increasing leaf nutrient uptake and soybean yields compared to conventional methods (Ghulamahdi et al., 2015). This system can suppress pyrite oxidation, prevent a decrease in pH, reduce Al and Fe, and increase nutrient availability (Noya et al., 2014), thereby increasing the number of branches and filled pods per plant, seed dry weight per plant, and soybean productivity compared to temporary flooding (Ghulamahdi et al., 2016). This system increases maize productivity by 28%, significantly higher than the temporary inundation treatment (Maulana et al., 2019). Maize production increases by about 7% when the soil is saturated with water and decreases by about 10% when the soil is dry (Peichl et al., 2018). This research aimed to study the land equivalence ratio, determine the best planting space and soybean varieties, and the best relay cropping of maize on saturated soil culture in tidal swamps.

MATERIALS AND METHODS

The research was conducted in an overflow type B tidal swamp, which is only flooded by large tides (Ghulamahdi et al., 2017), at Banyuasin Regency, South Sumatra, from July to December 2022. The experiment used a three-factor randomized complete block design with three replications. The first factor was soybean varieties, namely: Argomulyo, Gepak Kuning, Detap 1, and Demas 1. The second factor was soybean plant spacing, namely: 78 cm x 15 cm x 12.5 cm and 60 cm x 40 cm x 10 cm. The third factor was the relay cropping of maize at 30 and 45 days after planting (DAP) of soybeans. The calculated LER was determined by conducting monoculture maize and soybean experiments.

A trial plot was made sized 4.0 m x 3.0 m. Each plot was surrounded by a canal ditch with a width of 30 cm and a depth of 40 cm. The canals were filled with water as high as 20 cm from the bottom of the channel (the water level was 20 cm from the land surface) continuously from the planting until harvesting time so that the layer under the roots was water saturated. Furthermore, the soil amendment application consisted of 1.0 tons ha^{-1} of manure, 2.0 tons ha^{-1} of lime, and 500 kg ha^{-1} of husk charcoal.

In relay cropping, soybean seeds inoculated with *Rhizobium sp*. (5 g kg^{-1} seed) were planted at a spacing of 78 cm x 15 cm x 12.5 cm (400,000 plants ha^{-1}) and 60 cm x 40 cm x 10 cm (400,000 plants ha^{-1}). In monoculture, soybean planted at a spacing of 40 cm x

12.5 cm (400,000 plant ha^{-1}), with two seeds per planting hole, and maize was at 100 cm x 25 cm (40,000 plants ha^{-1}), with one seed per planting hole.

Fertilizer was applied one week before planting. The fertilizer for soybeans consisted of 200 kg ha^{-1} SP36, and 100 kg ha^{-1} KCl applied in grooves. Urea was applied through the foliar at 10 g Urea L^{-1} at 2, 3, 4, and 5 weeks after planting (WAP). Fertilizers for maize consisted of 200 kg ha^{-1} SP36, 100 kg ha^{-1} KCl, and 150 kg ha^{-1} urea applied in rows. The second fertilizer was 150 kg ha^{-1} urea for maize at 30 DAP.

Maintenance consisted of canal maintenance, weeding, and pest and disease control. The soybeans were harvested after plants have shed their leaves and pods had brownish yellow color with a moisture content of about 17-20%. Maize was harvested when the cob skin turned yellow and hard and shiny seeds with a moisture content of about 35%, then sun-dried for seven days to reach a moisture content of about 20% (Suparlan et al. 2018). The observations were carried out for plant growth and yield, including the calculation of the land equivalent ratio (LER).

The data were analyzed using ANOVA and then continued using Duncan Multiple Range Test (DMRT) posthoc test at 95% intervals of significance (Mattjik & Sumertajaya, 2013). Interception of sunlight was measured by comparing light intensity outside the maize canopy to the light intensity under the maize canopy using a lux photometer (LiCor model Li 189) in the morning (08:00 WIB), afternoon (12:00 WIB), and evening (17:00 WIB) followed Palijama et al. (2012). The LER value is the ratio between the area required in a monoculture system and the relay cropping pattern (Romyen et al. 2018).

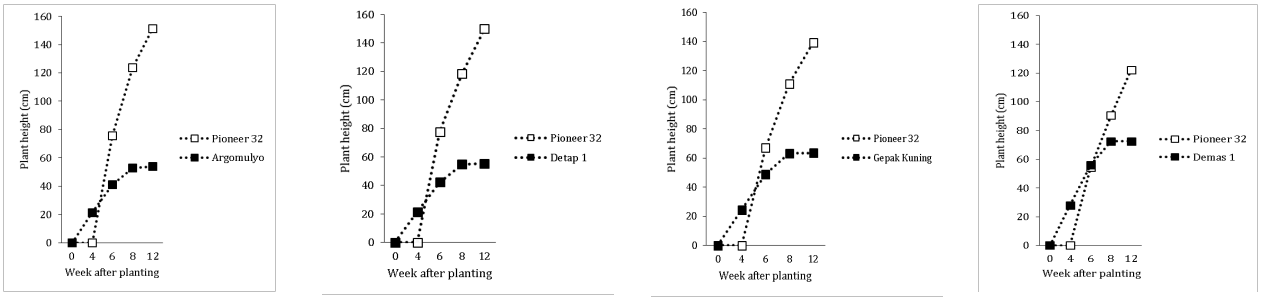
RESULTS AND DISCUSSION

Correlation between age and plant height of maize and soybean varieties

The growth performance of soybean at 8 WAP and maize at 4 WAP using relay cropping of soybean-maize is presented in Figure 1. Soybean varieties with moderate plant growth (Gepak Kuning) and higher plant growth (Demas 1) had higher shade levels for maize relay cropping compared to shorter-growth soybeans (Argomulyo and Detap 1). The maize with relay cropping at a soybean with a spacing of 78 cm x 15 cm x 12.5 cm, the varieties of Argomulyo and Detap 1, were shaded for two weeks, Gepak Kuning was shaded for three weeks, and Demas 1 was shaded for four weeks (Figure 2). The maize with relay cropping at a spacing of soybeans 60 cm x 40 cm x 10 cm for varieties Argomulyo and Detap 1, were shaded for three weeks, Gepak Kuning was shaded for four weeks, and Demas 1 was shaded for five weeks (Figure 3).

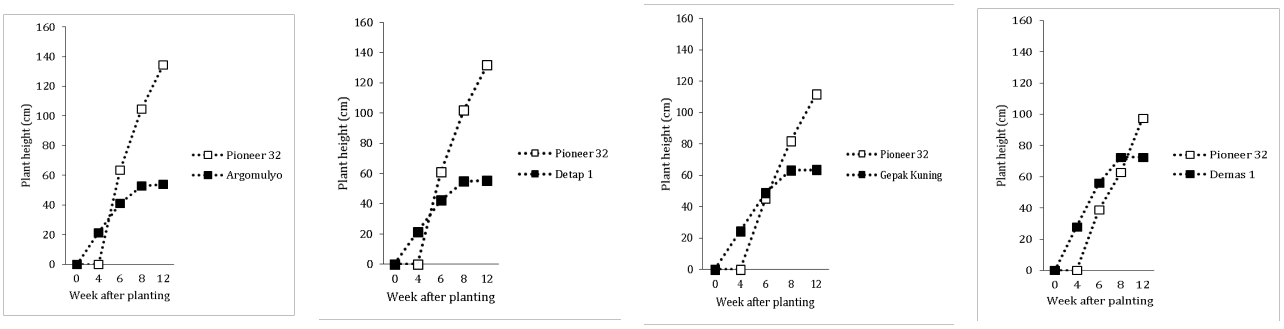
(a) Argomulyo+Maize (b) Detap 1 + Maize (c) Gepak Kuning + Maize (d) Demas 1 + Maize

Figure 1. Growth performance of soybean varieties at 8 WAP and maize 4 WAP relay cropping of soybean-maize.



(a) Argomulyo+Maize (b) Detap 1 + Maize (c) Gepak Kuning + Maize (d) Demas 1 + Maize

Figure 2. Relationship between plant age and height of maize and of soybean varieties in relay cropping with soybean spacing of 78 cm x 15 cm x 12.5 cm.



(a) Argomulyo+Maize (b) Detap 1 + Maize (c) Gepak Kuning + Maize (d) Demas 1 + Maize

Figure 3. Relationship between plant age and height of maize and of soybean varieties in relay cropping with soybean spacing of 60 cm x 40 cm x 10 cm.

Soybean growth and yield

Planting space did not significantly affect the plant height, the number of leaves, and the number of branches of soybean, but those variables significantly differed among varieties at 8 WAP (Table 1). The highest leaf and branch numbers were Demas 1, followed by Gepak Kuning, Argomulyo, and Detap 1. The relay cropping time of maize did not reduce soybean growth because maize was planted at 30 and 45 DAP, so the vegetative phase of soybeans was in a monoculture environment. Under monoculture cultivation, soybean received sufficient sunlight, water, and nutrients so that the process of photosynthesis in the leaves was optimal. Therefore, plant height, number of leaves, and branches of soybean were not significantly different as compared to monoculture.

Plant spacing had no significant effect on the number of filled pods, 100-seed weight, and seed yield, but variety had a significant effect on those variables (Table 2). The soybean variety with the number of productive pods and seed yield higher was Demas 1. The relay cropping time did not reduce the yield of soybean seeds. It is probable that for relay cropping at 30 and 45 DAP soybeans, the generative phase of soybeans in monoculture received sufficient sunlight, water, and nutrients therefore photosynthesis seemed optimum resulting in yield of soybean seeds was not significantly different from monoculture. In addition, soybean spacing is designed with the same population to increase soybean productivity by plant population, narrowing the soybean plant spacing in rows and stretching the plant spacing between soybeans for maize relay cropping. Therefore the competition for soybean plants has balanced the utilization of sunlight and nutrients (Irwan et al., 2019). Spacing with the same population causes enough

photosynthesis for soybean plants so that root becomes optimal (Widyaningrum et al., 2018; Raza et al., 2019).

Table 1. Plant height, number of leaves, and branches of soybean at spacing treatment, soybean varieties, on relay cropping and monocultures at 8 WAP.

Treatment	Plant height (cm)	Number of leaves	Number of branches
Soybean spacing			
78 cm x 15 cm x 12,5 cm	60.4a	23.8a	3.9a
60 cm x 40 cm x 10 cm	61.3a	23.6a	3.9a
Soybean varieties in relay cropping			
Argomulyo	52.9c	21.3c	3.1c
Gepak Kuning	63.3b	24.9b	4.3b
Detap 1	54.7c	21.4c	3.3c
Demas 1	72.5a	27.1a	5.3a
Soybean varieties in monoculture			
Argomulyo	51.0c	19.4c	3.1c
Gepak Kuning	62.3b	23.8b	4.2b
Detap 1	53.1c	19.7c	3.2c
Demas 1	70.2a	26.8a	5.2a

Note: Numbers followed by the same letters in the same column are not different significantly based on DMRT at 5% level.

Table 2. Number of filled pods, 100 seeds weight, and seed yield of soybean at spacing treatment, soybean varieties, on relay cropping and monocultures.

Treatment	Number of filled pods	100-seeds weight (g)	Seed yield (ton ha^{-1})
Soybean spacing			
78 cm x 15 cm x 12,5 cm	68.8a	17.1a	2.9a
60 cm x 40 cm x 10 cm	66.1a	16.7a	2.9a
Soybean varieties in relay cropping			
Argomulyo	42.6c	20.9a	2.2c
Gepak Kuning	84.7b	12.4b	3.2b
Detap 1	43.0c	20.5a	2.3c
Demas 1	103.6a	13.6b	4.2a
Soybean varieties in monoculture			
Argomulyo	40.7c	20.0a	2.2c
Gepak Kuning	83.7b	12.7b	3.2b
Detap 1	41.3c	20.7a	2.2c
Demas 1	101.3a	12.0b	4.1a

Note: Numbers followed by the same letters in the same column are not different significantly based on DMRT at 5% level.

Light interception of maize on spacing and soybean varieties

The interception of sunlight was significantly affected by spacing and soybean varieties (Table 3). Maize planted at a spacing of 78 cm x 15 cm x 12.5 cm from 15-60 DAP had higher light interception than that planted at a spacing of 60 cm x 40 cm x 10 cm. Maize with relay cropping on Argolmulyo and Detap 1 variety aged 15-60 DAP had significantly higher light intercept than that grown on relays on Gepak Kuning and Demas 1. The greater the absorption of sunlight, the better the growth of maize plants because adequate assimilate stimulates root growth and increases nutrient absorption (Soleymani, 2018). Meanwhile, maize grown in low intercepted sunlight decreases chlorophyll, carbohydrates, fat, N content, and grain yield as compared to those that receive full sunlight (Syafruddin et al., 2014).

Table 3. Interception of sunlight on maize with spacing treatment and soybean varieties.

Treatment	Maize light interception (%)			
	15 DAP	30 DAP	45 DAP	60 DAP
Soybean spacing				
78 cm x 15 cm x 12.5 cm	89.3a	80.4a	70.5a	57.8a
60 cm x 40 cm x 10 cm	83.7b	75.1b	65.1b	48.8b
Soybean varieties				
Argomulyo	89.2a	80.7a	71.3a	59.9a
Gepak Kuning	86.3b	76.8b	67.0b	52.6b
Detap 1	88.8a	80.5a	71.1a	59.4a
Demas 1	81.7c	72.8c	61.7c	41.0c

Note: Numbers followed by the same letters in the same column are not different significantly based on DMRT at 5% level.

Maize growth and yield

Soybean spacing significantly affected the plant height, stem diameters, and leaves of maize (Table 4). Plant height, stem diameters, and leaves the number of maize were highest at 30 DAP of soybean planting with a spacing of 78 cm x 15 cm x 12.5 cm compared to 45 DAP of soybean planting with a spacing of 60 cm x 40 cm x 10 cm. Therefore at 30 DAP, the soybean spacing of 78 cm x 15 cm x 12.5 cm, and the light intercept of maize of 80.39%, significantly higher than that of the 45 DAP, the soybean spacing of 60 cm x 40 cm x 10 cm, which was 75.05% (Table 3).

Table 4. Plant height, stem diameters, and leaf numbers of maize of relay cropping time and soybean spacing at 8 WAP.

Treatment	Plant height (cm)	Stem diameters (cm)	Leaf number
Soybean spacing in 30 DAP- planting time			
78 cm x 15 cm x 12.5 cm	154.3a	1.4a	11.2a
60 cm x 40 cm x 10 cm	133.8b	1.3b	9.0b
Soybean spacing in 45 DAP- planting time			
78 cm x 15 cm x 12.5 cm	127.2c	1.2bc	8.0cd
60 cm x 40 cm x 10 cm	103.9d	1.1c	6.7d

Note: Numbers followed by the same letters in the same column are not different significantly based on DMRT at 5% level.

Maize relay cropping on soybean varieties significantly affects the plant height, stem diameters, and leaf number. The higher values of plant height, stem diameters, and leaf number were in the relay cropping time of 30 DAP compared to 45 DAP. The higher plant height, stem diameters, and the number of leaves were in Argomulyo and Detap 1, followed consecutively by Gepak Kuning and Demas 1, both at relay cropping times of 30 and 45 DAP (Table 5).

Soybean spacing, soybean varieties, and maize planting date significantly affected 100-grain weight, and grain yield of maize. The 100-grain weight and grain yield of maize at a soybean spacing of 78 cm x 15 cm x 12.5 cm were significantly higher than at the spacing of 60 cm x 40 cm x 10 cm. The highest 100-grain weight and grain yield of maize were reached from the relay cropping with Argomulyo and Detap 1, followed consecutively by Gepak Kuning and Demas 1. Based on maize planting date, the 100-grain weight and the grain yield of maize were higher from relay cropping at 30 DAP compared to 45 DAP (Table 6). Such results could be due to at 30 DAP the intercept of light received by the maize of relay cropping on varieties Argomulyo, Detap 1, Gepak Kuning, and Demas 1 were significantly higher than that at 45 DAP (Table 3).

Table 5. Plant height, stem diameters, and leaf number of maize at 8 WAP, as affected by soybean varieties at two relay cropping times of maize and monocultures.

Treatment	Plant height (cm)	Stem diameters (cm)	Leaf number
Soybean varieties – maize planting date 30 DAP			
Argomulyo	155.5b	1.5b	11.3b
Gepak Kuning	141.3c	1.2c	9.6c
Detap 1	154.1b	1.5b	11.3b
Demas 1	125.4d	1.1cd	8.3d
Soybean varieties – maize planting date 45 DAP			
Argomulyo	129.1d	1.3c	7.9de
Gepak Kuning	109.8e	1.0de	7.2ef
Detap 1	128.6d	1.3c	7.9de
Demas 1	94.3f	0.9e	6.6f
Monoculture – maize planting date			
30 DAP	162.6a	1.6a	12.2a
45 DAP	162.5a	1.6a	12.1a

Note: Numbers followed by the same letters in the same column are not different significantly based on DMRT at 5% level.

Table 6. The 100-grain weight and yield of maize on the soybean spacing, soybean varieties, and relay cropping time.

Treatment	100-grain weight (g)	Grain yield (ton ha^{-1})
Soybean spacing		
78 cm x 15 cm x 12.5 cm	26.7b	4.5b
60 cm x 40 cm x 10 cm	23.8c	3.3c
Soybean varieties		
Argomulyo	26.9b	4.6b
Gepak Kuning	24.7c	3.6c
Detap 1	26.4b	4.6b
Demas 1	23.1d	2.9d
Maize planting date in relay cropping		
30 DAP	27.5b	4.8b
45 DAP	23.0c	3.1c
Maize planting date in monoculture		
30 DAP	30.3a	7.3a
45 DAP	30.7a	7.4a

Note: Numbers followed by the same letters in the same column are not different significantly based on DMRT at 5% level.

Overall, plant height, stem diameter, leaf number, 100-grain weight, and grain yield of maize were significantly lower in relay cropping compared to monoculture. In relay cropping, the vegetative phase of maize was in a shaded environment and insufficient sunlight. The longer and higher the shade level, the lower the sunlight absorbed by the maize, the lower the photosynthesis result, and the lower the maize grain yield. Maize is a C4 plant that is sensitive to low light. Maize in 35% shade decreased cob weight, cob length, grain number per row, and grain weight per ear compared to no shade (Andayani et al., 2020). At 50%, 70%, and 85% shade, maize experienced a decrease in grain yields of 9.0%, 18.4%, and 67.9%, respectively lower than without shaded (Yang et al., 2022).

Land equivalent ratio (LER)

The maize grain yield was determined by the height of soybean plants followed the soybean varieties. The order of maize yield from high to low following the soybean varieties Argomulyo and Detap 1 (short plant), Gepak Kuning (medium plant height), and Demas (highest plant). The different plant heights of soybean determined the reception of sunlight by maize.

The soybean-maize relay cropping significantly had a higher land use efficiency compared to monoculture. The LER values were higher at 30 DAP maize relay cropping compared to 45 DAP (Table 7). The highest LER values, 1.81 and 1.80, at 30 DAP relay cropping was reached when Argomulyo and Detap 1 varieties were used as the first crop before planting the maize. The LER value is the ratio of area needed under monoculture to a unit area of relay cropping at the same management level to give an equal amount of yield. The LER values > 1 indicate that relay cropping can increase land productivity as compared to monoculture (Romyen et al., 2018). The LER values of the maize + soybean relay cropping can reach 1.7-1.8 when the two plants are planted in optimal populations (Raza et al., 2019). It should be considered that result of Raza et al. (2019) was an experiment conducted on upland field unlike in present experiment that was conducted in swampy ecosystems.

Table 7. The LER values and yields of soybeans and maize in the treatment of relay cropping soybean-maize.

Perlakuan	Soybean yield (ton ha^{-1})	Maize yield (ton ha^{-1})	LER
Soybean varieties at maize planting date 30 DAP			
Argomulyo	2.2c	5.7b	1.81a
Gepak Kuning	3.2b	4.4c	1.60b
Detap 1	2.2c	5.6b	1.80a
Demas 1	4.2a	3.7d	1.50c
Soybean varieties at maize planting date 45 DAP			
Argomulyo	2.2c	3.6d	1.50c
Gepak Kuning	3.2b	2.8e	1.40d
Detap 1	2.3c	3.6f	1.50c
Demas 1	4.2a	2.2g	1.30d
Soybean varieties in monoculture			
Argomulyo	2.2c		
Gepak Kuning	3.2b		
Detap 1	2.2c		
Demas 1	4.1a		
Planting dates of maize in monoculture			
30 DAP		7.3a	
45 DAP		7.4a	

Note: Numbers followed by the same letters in the same column are not different significantly based on DMRT at 5% level.

CONCLUSIONS

The results concluded that plant height, number of leaves, number of filled pods, 100-seed weight, and seed yield of soybean differed significantly among varieties. The best soybean variety was Demas 1, with relay cropping and monoculture seed yield of 4.2 tons ha^{-1} and 4.1 tons ha^{-1}, respectively. Plant height, stem diameters, leaf number, 100-grain weight, and grain yield of maize were significantly higher at soybean spacing of 78 cm x 15 cm x 12.5 cm and relay cropping at 30 DAP. The highest LER values were obtained

from 30 DAP relay cropping with Argomulyo and Detap 1 soybean varieties, respectively 1.8 and 1.8.

ACKNOWLEDGEMENTS

The authors are grateful to the Indonesian Rubber Research Institute for facilitating this research. Thanks to the researchers at the Indonesian Rubber Research Institute for their assistance in data collection and research implementation, especially Mr. Herman, Hanif, Devid, and Budi Iskandar.

REFERENCES

Andayani, N.N., Riadi, M., Rafiuddin, Kalqutny, S.H., Efendi, R., & Azrai, M. (2020). Evaluation of yield and agronomic components of three-way cross maize hybrids under low-light environment. *Earth Environmental Science, 484*, 1-6. https://doi.org/10.1088/1755-1315/484/1/012016

Aziz, A., & El-razek, A.A. (2012). Yield and its components of maize/soybean intercropping systems as affected by planting time and distribution. *Australian Journal of Basic and Applied Sciences, 6*, 238–245.

[BAPPEDA] Badan Perencanaan Pembangunan Daerah dan Penanaman Modal. (2019). Rencana Tata Ruang Wilayah (RTRW) Kabupaten Banyuasin Tahun 2012-2032. *https://kec-tungkalilir.banyuasinkab.go.id/wp* content/uploads/sites/23/2019/05/rtrw-banyasin.pdf

Blessing, D.J., Gu, Y., Cao, M., Cui, Y., Wang, X., & Badu, B.A. 2022. Soybean has low light use efficiency (LUE) and radiation use efficiency (RUE) due to the deep shade created by the maize canopy. *Chilean Journal of Agricultural Research, 82*(1), 177-188.

[BPS] Badan Pusat Statistik. (2020). Analisis Hasil biji Jagung dan Kedelai di Indonesia 2020 (Hasil Survei Ubinan). Volumeke-2020. https://www.bps.go.id

Du, Q., Zhoud, O., Chena, P., Liue, X., Song, C., Yanga, F., Wanga, X., Liua, W., Suna, X., Du, J., Liua, J., Shua, K., Yanga, W., & Yonga, T. (2020). Relay-intercropping soybean with maize maintains soil fertility and increases nitrogen recovery efficiency by reducing nitrogen input. *The Crop Journal, 8,* 140-152. https://doi.org/10.1016/j.cj.2019.06.010

Ghulamahdi, M., Melati, M., Guntoro, D., & Sutandi, A. (2015). Nitrogenase activity and plant physiological process of soybean under saturated soil culture on mineral and peaty mineral soil. *International Journal of Sciences: Basic and Applied Research, 24*, 332–347. http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Ghulamahdi, M., Chaerunisa, R.S., Lubis, I., & Taylor, P. (2016). Response of five soybean varieties under saturated soil culture and temporary flooding on tidal swamp. *Procedia Environmental Science*, *33*, 87-93. https://doi.org/10.1016/j.proenv.2016.03.060

Ghulamahdi, M., Agustian, R., Lubis, I., & Taylor, P. (2017). Growth, productivity and land equivalent ratio of soybean-corn intercropping on the different potassium and husk ash dose under saturated soil culture on tidal swamp. *International Journal of Sciences: Basic and Applied Research, 36*, 170-182.

Irwan, A.W., Wahyudin, A., & Sunarto, T. (2019). Response of soybean due to spacing and concentration gibberellins on the ground inceptisol Jatinangor. (In Indonesian). *Jurnal Kultivasi, 18*, 924-932.

Khongdee, N., Hilger, T., Pansak, W., & Cadisch, G. (2021). Early planting and relay cropping: pathways to cope with heat and drought? *Journal of Agriculture and Rural Development in the Tropics and Subtropics, 122*, 61-71. https://doi.org/10.17170/kobra-202104133652

Mattjik, A.A. & Sumertajaya, M. (2013). Perencanaan Percobaan Dengan Aplikasi SAS dan Minitab. Bogor (ID): IPB Press.

Maulana, A.I., Ghulamahdi, M., & Lubis I. (2019). Response of corn varieties under saturated soil culture and temporary flooding in tidal swamp. *Journal of Tropical Crop Science, 6*, 41-49. https://doi.org/10.29244/jtcs.6.01.41-49

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 Journal of Plant Science, 13*, 18-25. https://doi.org/10.3923/ajps.2014.18.25

Palijama, W., Riry, J., & Wattimena, A.Y. (2012). Komunitas gulma pada pertanaman pala (*Myristica fragrans* H) belum menghasilkan dan menghasilkan di desa Hutumuri Kota Ambon. (In Indonesia), *Agrologia, 1*, 134-142.

Peichl, M., Thober, S., Meyer, V., & Samaniego, L. (2018). The effect of soil moisture anomalies on maize yield in Germany. *Natural Hazards and Earth System Sciences*, *18*, 889-906. https://doi.org/10.5194/nhess-18-889-2018

Pujiwati, H., Ghulamahdi, M., Yahya, S., Aziz, S.A., & Haridjaja, O. (2016). Produktivitas tiga genotipe kedelai dengan air berbeda dan kedalaman muka air pada berbagai kondisi tanah di pasang surut. (In Indonesia.), *J. Agron. Indonesia. 44*, 248-254.

Raza, M.A., Bin Khalid, M.H., Zhang, X., Feng, L., Khan, I., Hassan, M.J., Ahmed, M., Ansar, M., Chen, Y.K., Fan, Y., Yang, F., & Yang, W. (2019). Effect of planting patterns on yield, nutrient accumulation and distribution in maize and soybean under relay intercropping systems. *Scientific Reports, 9,* 1-14.https://doi.org/10.1038/s41598-019-41364-1

Romyen, A., Sausue, P., & Charenjiratragul, S. (2018). Investigation of rubber-based intercropping system in Southern Thailand. *Kasetsart J Soc Sci, 39*, 135-142. https://doi.org/10.1016/j.kjss.2017.12.002

Soleymani, A. (2018). Corn (*Zea mays* L.) yield and yield components as affected by light properties in response to plant parameters and N fertilization. *Biocatalysis and Agricultural Biotechnology, 15*, 173-180. https://doi.org/10.1016/j.bcab.2018.0 6.011

Suparlan, Marsudi, & Budiharti, U. (2018). Evaluation of technical and economical machine sheller corn argue. (In Indonesia). *Jurnal Keteknikan Pertanian, 6*, 225-232. https://doi.org/10.19028/jtep.06.2.225-232

Syafruddin, Suwarti, & Azrai, M. (2014). Fast screening and tolerance of maize plants to intensity low light. (In Indonesia). *Penelitian Pertanian Tanaman Pangan, 33*, 36-43.

Widyaningrum, I., Nugroho, A., & Heddy, Y.B.S. (2018). Influence distance plant and varieties to growth and yield of soybean (*Glycine max* L.). (In Indonesia.). *Jurnal Produksi Tanaman, 6*, 1796-1802.

Xu, Z., Li, C., Zhang, C., Yu, Y., Van der, W.W., & Zhang, F. (2020). Intercropping maize and soybean increases efficiency of land and fertilizer nitrogen use; A meta-analysis. *F Crop Res, 246*, 107-661. https://doi.org/10.1016/j.fcr.2019.107661

Yang, Y., Liu, G., Guo, X., Liu, W., Xue, J., Ming, B., Xie, R., Wang, K., Li, S., & Hou, P. (2022). Effect mechanism of solar radiation on maize yield formation. *Agriculture, 12*, 3-13. https://doi.org/ 10.3390/agriculture12122170

Yunita, S.R., Sutarno, & Fuskhah, E. (2018). Response of several soybean varieties (*Glycine max* L. Merr) to level salinity water sprinkling. (In Indonesia.). *J. Agro Complex. 2*, 43-51. https://doi.org/10.14710/joac.2.1.43-51

Zaeem, M., Nadeem, M., Pham, T.H., Ashiq, W., Ali, W., Gilani, S.S.M., Elavarthi, S., Kavanagh, V., Cheema, M., & Galagedara. (2019). The potential of corn-soybean intercropping to improve the soil health status and biomass production in cool climate boreal ecosystems. *Sci Rep, 9*, 1-17. https://doi.org/10.1038/s41598-019-49558-3

Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher(s) and/or the editor(s).

Copyright: © 2023 by the authors. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).